THE DEVELOPMENT OF AN INTEGRATED PROBLEM-BASED LEARNING (PBL) APPROACH IN A POST-MATRICULATION PROGRAMME AT THE UNIVERSITY OF STELLENBOSCH

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SUBMITTED TO THE DEPARTMENT
OF EDUCATIONAL PSYCHOLOGY
OF THE UNIVERSITY OF STELLENBOSCH
IN FULFILLMENT OF THE REQUIREMENTS
FOR THE DEGREE OF

DOCTOR OF PHILOSOPHY

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March 2008

Declaration

I, the undersigned hereby declare that the work contained in this dissertation is my own original work, and that I have not previously in its entirety or in part submitted it at any university for a degree.

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Signature

7 March 2008

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Date

SUMMARY

It is evident that many students admitted to higher education in South Africa are ill-prepared for tertiary study. The predominantly behaviorist school system encourages learner dependency and superficial understanding and fails to encourage reflection and self-direction. Changing times and a more diverse student population have heightened the need for a broader range of teaching and learning approaches at tertiary level. As a result, many departments, faculties and institutes such as SciMathUS have explored the merits of problem-based learning (PBL) which supports students as self-directed, independent learners. Problem-based learning is a different philosophical approach to the whole notion of teaching and learning where problems drive the learning and is one of the best examples of a constructivist learning environment. Thus far, problem-based learning has mainly been implemented in long-term medical curricula, so research findings focus mainly on the development of PBL for longer programmes. The purpose of this study is to evaluate whether introducing a *Hybrid PBL approach* in a shorter one-year foundation programme can create conditions for learners to develop and sustain self-directed learning skills and gain more control of the learning process.

This interpretive-constructivist study may be broadly termed evaluation research. A mixed-method approach that involved collecting and analyzing both qualitative and quantitative data was chosen.

Evaluation findings indicate that introducing students to a Hybrid PBL approach does promote more meaningful learning patterns, typified by processing the subject matter critically and self-regulating learning processes. However the sustainability of the meaning-directed learning activities is questionable if student beliefs do not support the activities employed. Findings also reveal that the Hybrid PBL approach contributes to overall programme improvement by promoting understanding in mathematics and science and improved staff relationships and subject knowledge. PBL helps to establish a learner-centered learning environment that emphasizes relations in mathematics and science, promotes deep approaches to learning which may lead to higher levels of achievement and success in Higher Education.

OPSOMMING

Menige studente wat toegang tot hoër onderwys in Suid-Afrika verkry, is swak voorberei vir tersiêre onderrig. Die oorwegende behavioristiese skoolsisteem waaraan meeste leerders blootgestel word, versterk leerder afhanklikheid, gebrekkige begrip, refleksie en selfgerigtheid. Aangesien veranderende tye en ‘n meer diverse studente populasie ‘n wyer verskeidenheid onderrig- en leerbenaderings vereis, word verskeie departemente, fakulteite en programme soos SciMathUS genoodsaak om benaderings soos probleemgesentreerde leer (PBL) te oorweeg aangesien dit studente as selfgerigte, onafhanklike leerders ondersteun. Probleemgesentreerde leer is ‘n filosofiese benadering tot die hele konsep van leer en onderrig waar probleme die leergeleentheid dryf en word beskou as een van die beste voorbeelde van ‘n konstruktivistiese leeromgewing. Probleemgesentreerde leer is oorwegend in langtermyn mediese kurrikula geïmplementeer en navorsingsbevindinge fokus hoofsaaklik op die ontwikkeling van PBL met hierdie langer programme in gedagte. Die doel van hierdie studie is om te evalueer of die blootstelling aan ‘n *Hibriede PBL benadering* binne ‘n korter een-jaar fondasieprogram toestande kan ondersteun waarin leerders selfgerigte vaardighede kan ontwikkel om meer beheer oor die leerproses te verkry en of hierdie toestande volhoubaar is.

In hierdie interpretistiese-konstruktivistiese evalueringsnavorsing is van ‘n gemengde benadering gebruik gemaak waarin beide kwalitatiewe en kwantitatiewe data versamel en geanaliseer is.

Die evalueringsbevindinge toon dat blootstelling aan ‘n Hibriede PBL benadering meer betekenisvolle leerpatrone in studente bevorder wat getipeer word deur die kritiese prosessering van leermateriaal en selfregulering van leerprosesse. Die volhoubaarheid van die betekenisvolle leeraktiwiteite word egter bevraagteken wanneer studente oortuiginge nie hul aktiwiteite ondersteun nie. Die bevindinge toon verder dat die Hibriede PBL benadering bydra tot algehele program verbetering deur die bevordering van begrip in wiskunde en wetenskap en verbeterde personeelverhoudinge en vakkennis. Probleemgesentreerde leer dra by tot ‘n leerdergesentreerde leeromgewing wat verhoudinge tussen wiskunde en wetenskap verbeter, ‘n diep benadering tot leer bevorder wat kan bydra tot beter prestasie en studiesukses in hoër onderwys.

ACKNOWLEDGEMENTS

With thanks

To God for the energy, clarity and wisdom I was granted to produce this work.

To my two daughters, Angelique and Amoré, and family and friends for their continuous love and understanding.

To Prof Petra Engelbrecht and Dr Wynoma Michaels for their consistent support, guidance and insight.

To my colleagues, Elza Lourens, May Marnewick and Ingrid Mostert at SciMathUS for their inspiration, hard work, perseverance, support and encouragement for making this journey possible.

To Dr Martin Kidd from the Centre for Statistical Consultation for all his assistance and support with the quantitative data.

To all the students at SciMathUS embarking on the journey of lifelong learning.

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CHAPTER 1: ORIENTATION AND STATEMENT OF THE PROBLEM

1.1 BACKGROUND AND IMPORTANCE OF THE RESEARCH

As part of the apartheid legacy the new South African government in 1994 inherited a higher education system that was segregated by race, ethnicity, class and geography (Strydom & Strydom, 2004:101). The separatist policies of the past and the poor state of some sectors of secondary schooling in South Africa have meant that the student intake into higher education in South Africa has changed, not only in numbers but also in terms of the level of preparedness (Kgaphola, 1999:38; Quinn, 2003:71). As Quinn (2003:71) has remarked, many of the students admitted to higher education are considerably ill-prepared for tertiary study.

At the same time, South African higher education is affected by global reform agendas. This is reflected in the demand by society in general and industry in particular for people who are professional, independent and flexible and have life skills (Kgaphola, 1999:41). It is not uncommon to hear education, community, and business leaders express concern about the number of graduates who lack skills in self-directed learning, communication, abstract thinking, problem solving and group dynamics (De Vita, 2004:70; Ward & Lee, 2004:73). Not only does higher education need to cater for larger and much more heterogeneous student populations than in the past but it faces additional pressure of having to increase the number of graduating students, and prepare them for lifelong learning if it is intended for students to stay current in their fields (Dunlap, 1997:1; Masui & De Corte, 2005:351; Quinn, 2003:71; Savin-Baden, 2000:140).

In order to be responsive to the needs of a diverse student population and the specific economic need of South African society to compete in the “new global economy” the higher education system thus needs to adapt its ways (Castells in Quinn, 2003:73). To realize these outcomes curriculum development and design as well as student-lecturer-teaching approaches need to be examined more closely. Educators are therefore obliged to rethink how and what they teach their students (Carl, 2002:25; Duch, Groh & Allen, 2001:4; Engelbrecht, 2001:5-6). In response to these needs transformational outcomes-based education (which is based on a more constructivist teaching philosophy) advocates a sharper focus on learner-centred pedagogy to involve learners and increase understanding by making them more accountable for their own learning (HSRC in Van Loggerenberg-Hattingh, 2003:52). Evidently traditional curricula are under pressure to become more integrated and interactive since the collaborative blending of course skills and content across all curricular areas helps to ensure meaningful and lifelong learning (Drake, 1993; Finucane, Johnson, Prideaux, 1998:445-448; Kgaphola, 1999:41). Current educational studies suggest that human understanding works best when students can see relationships within what they have learnt and to perceive their field of study in a broader perspective (Kgaphola, 1999:35). South African higher education is therefore implementing a curriculum restructuring policy aimed at the development of degree programmes that are more 'coherent and integrated' and typically 'trans-, inter- or multidisciplinary' in nature (Finucane *et al.,* 1998: 445-448). Furthermore the Green Paper (1996) and the White Paper (1995) on Higher Education (Kgaphola, 1999:15) make reference among other things, to the role of higher education as a provider of graduates with multifaceted skills. In particular they should be intellectually well-developed and have the ability to function autonomously in a knowledge-driven economic landscape and to create knowledge through scholarship and intellectual inquiry.

Although there is growing consensus amongst training institutions that training should be more integrated and that it should focus on the generation of a wider range of knowledge, skills and attitudes in order to cope with the demands of the complex South African situation, there seems to be little change in the ways in which, overall, training institutions attempt to meet the needs of the new customers in the higher education system (Engelbrecht, 2001:5; Quinn, 2003:71; Savin-Baden, 2000:140). Many institutions have kept their traditional curriculum formats and teaching regimes (Kgaphola, 1999:38) so many students continue to experience university teaching which encourages superficial ways of learning. The result is that key concepts are poorly understood and students have only weakly developed transferable skills. They lack the ability to be self-directed or reflexive (Engelbrecht, 2001:6-7).

It is against this background, that the SciMathUS programme (The Science and Mathematics Programme of the University of Stellenbosch) has realized the need to re-evaluate their curriculum (see Addendum A). To make it possible for students to cope with a more constructivist learning environment, how students are taught as well as what is taught will have to change. The SciMathUS programme which is fully sponsored by outside organizations has a one-year full time preparation year of coursework on grade 12 level targeting learners from weak academic backgrounds (Michaels, 2005:3). It has a particular concern to work against the discriminatory practices which limit the access of mainly black students and women students to fields such as Science, Engineering, Technology and Commerce. These practices have a detrimental effect on economic and social development (NCHE, 1996).

Recognizing that social, economic and educational disadvantages contribute to students' poor performances in grade 12 the programme allows three groups of about 25 students each (two in Mathematics and Physical Science and one in Mathematics and Accountancy) to rewrite the Senior Certificate examinations of the National Education Department at the end of the year. Through a holistic curriculum that integrates practical skills such as research, essay writing, critical reading, thinking, life and computer skills, these students are encouraged to become independent thinkers. The programme manager emphasizes that "at SciMathUS we want to develop the multiple facets of each individual to the extent that each person is sufficiently skilled and empowered to become a productive member of the Commerce, Science, and Engineering professions in South Africa which is the reason for the holistic approach of the programme". The aim at SciMathUS is that a minimum of 80% of the students qualify for tertiary programmes in the natural sciences, applied natural sciences and the economic and management sciences after completion of the SciMathUS year and are adequately equipped to succeed at their future tertiary studies (Michaels, 2005:3).

Teaching at SciMathUS focuses on the content of the grade 12 curriculum and greatly depends on the quality of the knowledge that the lecturer has and controls. One likely consequence of this teacher-centred approach is the development of a closed conception of teaching and a reproductive, superficial conception of learning strengthening learner dependency (Battista, 1999:4; De Vita, 2004:70; Drake, 1998:8; Engelbrecht, 2001:6; Michael, 2001:145-158; Ward & Lee, 2004:73). In this type of fragmented traditional teacher-centred pedagogy, time is further wasted in acquiring knowledge that is subsequently forgotten or found to be irrelevant whilst application and integration of the acquired knowledge may be non existent (Finucane *et al*., 1998:445-448; O'Grady, 2004:2). It became clear that reform was needed in the SciMathUS programme and one way to address this reform was to evaluate the characteristics of problem-based learning (PBL) as a possible approach to restructure the current curriculum in order to provide the necessary self-directed learning skills for students to cope within a more constructivist learning environment.

1.2 HIGHER EDUCATION IN A POST-APARTHEID SOUTH AFRICA: A SYSTEMIC PERSPECTIVE

1.2.1 Introduction

In the mid-1990s the newly-elected government of South Africa was confronted with the daunting challenge of building democracy from the deeply divided, largely impoverished society handed down to it by the apartheid regime. It had to face a far more complex set of local and international circumstances vastly more difficult than any previous regime. Every sector of society required reconstruction and development, most notably education, which was rightly viewed as a key mechanism to improve the life chances of all South Africans and the means to secure sound social and economic development into the new millennium (Ensor, 2004:339).

PBL seemed to offer a way of addressing the challenges presented by the interplay between universal and global trends impacting on higher education, as well as the effects of the apartheid legacy on learners. Before making a firm decision, however, it was necessary to explore whether PBL could be used in a post-matriculation programme or foundational programme such as SciMathUS. To accomplish this mission the researcher used Bronfenbrenner’s (1990) ecological systems theory and Drake’s (1998:4) story model to illustrate the systemic interplay between universal, global as well as local trends impacting on higher education in South Africa from a social constructivist perspective.

1.2.2 A systemic perspective

Systems theory sees the world in terms of ‘systems’, where each system is a ‘whole’ that is more than the sum of its parts, but also itself ‘part’ of a larger system. Systems theory stresses the interdependent and interrelated nature of the relationships that exist among all components of a system and its underlying sub-systems. The system thus affects the environment and is affected by the environment. Every part of the system has an effect on every other part of the system, where change in one part of the system will result in a change in another part of the system. In order to survive in a changing environment, the system has to be adaptable (Flint, 1997:2). Another fundamental principle of systemic thinking is that cause and effect relationships are not seen as linear. They are seen as occurring in circles or, more accurately, in cycles. It must be noted that Flint (1997:1) views systems theory not as a theory but rather as a perspective or analogy which guides our understanding of the individual in the world. Bronfenbrenner's (1990) ecological systems theory which looks at development within the context of the system of relationships that form the learner's environment emphasizes that in order to understand the learner's development, one must not only look at the learner and his immediate environment, but also at the interaction of the larger environment. Bronfenbrenner sees the learner's environment as having the following four levels. *The macro-system* which is considered the outermost layer of the individual's environment is comprised of universal and global trends, cultural values, customs and laws. The effects of larger principles defined by the macro-system have a cascading influence throughout the interactions of all other layers. *The exo-system* which defines the larger social system in which the individual does not function directly, comprises societal, cultural and community trends. *The meso-system* provides the connection between the structures of the individual's micro-system. *The micro-system* consists of the layer closest to the learner which contains the structures with which the learner has direct contact. The micro-system encompasses the relationships and interactions a learner has with his immediate surroundings which comprises of his family, school, neighbourhood, and so forth. The interaction of structures within a layer and interactions between layers is key to Bronfenbrenner's (1990) theory. At the micro-system level, bi-directional influences are strongest and have the greatest impact on the learner. However, interactions at outer levels still impact the inner structures (Berk, 2000:23-38).

1.2.3 Shifts happening in higher education

Due to the fact that there is an inter-relationship between the individual and society, focusing on one aspect without the other is to present a false picture of reality (Jarvis, 1996:15). Drake's (1998:4) story model, which is used to explain the shifts happening in education today, is divided into four phases: namely the universal, global, cultural, and personal story phase akin to Bronfenbrener's (1990) macro-, exo-, meso- and micro-system. It should be noted that these phases are not discrete entities: dividing them is done solely for the purpose of analysis.

1.2.3.1 The universal story

According to Drake (1998:5) our universal story connects us all as human beings regardless of time or culture. We are all experiencing a time of vast technology advances, rapid scientific developments, information explosion (Drake, 1998:3; Kgaphola, 1999:41) and consequently a more sophisticated job market (Drake, 1998:12; Dunlap, 1997:1; Tynjälä, 1999:357). These changes in society have been described by many theorists as a transitional stage where a modern society is moving to a postmodernist information society (Drake, 1998:3, 6). The question therefore arises whether we can teach the same way we have always taught in a fast changing postmodernist information society (*ibid.*:11). Many traditional approaches to education are therefore being questioned, typified by the move towards a more student-centred pedagogy. The Stellenbosch University Strategy for Learning and Teaching (2002-2004) (in Adendorff, 2006) explains student-centred learning as follows: "Within student-centred higher education, teaching that aims mainly at 'transferring knowledge' is replaced by teaching activities that facilitate learning. The focus unequivocally falls on the students and on the quality and quantity of what they learn and not on the lecturers or the methods the lecturers use for transmitting discipline-specific subject knowledge.

The teacher-centred approach assumes that teachers serve as the centre of epistemological knowledge, directing the learning process and controlling students' access of information. Students are viewed as 'empty' vessels and learning is viewed as an additive process, while instruction is geared for the 'average' student where everyone is forced to progress at the same rate (Adendorff, 2006). Drake (1998:6) refers to the teacher-centred approach as 'old story practices' with its embedded assumptions (see Table 1.1).

Old story practices	**Embedded assumptions**
The teacher lectures	The teacher is the expert
The student is a passive learner	The student is a blank slate
The classroom is set up in fixed rows	The best way to learn is alone
The bell curve is employed	Only a very few will demonstrate exceptional success or failure. The majority of students will be average
Pencil-and-paper measurements are used	Knowledge worth knowing can be written

Old story practices	Embedded assumptions
Standardized tests are emphasized	Accountability gained through standardized testing allows us to compare students, teachers, districts, states, provinces, and nations
The status quo is maintained	A few people will do well, leaving the power structures in place

Table 1.1: Old story practices and its embedded assumptions (Drake, 1998:6)

By contrast, the move towards a more student-centred approach, which Drake (1998:8) refers to as the ‘new story practices’ rests on the assumption that students are not empty vessels (Freire, 1985:22) but that they come with their own perceptual frameworks, that they learn in different ways, and that learning is an active, dynamic process in which connections are constantly changing and their structure is continually reformatted (Adendorff, 2006).

In the learner-centred approach the embedded assumptions, typified by ‘old story practices’ are therefore challenged. At stake here are the central questions that have been asked for centuries: What is the purpose of education? What is worth knowing? How do people learn best? How do we teach to insure that we are aligned with learning principles? Who is in control of education? Drake (1998:6) refers to the new learner-centred approach as the ‘new story practices’ with its embedded assumptions (see Table 1.2).

New story practices	Embedded assumptions
The teacher is a facilitator of student learning experiences	The student constructs meaning through relevant experiences
The student is an active learner	The student learns by being actively involved
Teaching for understanding	The learning can be transferred to applicable contexts
Collaborative learning	The student constructs meaning socially
Ongoing assessment	Ongoing feedback is used as a learning tool
Alternative assessment (aligned with instructional strategies)	Knowledge is ambiguous, indeterminate; there are multiple realities and no one right

New story practices	Embedded assumptions
	answer
Emphasis on life and work-related skills	Assessment should demonstrate application of knowledge
Clear expectations	Explicit criteria facilitate student learning
Cross-disciplinary approaches	The boundaries of disciplines are superficial

Table 1.2: New story practices and its embedded assumptions (Drake, 1998:8)

Education institutions are therefore encountering increasing pressures to change their instructional practices (Hommes, 1997:1; Tynjälä, 1999:358). Consequently, the Department of Education introduced Curriculum 2005 to South African schools in 1998 as a way of meeting some of these pressures and addressing the deficiencies of the past (Meel, 2003). Outcomes-based education (OBE) is conceptually a radical education policy initiative which challenges the status quo. OBE is based on a more constructivist teaching philosophy which advocates a sharper focus on learner-centred pedagogy (HSRC in Van Loggerenberg-Hattingh, 2003:52) to make more active student learning possible (Ramsden in Venkatachary, 2004:1) and to involve learners more by making them more accountable for their own learning (Van Loggerenberg-Hattingh, 2003:52).

PBL which is one of the best examples of a constructivist learning environment is not just a different method or style of teaching. Instead it is a different philosophical approach to the whole notion of teaching and learning (Savin-Baden, 2000:13) adhering to the following principles akin to Drake's (1998:8) new story practices, namely:

- It is a student-centred approach (Charlin, Mann & Hansen, 1998:323-330) that shifts the classroom focus from teaching to learning (Burch, 2001:194).
- It ties into social constructivism (De Villiers & Queiros, 2003:116) which emphasizes student interactions rather than learning as a solitary activity (Prince, 2004:223).
- It describes a student-centred learning environment in which problems drive the learning (Dunlap, 1997:1; Miflin, 2004b:450; Savin-Baden, 2000:15; Sonmez & Lee, 2003:1).

- Teachers are facilitators or guides of the student learning experiences (Barrows, 1996:5).
- It supports the learning process of an active learner, a main principle of constructivist pedagogy (Tynjälä, 1999:427).
- It builds on the skills of 'learning to learn' which are essential in the continuing change of work-life and professions (Poikela & Poikela, 1997:11).
- It recognizes that knowledge transcends artificial boundaries by highlighting the interconnections between disciplines and the integration of concepts (Duch, Groh & Allen, 2001:7) which leads to deeper understanding (Van Loggerenberg-Hattingh, 2003:53).
- Continuous, self-and peer assessment form an integral part of the learning process (Tynjälä, 1999:427).

From the postmodernist point of view PBL is therefore a strategic answer to the needs of the competencies of the information society (Poikela & Poikela, 1997:9).

1.2.3.2 The global story

Because education is a concern across the planet it is important to know how other systems are adapting to changing times so that one can be aware of the educational picture in its widest sense (Drake, 1998:5). With information explosion, the greater emphasis placed on professional competencies (Poikela & Poikela, 1997:10) and the need for 'continuing lifelong learning' (Kgaphola, 1999:41; Masui & De Corte, 2005:351; Quinn, 2003:71; Savin-Baden, 2000:140) higher education institutions across the world are forced to rethink their ways of operation (Drake, 1998:30; Ensor, 2004:347). The National Commission on Higher Education's (NCHE) report (1996) refers here to a chronic mismatch between higher education's output and the needs of a growing economy. Educational practices in higher education have thus been criticized for not developing the prerequisites of professional expertise (Quinn, 2003:71). The main point of these critics is that educational practices do not provide students with the expertise required in the real environments for which students are supposed to be prepared (Tynjälä, 1999:357).

Much has been written about how training institutions have had to change from the traditional model, where the purpose was to generate knowledge for its own sake (the knowing part), to what some now call the "market" university where knowledge is "commodified" (the doing part). Many of the professional subjects in higher education have thus been orientated towards their 'use-value', as they were created in response to the needs of the world of work (Silver & Brennan, 1988).
As a result of the awareness of the importance of being responsive to the performance needs of society (the doing part) as well as the need to facilitate improved understanding (the knowing part) more effectively there is a growing global interest in curricula grounded in the world of work (Savin-Baden, 2000:26) which offer students opportunities for inter-professional education as well as in integrated curricula (Drake, 1998:307; Ensor, 2004:347) which help students develop a deeper understanding of the subject matter within a broader context (Kgaphola, 1999:35; McAllister in Van Loggerenberg-Hattingh, 2003:53). Based upon current international reform documents in science and mathematics education, there is also strong philosophical support for the integration of science and mathematics education as a way to enrich learning experiences and improve student understanding and attitude toward these disciplines (Berlin & Lee, 2005:16; American Association for the Advancement of Science, 1993:3; NCTM, 2000:66). Opportunities for students to apply their knowledge of mathematics and science in contexts outside of these disciplines are deemed important.

According to Drake (1998:28), many higher education institutions still anchored in the traditional disciplines and specialization are responding to these calls and are on the brink of change. McMaster, University of Newcastle, the University of Linköping in Sweden and the University of Maastricht in Netherland have already moved toward interdisciplinary medical education that is grounded in PBL (Dochy, Heylen & Van de Mosselaer, 2000:22; Drake, 1998:31). More than 82% of the medical schools in the United States teach the basic sciences using PBL to various degrees. PBL is also being used in other health science curricula such as nursing, dentistry, and occupational therapy. PBL has also been adapted and been used in different disciplines including business, education, architecture, law, engineering, social work, counselling, psychotherapy, geography, leadership education, mathematics, science, chemical engineering, zoology, and even high school education (Lam, 2004:374).

Akin to worldwide trends South African higher education, emerging from a period of relative isolation (NCHE, 1996) is attending to the challenges of globalization, the knowledge society, and the local challenges of reconstruction and development (Ensor, 2004:340) and is implementing a curriculum restructuring policy aimed at the development of degree programmes that are more 'coherent and integrated' and typically 'trans-, inter- or multidisciplinary' in nature (Finucane *et al.*, 1998: 445-448). The NCHE Report (1996) describes the realities and opportunities facing higher education in South Africa as follows:

> *As South Africa locates itself in this network of global exchanges and interactions, higher education will have to produce the skills and technological innovations necessary for successful economic participation in the global market. It must also realize a new generation with the requisite cultural values and communication competencies to become citizens of an international and global community.*

The National Qualifications Framework (NQF), which is intended to bring formal academic education and vocational training into closer alignment and prepare graduates more effectively for the workplace, has been at the centre of South Africa's national education policy framework since the mid-1990s. The NQF encapsulates the desire of education policy makers to erode three sets of boundaries: between education and training, *between academic and everyday (real-world) knowledge,* and *between different knowledge, disciplines or subjects* within the academic domain (Ensor, 2004:340).

It was against the backdrop of the newly established NQF and a set of policies that the newly-elected South African government appointed the National Commission on Higher Education (NCHE) in February 1995 to recommend ways in which the racially divided, exclusive, differentiated South African higher education system could be unified, and made more responsive to South Africa's agenda for economic and social reconstruction (Green Paper on higher education transformation, 1996) in order to compete in the "new global economy". This framework intends to produce curricula in schools and higher education institutions that are relevant to the world of work by eroding traditional disciplinary boundaries in favour of interdisciplinary and at other times recruiting from both simultaneously (Ensor, 2004:341).

PBL features strongly in the new debates on professional education (Savin-Baden, 2000:21). As a result many higher education institutions in South Africa are exploring the merits of PBL, which not only offers opportunities for inter-professional education, and for implementing teaching that is grounded in the world of work (*ibid*.:26) but it also provides opportunities for students to develop meaningful solutions to real-life problems through integrated curricula (McAllister in Van Loggerenberg-Hattingh, 2003:53).

Four out of the eight medical schools in South Africa have already adopted PBL curricula. According to Meel (2003), the Faculty of Health Sciences at the University of Transkei (UNITRA) is currently the leading institution in Southern Africa with regard to PBL. It introduced PBL into the medical school curriculum during 1992 as a means of fostering effective learning among learners with weak academic backgrounds. The University of Pretoria has implemented a new problem-oriented, vertical and horizontally integrated MBChB curriculum at first year level in an attempt to change its conservative educational philosophy to a more innovative one. The University of the Witwatersrand (Wits) has implemented PBL in the form of simulation games in the International Relations foundation course (Ala & Hyde-Clarke, 2006:121). The University of Kwa-Zulu Natal's Nelson R. Mandela School of Medicine has implemented PBL (McLean, 2004:301-303). In addition the Medical School of the University of Stellenbosch is currently giving serious consideration to using PBL as a means of enhancing professional education.

1.2.3.3 The cultural story

According to Drake (1998:5) the culture that we live in sends out powerful messages about what is 'true'. This cultural story influences how we conduct education since the beliefs and assumptions that we accept as unquestioned truths drive our behaviour.

It is evident that when reflecting on South Africa's past, education cannot be separated from politics and power relationships (Harley, Aitchison, Lyster & Land, 1996:3; Van Niekerk, 1996:27). Students who come from a behaviourist school system into higher education are ill-prepared for a more constructivist learning environment. The hope is that students who have had the benefit of Outcomes-based education (OBE) will be in a better position (Kgaphola, 1999:38; Quinn, 2003:71). However, there is still an urgent need to articulate a new teaching and learning regime in higher education to take account of the changing academic profile of the students and focus on the development of a wider range of knowledge, skills and attitudes for coping with the demands of the complex South African situation (Carl, 2002:25; NCHE, 1996). These outcomes have serious repercussions on the day-to-day affairs of academic practice (Engelbrecht, 2001:5). According to Adendorff (2006) the focus placed on student learning and responsibility means that teaching staff have an even greater responsibility for creating opportunities for learners to attain the necessary outcomes and create assessment that support students as independent learners.

But in reality many institutions have kept their traditional curriculum formats and teaching regimes in spite of the changing academic demography of their students and new demands placed upon them (Kgaphola, 1999:38). Students are still perceived as empty vessels to be filled with facts through traditional means (Adendorff, 2006) which increases dependency and leads to a reproductive, superficial conception of learning. Learning is still viewed as an additive process, where application and integration of the acquired knowledge in most cases remain non existent (Engelbrecht, 2001:6; Finucane *et al*., 1998:445-448; O'Grady, 2004:2). According to Duch (2001a:5) a traditional teaching method like lecturing continues to be used because it is familiar even though it does little to foster the development of process skills to complement content knowledge. Furthermore, Kgaphola (1999:38) remarks that technological developments and knowledge explosion have only produced a greater impulse to increase course content and overburden the curricula without adjusting teaching approaches or time needed for students to digest the material. In order to release pressure from overburdened curricula, self-directed learning is thus expected of learners who are often ill-prepared for this responsibility (Johnston & Tinning, 2001:161–169).

Since changing times and a more diverse student population require a broader range of teaching and learning approaches, which take into account a variety of student learning needs and study patterns, such demands have caused many departments to consider such approaches as PBL to take account of students' requirements (Savin-Baden, 2000:21). Flexible approaches such as PBL prepares students for lifelong learning, helps students develop meta-cognitive, self-directed learning skills needed to remain competitive in an ever-changing world (Dunlap, 1997:1). More specific outcomes of PBL have further been described as integrated knowledge base; promoting understanding (Gallagher, 1997:332-362); enhancing problem-solving abilities; (Finucane *et al*., 1998:445-448) and social adeptness, for example (O'Grady, 2004:3).

1.2.3.4 The personal story

Drake (1998:4-5) suggests that in using the story model to explain the shifts happening in education today, our ways of knowing need to be examined. Our knowing is influenced primarily by the personal events of our lives. We actively construct knowledge and make meaning of it through the lens of our personal story, and that is why individuals interpret the same events so differently.

The view of the learner as an active constructor of meaning is based on *constructivism*, a broad term with philosophical, learning and teaching dimensions, echoed throughout current theories of learning and teaching (Drake, 1998:153). Constructivism is based on the assumption that personal knowledge develops as an individual actively attempts to understand or know his environment (Savery & Duffy, 1994:1). Learning therefore occurs as students derive meaning from the experiences the environment (the interplay between the different systems and subsystems) places upon them (Von Glasersfeld, 1995:7).

In this study the implementation of PBL as an approach to learning can be thought of as a combination of cognitive, scientific and social constructivist theories (as developed by Piaget and Vygotsky) (Kim, 2001:1) in which learning is not only constructed by students personally as they try to make sense of their realities but where learning is also viewed as a social process. Learning therefore does not take place only within an individual, nor is it a passive development of behaviours that are shaped by external forces but also occurs when individuals are engaged in social activities.

Every educator also has a different context and thus stories his perceptions differently (Drake, 1998:4-5). An educator who views knowledge as production that is essentially positivist, for example, is likely to see teaching as transmission of such knowledge and thus encourage learner dependency (Quinn, 2003:66). As a result Quinn (2003:67) recommends that educators should be encouraged to think about ways of teaching that exhibit an understanding of the constructed and contested nature of knowledge. This means developing an understanding based on the belief that for real learning to occur students need to transform knowledge. Knowledge can thus not merely be transferred directly from the mind of teachers to the mind of learners (Charlin *et al*., 1998:323-330) but the learners need to engage with it in an active way in order for it to be meaningful to them, to construct new concepts or ideas for themselves and take personal responsibility for their learning, in other words become more self-directed (Quinn, 2003:67).

1.2.3.5 The SciMathUS story

The coursework at SciMathUS depends largely on lectures alternated with some group work, work with textbooks and some relevant practical work. Teaching, which focuses on the content of the grade 12 curriculum, is directly affected by the quality of the knowledge that the lecturer has and controls. Much of the weaknesses inherited from the schools system can be described as follows. Mathematics and science topics were learnt in self-contained environments where what was being learned had little immediate use in the lives of these students. This kind of traditional, behaviourist teaching meant that the students developed little skill at transferring their mathematics and science knowledge and skills into non-mathematics/science disciplines or into problems that they encountered outside of school (Moursund, 2006:2). After the first test during March 2005 it was apparent that most of the students could not remember or maintain the mathematics and science knowledge and skills that they initially developed in their formal schooling years.

This traditional content-orientated approach to which these students were exposed saw good teaching as requiring sound academic knowledge which was transmitted at a surface level by a presenter possessing knowledge to a recipient with lesser knowledge (Engelbrecht, 2001:5). Within this fragmented teacher-centred pedagogy learner dependency and passivity was encouraged, time was wasted in acquiring knowledge that was subsequently forgotten or found to be irrelevant, application and integration of the acquired knowledge being non existent (Finucane *et al.*, 1998:445-448; O'Grady, 2004:2) all leading to a closed conception of teaching and a reproductive, superficial conception of learning (Engelbrecht, 2001:6).

Until recently teaching at SciMathUS was organized without real consideration of other subjects or disciplines where each subject was viewed as an entity in itself. This can be clearly observed in the slots in the timetables labelling the name of the subject for SciMathUS specifically. It must be noted that the simple fact that subjects are named in the traditional way, does not imply that there is no integration. Furthermore, the objectives were seen as a mastery of the subject and these were tested in a subject-based assessment of the students' knowledge and understanding of the subject. The relationships between subjects were not explicitly covered and related topics from the two main subjects (mathematics and science) were not intentionally correlated. Students therefore attended different lectures with none of the lecturers being aware of what was covered in the other lectures (Harden, 2000:551-552).

There was, therefore, an urgent need to articulate a new teaching and learning approach for SciMathUS, focusing on the development of self-directed learning skills, a wider range of knowledge as well as attitudes in order to equip the students to cope within a more constructivist higher education environment and meet the demands of a complex South African situation (Carl, 2002:25; NCHE, 1996). To address these needs a strategic planning session for SciMathUS was held on the 14th of March 2005 which yielded the following strategic objectives:

- SO2: "To *empower students* by using an *integrated and focused curriculum* to guide them to *take responsibility and be accountable"*
- SO8: "To *continuously assess and adapt the programme content* in order to stay optimally relevant" (Parsadh, 2005:4).

It is important to point out that this mission was not to 'fix' something that was necessarily 'broken', (which could be described as a reactive approach towards programme improvement) but to make something that is 'right' even 'better' (a more proactive approach towards programme improvement).

1.3 PROBLEM STATEMENT

The diverse student intake into higher education in South Africa has not only changed in terms of numbers but also in terms of the level of preparedness (Kgaphola, 1999:38; Quinn, 2003:71). A predominantly traditional, behaviourist school system does not prepare learners for the self-directed learning a more constructivist learning environment requires (Ala & Hyde-Clarke, 2006:121-132; Cross, 2004:337; Engelbrecht, 2001:6; Finucane *et al*., 1998:445-448; O'Grady, 2004:2). Consequently, most institutions are attempting to expand academic development and foundational programmes (such as SciMathUS) in order to provide learning outcomes, opportunities and assessment that support students as self-directed, independent learners (Adendorff, 2006; De Vita, 2004:70; Johnston & Tinning, 2001:161–169; Kgaphola, 1999:38; Ward & Lee, 2004:73).

Research has indicated that the use of self-directed and learner controlled methods such as PBL is one way to create and support conditions for learners to gain more control of the learning process thereby empowering learners to cope within a more constructivist learning environment and remain competitive in an ever changing world (Dunlap, 1997:1). However, the design and development of PBL is related to long-term medical curricula and research. The question then is whether introducing a *Hybrid PBL approach* (an adapted version of PBL for a specific group of students) within a shorter one-year foundation programme can create and support conditions for learners to develop self-directed learning skills and gain more control and ownership of the learning process.

Therefore, the primary purpose of this study is to describe the development and implementation of a Hybrid PBL approach as a tool for overall programme improvement to assist students to participate successfully in a more constructivist learning environment. The secondary purpose of this study is to evaluate whether exposure to a Hybrid PBL approach in a one-year foundation programme can produce change in the learning patterns and specifically the self-regulation of learning processes of learners and whether the skills attained are sustainable.

1. 4 RESEARCH QUESTIONS

In order to evaluate the processes involved in the development and implementation of a Hybrid PBL approach in a one-year foundation programme the following research questions were formulated:

- What is PBL?
- Is there a need to introduce PBL into the SciMathUS curriculum?
- What PBL model could be appropriately adapted for SciMathUS?
- Was the Hybrid PBL approach well designed?
- Was the Hybrid PBL approach implemented effectively?

In order to determine whether the Hybrid PBL approach did produce change in the learning patterns and learning processes of the students and whether the skills attained are sustainable the following research questions were formulated:

- Did the Hybrid PBL approach reach the intended outcomes of improving the learning patterns and specifically the self-regulation of learning processes of learners?
- Are these skills sustainable?
- Is this type of innovation a worthwhile undertaking for a one year foundation programme such as SciMathUS and its members?

1.5 RESEARCH DESIGN AND METHODOLOGY

1.5.1 Evaluation research

This study is located under the broad heading of evaluation research, sometimes referred to as programme evaluation (Rossi, Lipsey, & Freeman, 2004:2). In this study the purpose of the evaluation is formative and developmental in nature (improvement-orientated) (Babbie & Mouton, 2001:338,345; Mertens, 2005:232;; Rossi *et al.,* 2004:44) as well as summative (judgment-orientated) (Babbie & Mouton, 2001:357) and takes place while the programme is being implemented (so-called ongoing evaluation) (*ibid.*:xxxi).

The theoretical perspective that forms the framework in this evaluation research is an interpretive-constructivist approach with a pragmatic focus typified by the following key features: the insiders' perspective is emphasized, the research is conducted in the natural setting of social actors, the researcher is seen as the 'main instrument' in the research process, the product of the inquiry is richly descriptive and the research process is primarily abductive (Creswell, 2003:4,9; Denzin & Lincoln, 2000:20; Morgan, 2007:48).

1.5.2 Study implementation

The study commenced in 2005. Phase I focused on a needs assessment, followed by Phase II the pilot study phase during 2006 whereas Phase III, IV and V focused on the case study phase during 2007. The pilot study phase focused on the programme theory (design and plan of the Hybrid PBL approach) during Phase I and Phase II; the case study phase focused on the programme process (implementation of the Hybrid PBL approach) during Phase III; Phase 1V focused on programme outcomes (impact) and sustainability (maintenance); and Phase V focused on programme improvement. Given the evaluative nature of this study the researcher started off with a broad evaluation plan and moved it around as the research progressed.

1.5.3 Research design

This evaluation study could be framed as a single case-study (Green & McClintock, 1991:14). In this single case-study the researcher explored in depth the process of conceptualizing, designing, implementing and evaluating a Hybrid PBL approach in a single programme at the University of Stellenbosch where the researcher used purposive sampling by observing the participants involved in the SciMathUS programme during 2007 which consisted of 42 adult students (ranging between the ages of 17 and 22) and three lecturers (two mathematics lecturers and one physical science lecturer).

1.5.4 Research methodology

A mixed-method approach to programme evaluation that involved collecting and analyzing both qualitative and quantitative data (Babbie & Mouton, 2001:368; Cresswell, 2003:14; Greene & McClintock, 1991:19) was used in this study. The combination of qualitative and quantitative methods emphasized the largely pragmatic approach adhered to in this study (Morgan, 2007:48-53). The main rationale for using the mixed-method approach was to converge or confirm outcome findings from different data sources (Creswell, 2003:210) which could enhance the validity of the findings (Merriam, 2002:12).

Within this study the researcher selected a *concurrent nested mixed-method strategy* which seeks to elaborate on or expand the findings of one method with another method. The concurrent nested strategy within this study could be identified by its use of one data collection phase (the pre- evaluation phase at the beginning of the study), during which both quantitative and qualitative data were collected simultaneously followed by a predominantly qualitative data collection phase during the implementation process of PBL followed by a post-evaluation phase at the end of the study where both quantitative and qualitative data again were collected simultaneously. A nested approach has a predominant method that guides the research. Given less priority, the quantitative method in this study was embedded or nested within the predominant qualitative method. This nesting meant that the embedded method sought information from different levels. The data collected from the two methods were mixed during the analysis and interpretation phase of the research (Cresswell, 2003:14).

Multiple data construction strategies were used in this study (Mertens, 2005:16) most of which resulted in qualitative data that were generated from the programme evaluation of the study whilst quantitative data were generated during the pre- and post evaluation stages of the study. Whilst the qualitative data provided rich descriptive materials the quantitative data gave more precise numerical measures. Within the mixed method approach the researcher based the inquiry on the assumption that collecting diverse types of data best provided a better understanding of the research problem (Creswell, 2003:21).

Data was collected at key points over a sustained two-year time period. Different sources of information were used. Primary data were collected through the application of the Inventory of Learning Styles (ILS) on students' regulation of learning processes in higher education, semi-structured focus group interviews and classroom observations. The Inventory of Learning Styles (ILS) (Vermunt & Vermetten, 2004:364) was used in this study as a pre- and a post evaluation instrument. The ILS questionnaire was constructed by Jan Vermunt (2004a; 2004b) in the context of a research project at Maastricht aimed at measuring four components of student learning, whilst providing an integrative learning theory focusing on the interplay between self-regulation and external regulation of learning processes (Vermunt & Vermetten, 2004:359). Secondary data were collected through document analysis (including a literature review) and records of meetings in order to satisfy the information needs of stakeholders[1] (Babbie & Mouton, 2001:76; Capeling-Alakija, Lopes, Benbouali & Diallo, 1997; Claessens & Jochems, 1993:51; Mertens, 2005:71, 390). The primary and secondary data that were collected formed the case study data base.

[1] Stakeholders: An actor that has vested interest in a given project. In the case of SciMathUS stakeholders included the lecturers, the learners, project managers, the funders, the researcher herself and the University of Stellenbosch (Capeling-Alakija *et al.*, 1997).

1.5.5 Data analysis

In choosing data analysis procedures the researcher considered the evaluation questions, approaches, data collection techniques, and kinds of data collected. Data collection and data analysis occurred simultaneously as an interactive, continuous and on-going process (Cocklin, 1996:94; De Vos, Strydom, Fouché & Delport, 2002:341). The data analysis within this mixed method research occurred both *within* the quantitative approach and the qualitative approach, and also *between* the two approaches (Creswell, 2003:220). The quantitative and qualitative data generated from the evaluation research required vastly different competencies of the researcher in the analysis process. The quantitative data focusing on changes in students' learning patterns gave precise numerical measures whereas the qualitative data provided rich descriptive materials (*ibid.*:222).

Analysis of the quantitative data consisted of identifying the variables that the ILS questionnaire measured. The ILS questionnaire was used to measure the relationship between the dependent variable (Y), namely student learning patterns (in other words self-regulated learning) and the independent variable (X), namely introducing the students to the Hybrid PBL approach. The pre-post evaluation design involved observations and measurements before commencement or implementation of the PBL intervention (O1) followed by the PBL intervention (X). After completion of the PBL programme, another set of post-evaluation observations and measurements was administered (O2). Standard quantitative analyses, such as a comparison of mean scores between O1 and O2, a t-test and an analysis of variance (ANOVA) then indicated whether there was a statistic significant difference between the pre-evaluation and post-evaluation participants. The key question, namely did the programme participants change, was answered through this pre-evaluation-post-evaluation design (Babbie & Mouton, 2001: 349).

The *qualitative data* from the various observations made by the tutors, the researcher and students were analysed using the thematic and content analysis procedure of open coding as described in Berg (1995:185) and Frank and Barzilai (2004:46). The researcher grouped data from the text under the components and patterns (themes) of student learning identified in the ILS questionnaire (Ely, 1991:150). These patterns were given names (codes) and were refined and adjusted as the analysis proceeded (Merriam, 2002:14; Mertens, 2005:423; Miles & Huberman, 1994:9). The units of data which were coded into themes were clustered into the relevant components (categories) identified on the ILS questionnaire. The categories reflected the purpose of the study and they were exhaustive in allowing all the data to be categorized.

1.5.6 Limitations to research design and methodology

Constraints on this envisioned programme improvement and evaluation process were:

- Programme circumstances and activities could change during the course of the evaluation.
- Finding an appropriate balance between scientific and pragmatic considerations in the evaluation design proved to be at times difficult.
- Every improvement and evaluation plan must negotiate a middle way between optimizing the situation for research purposes and minimizing the disruption caused to normal operations.
- The distinction between programme development and evaluation could become increasingly blurred (Mertens, 1998:235, Rossi *et al.,* 2004:21-22, Terre Blanche & Durheim, 1999:224).

1.5.7 Ethical Issues

The following ethical requirements were met during this study:

- Participants were provided with the opportunity to give their consent to participate freely in the study.
- The purpose, goals and objectives and various supporting or competing agendas were openly discussed and everyone had the opportunity to influence and shape events (in the interests of transparency).
- Participants had the right to remain anonymous in documentation of the research results.
- The researcher ensured that the evaluation was conducted with honesty and integrity in its entirety.
- The evaluator respected the security, dignity, and self-worth of all the stakeholders.
- The researcher worked towards a true participatory and democratic relationship with stakeholders in a spirit of collaboration, capacity-building and co-ownership (Babbie & Mouton, 2001:359; Capeling-Alakija *et al.,* 1997; Mertens, 2005:81; Miles and Huberman, 1994:291-292; Tuckman, 1978:16).

1.6 CONCEPTUAL CLARIFICATION

The use of the terms problem-based approach, as well as the SciMathUS post-matriculation programme in this research will be clarified below. It must also be noted that the use of the male pronoun (he) for the learners is for the sake of convenience and no gender discrimination is intended.

A problem-based approach

The introduction of problem-based learning within other disciplines with their own traditions and characteristics has led to the emergence of several varieties or approaches to PBL (Savin-Baden, 2000:16). Within the scope of this study the PBL approaches refer to the various ways that PBL is described and practised in different settings. The way the PBL curriculum is designed can be broadly categorized on a continuum ranging from ‘hybrid’ (or ‘adapted’) approaches, also referred to as transitional semi-problem-based curricula to the ‘full’ (or ‘pure’ ‘rigorous’ and ‘authentic’) PBL approaches (Margetson, 1999:359,364; Newman, 2004:13; O’ Grady, 2004:3).

SciMathUS post-matriculation programme

Matric is a term used for grade 12 level in South African schools where students write the Senior Certificate examinations of the National Education Department at the end of the year. The SciMathUS post-matriculation programme (The Science and Mathematics Programme of the University of Stellenbosch) is characterized by a 1-year full time preparation year of coursework on grade 12 level targeting learners from weak academic backgrounds. The programme offers grade 12 students the opportunity to rewrite the Senior Certificate examinations in order to provide them access for tertiary programmes in the natural sciences, applied natural sciences and the economic and management sciences in order to equip them to succeed at their future tertiary studies (Michaels, 2005:3).

1.7 CHAPTER DIVISIONS

The chapters are divided as follows:

Chapter 1 provides a theoretical orientation to the research, the research problem and research methodology, stating the importance of the research within the South African higher education context from a systemic perspective, by describing the development of PBL within global as well as South African higher education institutions in order to evaluate the characteristics of PBL as a possible teaching approach at SciMathUS.

Chapter 2 provides the theoretical basis of the proposed PBL approach within this study along with a general overview of PBL where the discussion will move toward the different PBL models available from within an international perspective.

Chapter 3 focuses on the design and the implementation of a Hybrid PBL approach for SciMathUS integrating the theoretical stance with the design and implementation of the actual Hybrid PBL approach.

Chapter 4 describes the research methodology used to execute the research. This study will be located under the broad heading of evaluation research which entails the use of scientific methods to measure the conceptualization, design, implementation and outcomes of the Hybrid PBL approach within the SciMathUS programme. The mixed-method approach used for data-construction and data-analysis is described in rich detail.

In **Chapter 5** the research findings regarding the impact of the Hybrid PBL approach on student learning patterns are presented and discussed according to the categories determined at the final data-analysis stage in order to get a clearer understanding of the outcomes achieved with the Hybrid PBL approach within the SciMathUS programme and the sustainability thereof.

Chapter 6 focuses on suggestions for improvement of the Hybrid PBL approach within the SciMathUS programme by discussing some of the challenges experienced and the formulation of recommendations for current and future programmes as a means of programme improvement.

1.8 CONCLUSION

The move towards a mass rather than an élite system in higher education in South Africa (NCHE, 1996; Savin-Baden, 2000:139; Quinn, 2003:71) brought about by social and political developments as well as global reform agendas (Masui & De Corte, 2005:351; Quinn, 2003:71) pose new challenges (Savin-Baden, 2000:20). Higher education institutions are having to adjust to larger and much more heterogeneous student populations than in the past (Longwell-Grice, 2003:40-53; Masui & De Corte, 2005:351) with many students considerably ill-prepared for tertiary study (Quinn, 2003:71). The emphasis on professional competencies (Kgaphola, 1999:41; Poikela & Poikela, 1997:10) as well as on 'continuing lifelong learning' (Masui & De Corte, 2005:351; Quinn, 2003:71; Savin-Baden, 2000:140) reflect some of these challenges. Different competencies and skills are therefore needed to cope within a postmodernist information society (Poikela & Poikela, 1997:10); competencies that many of our customers in higher education do not possess (De Vita, 2004:70; Ward & Lee, 2004:73). Research indicates that a large number of graduates still are unable to meet the demands of self-directed learning, communication, abstract thinking, problem solving and group dynamics at tertiary level (De Vita, 2004:70; Ward & Lee, 2004:73) which has led to many traditional approaches to education being questioned (Williams, 2001b:86). The question therefore is not whether or not there is a need for fundamental change, but what such change should entail at the micro-level of educational delivery (Kgaphola, 1999:xi). According to Masui and De Corte (2005:351) improving learning competence can make a substantial contribution to solving each of these major concerns.

Recent policy proposals reflect some of these changes. The introduction of Outcomes-based education, based on a more constructivist teaching philosophy advocates a sharper focus on learner-centred pedagogy (HSRC in Van Loggerenberg-Hattingh, 2003:52) reflecting a commitment towards lifelong learning and learner responsibility. The concomitant need to create more constructivist and supportive learning environments means that traditional curricula are also facing pressure to become more integrated and interactive (Kgaphola, 1999:viii). Furthermore, the Green Paper and the White Paper on higher education make reference to the role of higher education as a provider of graduates with versatile skills in order to function in a postmodernist society (*ibid.*:15,39).

South African campuses have thus embarked upon a wide range of initiatives to respond to these demands (Cross, 2004:336-337). There is growing consensus in higher education institutions that training must focus on the generation of a wider range of knowledge, skills and attitudes. This directly affects academic practice. For instance it requires academic staff to critically re-examine curriculum development and design as well as student-lecturer-teaching approaches (Engelbrecht, 2001:5-6). A central question involved in the development of university instruction is the integration of theoretical, practical, and self-regulative knowledge (Tynjälä, 1999:427) where PBL can be seen as a promising approach to integrating these different forms of knowledge.

Although there is growing consensus that old ways do not work any more there seems to be little change in the ways in which the institutions have adapted their processes to meet the needs of the new customers in the system (Quinn, 2003:71; Savin-Baden, 2000:140). While in theory traditional teacher-centred approaches are giving way to more student-centred, flexible, integrated approaches (Adendorff, 2006), the majority of institutions have kept their traditional curriculum formats and teaching regimes (Kgaphola, 1999:38). It is against this background and the endeavour to continuously improve their programme that SciMathUS has realised the need to re-evaluate and reconsider their curriculum and teaching approaches by using PBL as a tool to restructure the curriculum.

Since the goal of the educational process in South Africa is to produce independent, empowered lifelong learners (Dunlap, 1997:1) the use of self-directed and learner controlled methods such as PBL not only models changed power relationships between teachers and learners, but through the development of core skills also provides learners with the competitive edge needed to deal with the challenges in an ever-changing world. Chapter 2 will therefore provide the philosophical basis of PBL in order to assess the characteristics of PBL as a possible teaching approach at SciMathUS along with a general overview of PBL where the discussion will move toward PBL in general and the different PBL approaches available from within an international perspective.

CHAPTER 2: A MULTI-THEORETICAL PERSPECTIVE AND GENERAL OVERVIEW OF PROBLEM-BASED LEARNING (PBL)

2.1 INTRODUCTION

Problem-based learning is becoming an increasingly popular teaching and learning approach in higher education institutions across the world (Mierson, 1998:16) as well as in South Africa (Ala and Hyde-Clarke, 2006:121; Dunlap, 1997:1; Engelbrecht, 2001:5). Since Problem-based learning is a philosophical approach to teaching and learning that has been designed using theory and research evidence about the nature of learning (Newman, 2004:6) this chapter will present Newman's (2004:15) conceptual model in order to reflect upon the many theoretical perspectives underpinning PBL and provide a general overview of PBL where the discussion will move toward the general characteristics of PBL and an international perspective on the different PBL approaches available.

2.2 A MULTI-THEORETICAL PERSPECTIVE OF PBL

Newman (2004:7, 16) argues that the philosophical and theoretical underpinnings of problem-based learning are not explicitly discussed in the early PBL literature. Miflin (2004a:44) makes a similar point in contending that there is a general absence of definition in PBL theory and that a "conceptual fog" continues to surround it. In the discourse of PBL there is a general assumption that everyone shares the same principles, aims and values that underpin the approach. Even within PBL there is variation in the way that problem-based learning is theorized, described and practised (Newman, 2004:7). In order to evaluate the characteristics of PBL as a teaching strategy for a programme such as SciMathUS, an examination of the philosophical underpinnings of PBL is therefore important.

2.2.1 Newman's conceptual model

Newman's (2004:15) conceptual model (see Figure 2.1) presents an opportunity to reflect upon the many theoretical perspectives underpinning PBL. It identifies what appear to be the key features of curricula that use PBL and the theoretical basis of the concepts that underpin them. The solid blocks at the centre of the model summarize the *key features*, the grey shaded blocks the *concepts underpinning each feature* and the clear boxes the *theoretical basis of the concepts.* Tynjälä (in Newman, 2004:16) considers all the 'educational theories' which underpin PBL in Newman's model to be examples of *constructivism* whether social, cognitive or both. It is important to note that it is not the intention of the researcher to give a detailed account of *all* the concepts and theories that underpin PBL, as noted by Newman, but rather to provide a theoretical description of the *specific* set of concepts that explain PBL within the specific context of the study. The researcher will therefore use Newman's conceptual model to provide a detailed account of the theoretical basis of the constituent parts of problem-based learning and the concepts that underpin them within the SciMathUS curriculum before an overview of the key features in the *practice* of problem-based learning will be discussed.

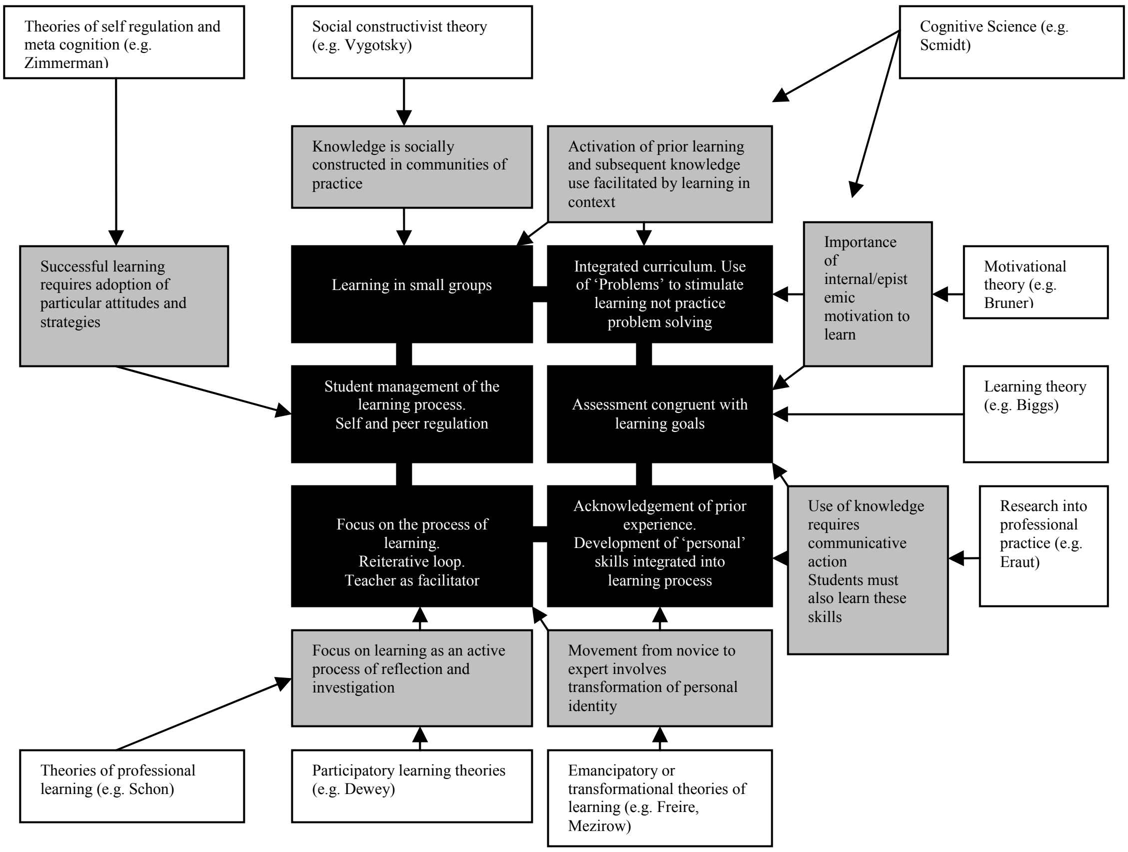


Figure 2.1: Summary of the key features and conceptual basis of PBL (Newman, 2004:15).

2.2.2 Constructivism

All the educational theories which underpin PBL in Newman's model can be considered to be examples of constructivism (Tynjälä in Newman, 2004:16). Constructivism is a philosophy that is student-centred and guided by certain beliefs about learning (Drake, 1998:152). Constructivism is based on a view in which 'knowledge' is not absolute, but is actively constructed by the student based on previous knowledge and overall views of the world (Baker, 2000:260; Oxford, 1997:36). It therefore suggests that knowledge is both socially and cognitively constructed where the knower interprets and constructs a reality based on his experiences and interactions with his environment (Von Glasersfeld 1995:7).

From the literature review it became clear that constructivism as a learning theory is vast and complexly configured and that it is not a unified theory, but rather a conglomeration of different positions with varying emphases (Engelbrecht, 2001:9; Gergen, 1997:195-201; Phillips, 1997a:273-284; Phillips, 1997b:161). In order to simplify matters, writers like Gergen (1997:195-201), Phillips (1997a:273-284), Tynjälä (1999:364), and others analyzed constructivism into categories (or branches), ranging from *radical* or *cognitive constructivism, social constructivism*; the *sociocultural approach* to *social constructionism*. Battista (1999:6) added to this array of branches *'scientific constructivism'* – a well-developed scientific theory that has proved invaluable in understanding empirical research on student learning of subjects like mathematics.

The basic premises of these branches are as follow:

- *Radical or cognitive constructivism* as well as *scientific* constructivism coined by Battista (1999:7) emphasize that the mind is the chief site of knowledge construction (for example Von Glasersfeld and Jean Piaget in Phillips, 1997b:154). Cognitive constructivism is about how the individual student understands things (Atherton, 2003:2; Tynjälä, 1999:364).
- *Social constructivism* emphasizes that the mind constructs within relationship to the world and the categories supplied by the surrounding culture (i.e. Lev Vygotsky). Social constructivists are therefore more interested in social, dialogical, and collaborative processes (Tynjälä, 1999:364) and emphasize how meanings and understandings grow out of social encounters (Atherton, 2003:2).

- The *sociocultural approach* and *social constructionism* emphasize that what we take to be knowledge is derived from micro social (and largely discursive) relations (Tynjälä, 1999:364).

Ernest (2005:2), Ismat (1998:1-4) and Tynjälä (1999:364) point out that these various branches of constructivism are not necessarily incompatible with one another. Common to these schools of thought is the perspective that gaining knowledge is a building process in which knowledge is actively constructed by individuals or social communities and not passively received. They share the idea that what the student has to *do* to create or construct knowledge is the important thing (Biggs, 2003:13). The constructivist perspective of learning further assumes that knowledge acquisition is a *continuous process* of building and reshaping understanding as a natural consequence of experience in the world (Williams, 2001a:92) as well as a *collaborative process* in which the individual understanding has its roots in social interaction (Colliver, 2000:51).

In this study PBL can be thought of as a combination of cognitive 'scientific' and social constructivist theories (as developed by Piaget and Vygotsky) in which learning is not only constructed by students personally as they try to make sense of their realities but where learning is also viewed as a social process. By combining these different perspectives learning is viewed as an activity that does not take place only within an individual, nor is it a passive development of behaviours that are shaped by external forces but that it occurs when individuals are engaged in social activities (Kim, 2001:1). The considerations that will be presented may therefore sometimes derive from cognitive constructivism, scientific constructivism and sometimes from the social approaches (Tynjälä, 1999:364) since mathematical and scientific knowledge construction are both an individual and a social construction process (Murray in Ernest, 2005:4).

2.2.2.1 Cognitive constructivism

Researchers working from a cognitive perspective focus strongly on internal mental processes; coined *cognitive information processing theory* (Albanese, 2000:729-738; Williams, 2001a:91). They are interested in how the mind makes sense out of stimuli in the environment; how information is processed, stored and retrieved (Merriam & Caffarella, 1991:137). The information-processing theory of PBL (Albanese, 2000:729-738; Williams, 2001a:91) reflects the theoretical perspectives of cognitive science particularly the contributions of Dewey, Bruner and Piaget (Williams, 2001a:91). The information-processing theory of PBL involves the following major elements: prior knowledge activation, encoding specificity, elaboration through small-group problem analysis, the construction of problem-oriented mental models in the form of semantic networks, including contextual cues derived from professionally relevant problems, and the fostering of epistemic curiosity (Albanese, 2000:729-738).

The theoretical links between PBL and cognitive constructivism

There are various principles that govern the design of PBL based on the cognitive constructivist perspective. Newman (2004:15) emphasizes the following concepts underpinning the key features of PBL from within a cognitive constructivist perspective, namely, the activation and elaboration of prior knowledge, the use of knowledge facilitated by learning in context and the importance of internal motivation to learn.

The activation and elaboration of prior knowledge

In a PBL activity relevant prior knowledge is activated by confronting students with real life problems where students need to reconstruct what they know and do not know about the situation (Schmidt, Moust & Boshuizen, nd:22). Prior knowledge mobilized by one student tends to activate previously more difficult accessible knowledge in another student. Not only activation takes place, but students also begin to elaborate on what they know and try to build bridges between their knowledge and the phenomena described in the particular problem (Schmidt *et al*., nd:20).

The use of knowledge facilitated by learning in context

Within PBL authentic practical situations that reflect the types of situations students will face as professionals can serve as the framework for storing contextual cues, improving students' abilities to retrieve relevant knowledge when faced with similar situations in the future. In the PBL approach where students are confronted with a real-life problem, content and knowledge occur as a result of student learning which the student constructs for himself. This changes his own conception of content and knowledge and himself as a professional. The key features of PBL here will thus include making use of real life problems to stimulate learning (Newman, 2004:15).

The importance of internal motivation to learn

Students are motivated and spend more time processing information when they are discussing authentic practical situations, which they perceive as relevant and meaningful (Williams, 2001a:92). When a gap is perceived between what is known and not known a strong intrinsic motivation to learn is induced (Schmidt *et al*., nd:22).

2.2.2.2 Scientific constructivism

Scientific constructivism is a well-developed scientific theory based on more than two decades of scientific research into gaining greater understanding of students' learning of mathematics (Battista, 1999:6). The researcher focuses on mathematics learning because of its unique features in the learning process and because of the importance of mathematics within the SciMathUS programme.

All current major scientific theories describing students' mathematics learning agree that mathematical ideas must be personally constructed by students as they try to make sense of situations and actively seek to interpret it (*ibid*.:5). However, since subjects, such as mathematics, are more 'bounded' than others by rules, formulae, and procedures they are more likely to be regarded by teachers as producing problems and tasks to which there are 'correct' answers. Individual interpretations and construction of ideas and concepts are therefore less likely to be encouraged by teachers than in subjects such as literature and writing for instance (Ismat, 1998:1-4). According to Battista (1999:9) traditional mathematical instruction which ignores students' personal construction of mathematical meaning, results in the development of students' mathematical thought not being properly nurtured, resulting in stunted growth. To develop powerful mathematical thinking in students, instruction must therefore focus on, guide, and support their personal construction of ideas. Such instruction encourages students to invent, test, and refine their own ideas rather than blindly follow procedures given to them by others. Research clearly shows that such 'construction-focused' mathematics instruction produces more powerful mathematical thinkers.

To illustrate the depth of scientific constructivism, Battista (1999:6) discusses its description of fundamental learning mechanisms namely abstraction, reflection, and learning and offers an example of the type of insight that can result from constructivist research. In scientific constructivist accounts of learning, *abstraction* is the fundamental mental mechanism by which new mathematical knowledge is generated. Abstraction is the process by which the mind selects, coordinates, combines, and registers in memory a collection of mental items or acts that appear in the attention field. Abstraction is the critical mechanism that enables the mind to construct the mental entities that individuals use to reason about their 'mathematical' realities. But understanding mathematics requires more than abstraction. It also requires *reflection*, which is the conscious process of mentally replaying experiences, actions, or mental processes and considering their results or how they are composed. As these acts of reflection are themselves abstracted, they can become the content – what is acted upon – in future acts of reflection and abstraction.

What emerges from this theory is a picture of meaningful mathematics learning, which arises as individuals recursively cycle through phases of *action* (physical and mental), *reflection*, and *abstraction* in a way that enables them to integrate related abstractions into ever more sophisticated mental models of phenomena. In fact, students' ability to understand and effectively use the formal mathematical systems of our culture to make sense of their quantitative and spatial surroundings depends on their construction of elaborated sequences of mental models. Initial models in these sequences enable students working with real-world objects to reason about their physical manipulations. Later models permit them to reason using mental images of real-world objects. Finally, symbolic models enable them to reason by meaningfully manipulating mathematical symbols that represent real-world situations. Without this recursively developed sequence of mental models, students' learning about mathematical symbol systems is strictly syntactic, and their use of symbolic procedures is totally disconnected from real-world situations. Research has shown repeatedly that rote learning of syntactic rules for manipulating symbols is exactly what results for most students in traditional mathematics curricula (*ibid*.:7).

Instead of presenting students with problems from the outset, traditional education seems to be more preoccupied with giving content. The content is often content which teachers themselves are most knowledgeable about or comfortable with, or content they think will be useful for solving some problems without also dealing explicitly with the process of acquiring this content (Bolhuis, 2003:339). According to Moursund (2006:1) much of the weaknesses in the traditional education system can be discerned by carefully thinking about the following diagram: a simplified 4-step model explaining the use of mathematics to solve a problem (see Figure 2.2).

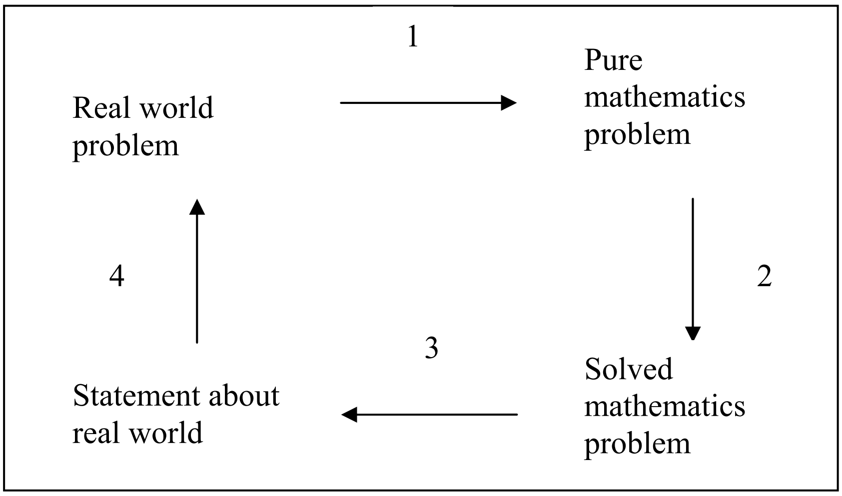


Figure 2.2: Simplified 4-step model of using mathematics to solve a problem (Moursund, 2006:1).

Standard estimates are that 80% of mathematics education at grade 12 level is focused on part 2 of the diagram, thus helping students to learn to carry out a number of different types of 'step 2' combinations. When the teacher starts the instructional process from part 2 of the diagram the teacher usually shows students several examples of how to solve a certain type of problem and then has them practise this method in class and in homework leading to "mindless mimicry mathematics" (Battista, 1999:4) or as O'Brien (1999) (in Moursund, 2006:4) terms "parrot math".

Within this traditional mathematics teaching approach, school mathematics is an endless sequence of memorizing and forgetting facts and procedures that are superficial and that make little sense to students. Doing mathematics then becomes an academic ritual that has no real-world usefulness (Battista, 1999:4-5). Because students in traditional curricula learn ideas and procedures by rote rather than meaningfully, they quickly forget them, so the ideas must be re-taught year after year which, according to Battista (1999:2) handicaps our nation in a competitive and increasingly technological global marketplace. Teachers, who teach students rote procedures for doing these novel items, do not test understanding, but mere memorization (*ibid.*:12).

In sense-making curricula, because students retain learned ideas for long periods of time, and because a natural part of sense making is to relate ideas, students accumulate an ever-increasing store of well-integrated knowledge (*ibid*.:11). Students therefore need enough opportunities to construct through experience the appropriate mental models to serve as the foundation for such abstract learning. If this does not occur students either drop out of the study of mathematics or resort to mindless mimicry (*ibid*.:12). In part 2 of the diagram mathematics topics are thus learned in a self-contained environment where what is being learned has little immediate use in the lives of students. Students therefore develop little skill at transferring their mathematics knowledge and skills into non-mathematics disciplines or into problems that they encounter outside of school (Moursund, 2006:2).

All current major scientific theories describing students' mathematics learning therefore agree that mathematical ideas must be personally constructed by students as they try to make sense of situations and actively seek to interpret it (Battista, 1999:5-6). A new classroom environment thus envisions teachers providing students with numerous opportunities to solve complex and interesting problems; to read, write and discuss mathematics; and to formulate and test the validity of personally constructed mathematical ideas so that they can draw their own conclusions (*ibid*.:4). According to Battista (1999:5) obtaining the facts in the information age is therefore not the problem anymore; it is the analyzing and making sense of these facts by solving problems, reasoning, justifying ideas, making sense of complex situations, and learning new ideas independently, that are of importance. Students should therefore not just follow rules invented by others, but instead make personal sense of the ideas. Developing powerful conceptual structures and patterns of reasoning will enable students to apply their mathematical knowledge and understanding to numerous real-world situations, thus giving them intellectual autonomy in their mathematical reasoning.

The theoretical links between PBL and scientific constructivism

PBL instruction begins at part 1 of Moursund's (2006:1) diagram which supports the students' personal construction of ideas set in a real-world context which can produce more powerful mathematical thinkers by increasing understanding and providing opportunities to apply knowledge in novel situations. This type of practice is consistent with the latest scientific research regarding learning and specifically the learning of mathematics (Battista, 1999:12-13).

In PBL students are further encouraged to apply their existing knowledge and to identify their further learning needs. Learning is student-centred and cooperative, with students encountering real-world problem-solving situations in small groups (as seen on part 1 of Moursund's) diagram that are guided by a tutor whose role it is to facilitate the learning process. This is quite different from most university teaching approaches which concentrate on the transmission of factual knowledge (Yeung; Au-Yeung; Chiu; Mok, & Lai, 2003:237). Students are thus actively engaged in the learning process in constructing personal meaning within their context (Prince, 2004:223). It is however important to note that PBL does not deny the importance of 'content' but it does deny that content is best acquired in the abstract, in vast quantities, and in a purely prepositional form, to be brought out and 'applied' much later to problems (as seen on part 2 of Moursund's diagram). Problem-based learning therefore requires a much greater integration of 'knowing that' with 'knowing how' (White, 2001:69).

2.2.2.3 Social constructivism

Social constructivism is gaining in popularity. This is a theory which acknowledges that both social processes and individual sense making have central and essential parts to play in learning (Bolhuis, 2003:329; Ernest, 2005:2). This is especially important within the fields of mathematics and science education where individual interpretations are more constrained. Hunt (1997:204-211) for instance explains that when a theorem is accepted within these fields as valid its conclusion is part of mathematical and scientific knowledge, regardless of subsequent cultural changes in the interest the theorem excites. Social demand may however determine the order in which objective knowledge about science or mathematics is acquired. Social constructivism is based on specific assumptions about reality, knowledge, and learning (Kim, 2001:1). To understand and apply models of instruction that are also rooted in the perspectives of social constructivists, such as PBL practitioners (De Villiers & Queiros, 2003:116), it is important to know the premises that underlie these learning assumptions (Kim, 2001:1).

Social constructivists view learning as a social process (Bolhuis, 2003:330). It does not take place only within an individual, nor is it a passive development of behaviours that are shaped by external forces. Meaningful learning occurs when individuals are engaged in social activities (Kim, 2001:1). Social constructivists, therefore, see both *the context in which* *learning occurs* and the *social contexts that students bring* to their learning environment as crucial (Kim, 2001:1; Merriam & Caffarella, 1991:139).

Within this research social constructivism is viewed as a *learning theory* which reflects a theory of human development that situates the individual within a socio-cultural context. Learning is viewed as a social process (Kim, 2001:1; Rogers, 1996:99-100), but the psychological orientation is not discounted (Hunt, 1997:204-211). Individual development derives from social interactions within which cultural meanings are shared by the group and eventually internalized by the individual (Kim, 2001:1). Interpretations of significant others in a social context may, therefore, be internalized by the student with or without conscious or critical reflection (Bolhuis, 2003:331; Kimeiko, 2006; Mezirow & Associates, 2000:3). From this social constructivist perspective individual sense-making is not deemed less important but the focus here is more on the social to the individual rather than the individual to the social. From this perspective individuals are seen as constructing knowledge in transaction with the environment and in the process both the individual and the environment are changed (Bolhuis, 2003:329).

The theoretical links between PBL and social constructivism

PBL ties into social constructivism (De Villiers & Queiros, 2003:116) which emphasizes student interactions rather than learning as a solitary activity (Prince, 2004:223). The cooperative nature of PBL stresses the importance and effectiveness of social learning. This promotes the students' self-esteem and gives them opportunity to acquire life skills. Students serve as a source of information and help and learn from each other: students experience the social construction and the social origin of knowledge (Bolhuis, 2003:331). Through collaborative group work and accessing a wide variety of resources, students experience and develop an appreciation for multiple perspectives (Williams, 2001a:93). Through PBL educators may help students to experience learning as the social construction of reality through cooperative learning and classroom discussions (Bolhuis, 2003:341). These collaborative learning situations allow students to construct meaning socially by working jointly on a problem (Drake, 1998:6). The student-centred approach that is adopted creates an ethos in which individual contributions are respected in a context of consensus building (De Villiers & Queiros, 2003:116).

2.2.2.4 Theories of self-direction and self-regulation

The fact that the psychological basis of learning has shifted gradually from a teacher-centred approach to a student-centred approach over the last three decades has placed an increasing responsibility on students for their own learning (Sungur & Tekkaya: 2006:307; Williams, 2001a:87). The term 'self-directed learning' (SDL) emerged in the literature on general adult education in the mid-1970s and has become a prominent feature of adult education theory, practice and research (Williams, 2001a:87). The origins of SDL can be traced to John Dewey (in Williams, 2001a:87) who proposed that all people are born with unlimited potential for growth and development.

The literature review revealed that the concept of self-direction is used in many different contexts and that the terms self-directed learning (SDL) and self-regulated learning (SRL) are often used interchangeably (Bolhuis, 2003:335). Candy (in Miflin, 2004a:47) warns against accepting the use of these terms in 'simplistic and uncritical' ways. It was therefore important for the researcher to clarify the way terms such as SDL and SRL are used in the context of this study. In this study a focus on self-direction refers to the goal-dimension (towards lifelong learning) while self-regulation refers to the actual activities necessary to move towards the goal (Bolhuis, 2003:335). SDL entails the movement towards autonomous lifelong learning whilst SRL entails the activities to get there. The two focal points will now be discussed separately.

Self-directed learning

The concept of self-directed learning has undergone close scrutiny over the last three decades and three principal, but distinct ideas have emerged from inquiry into the nature and processes of self-directed learning. It has been described as:

- A self-initiated process of learning that stresses that ability of individuals to plan and manage their own learning.
- An attribute or characteristic of students.
- A way of organising learning in formal settings that allows for greater student control (Williams, 2001a:87).

The concept of SDL in this study assumes a more social constructivist character, and it should be understood in that context. At its heart is the notion of personal autonomy (Brookfield, 1985:14) which Candy (1991:101) defines as being self-directing to the extent that one is in control of one's *destiny.* This should be the goal of all education but it is ephemeral in the sense that it is a long-term goal (Miflin, 2004a:47). According to Candy (1991:101) personal autonomy means having "a disposition toward acting and thinking autonomously in all situations" and having the willingness to assume ownership of thoughts and actions, as well as the consequences of those actions (Williams, 2001a:88). SDL is concerned much more with an internal change of consciousness than with the external management of mere instructional events (referred to as SRL within this study). From a social constructivist perspective self-directed learning does not imply that the students operate completely independently of classes, other students, or of the faculty. Although the concept of SDL has connotations of autonomy, independence, and isolation, this does not imply solitary learning where the self-directed student is one who pursues learning with a minimum assistance from external sources (Miflin, 2004a:46; Williams, 2001a:88). According to Brookfield (1985:7) no act of learning can be self-directed without external human or material sources of assistance since learning pursuits are usually undertaken within community groups, societies and other learning networks (Brockett & Hiemstra, 1991:12; Greyling, Geyser & Fourie, 2002:114).

Brookfield (1985:14) and Rodríguez and Cano (2006:619) stress the importance of distinguishing between the *techniques* or *approaches* of self-direction (referred to in this study as SRL) and the *internal change in consciousness* or *beliefs* (referred to in this study as SDL). According to Brookfield (1985:15) and Rodríguez and Cano (2006:622) the most complete form of SDL occurs when the external technical dimension is fused with the internal, reflective dimension (the internal change in consciousness). At that point, adults come to appreciate the culturally constructed nature of knowledge and values and act on the strength of that appreciation to reinterpret and recreate their personal and social worlds. A fully adult form of autonomous SDL is therefore manifested in such a praxis of thought and action. In this study the concept of SDL thus diverges sharply from a purely technicist (or mechanistic) perspective. Even though the student uses all the techniques of SDL he may not exhibit autonomous critical thought concerning alternative options or possibilities or being aware of the social context (Brookfield, 1985:9, 15).

When the concept of SDL is thus fully understood and incorporated properly it becomes valuable. It can help the student avoid blind acceptance of existing knowledge, and encourage him to use his energies on what is personally important and consistent with his personal values. It can also help him adapt to a rapidly changing environment. It can also assist the student to retain more and make better use of information, and thus enhance motivation to continue learning (Greyling *et al*., 2002:113). Candy (1991:101) emphasizes that the idea of personal autonomy captures the “spirit of the times”, embodying “the democratic ideal, the ideology of individualism, the concept of egalitarianism, the subjective of relativistic epistemology, the principles of humanism, and the construct of adulthood”. Knowles (1975:18) asserts that to be adequate for our new world, we must come to think of learning as the same as living. “We must learn from everything we do; we must exploit every experience as a learning experience”. When higher education institutions encourage students to become self-directed learners, they need to think of learning as extending far beyond educational participation. The student needs to take ownership of his own learning. Different learning approaches such as PBL may help him acquire the learning skills, attitudes and knowledge to empower this ownership (Bolhuis, 2003:329).

Self-regulated learning / self management

The concept of self-regulated learning (SRL) (as coined by Newman, 2004:15) in this study refers to a more technical or mechanistic view of learning emphasizing the activities that need to be performed by the student to move towards the goal of self-directed learning and ultimately lifelong learning. In this sense personal autonomy means the ability and willingness of the student to take control of his own *learning* in a learning situation (Candy, 1991:101) which will determine his potential for SDL (Williams, 2001a:88) and may ultimately lead to his being in control of his *destiny*. The student will then determine what is to be learned and how it is to be learned, taking primary responsibility for the learning process (Linares, 1999:407). According to Knowles (1975:18) this is a process in which students take the initiative, “in diagnosing their learning needs, formulating learning goals, identifying human and material resources for learning, choosing and implementing appropriate strategies, and evaluating learning outcomes".

Self-regulated learning involves the regulation of three general aspects of academic learning:

- First, self-regulation of *behaviour* involves the active control of the various resources students have available to them, such as competence in literature search and literature review and other library related skills, their time, their study environment, and the use of others such as peers and faculty members to help them (Pintrich, 1995:7).

- Second, self-regulation of *motivation* (self-determination) and affect involves controlling and changing motivational beliefs such as efficacy and goal orientation, so that students can adapt to the demands of a course. In addition, students can learn how to control their emotions and affect (such as anxiety) in ways that improve their learning (*ibid*.:7).
- Third, self-regulation of *cognition* involves the various cognitive strategies for learning, such as the use of deep processing strategies that result in better learning and performance (Pintrich, 1995:7; Vermunt & Vermetten, 2004:360). This includes the strategy of meta-cognition (the skill in reflecting on one's own learning) (Troskie-de-Bruin 1999:249). In order to progress through the process students should learn to ask relevant questions, such as the following: What do I know? What do I need to learn? Where do I find the information? How do I learn it? How do I progress? (Greyling *et al*., 2002:114).

In short SRL therefore involves the active, goal-directed, self-control of behaviour, motivation, and cognition for academic tasks by the student (Pintrich, 1995:5). Williams (2001a:88) notes that adult students will possess varying degrees of ability and willingness to accept responsibility for themselves as students. Siaw (2000), for instance, remarks that not all adult students may prefer or are comfortable with the notion or practice of SRL. Some may tend to be more self-regulated than others, and some may prefer or reject SRL in different situations. Bolhuis (2003:339) expands on this observation by noting that students with a high tolerance of uncertainty and well developed self-regulation skills will profit from instruction demanding a high degree of student control (such as PBL), whereas students with a low tolerance of uncertainty and lacking self-regulation skills may profit more from explicit and direct instruction with a high degree of teacher control.

The four learning components

To measure the self-directive and self-regulative components of learning Jan Vermunt constructed The Inventory of Learning Styles (ILS) on students' regulation of learning processes in higher education (Vermunt & Vermetten, 2004:364). The ILS provides an integrative learning theory focusing on the interplay between self-regulation and external regulation of learning processes (*ibid.*:359). The four learning components can be divided into two self-directive and two self-regulative learning components. The two *self-regulative components* of student learning consist of cognitive processing and meta-cognitive regulation strategies employed by students. *Cognitive processing strategies* include the thinking that the students use to process the subject matter, namely their deep and/or surface approaches to learning which directly leads to learning outcomes in terms of knowledge, understanding and skill (*ibid.*:361). *Meta-cognitive regulation strategies* include the students' thinking about their thinking, namely the self-regulation, external regulation or lack of regulation in their thinking (Linares, 1999:407) which entail internal versus external control of the learning processes (Vermunt & Vermetten, 2004:362).

Vermunt and Vermetten (2004:360) further note that certain teaching activities could promote high quality student learning. These teaching strategies constitute different levels of external regulation and, therefore, also the degrees of control students are expected to exert over their own learning. Congruence or friction can arise between learning and teaching strategies during the interplay between self-regulation and external regulation of learning. Congruence occurs when students' learning strategies and teachers' teaching strategies are compatible. Friction occurs when this is not the case. There are two further kinds of friction namely constructive and destructive friction. Constructive friction can stimulate students to employ learning and thinking strategies that they have not used before and hence give rise to an increase in the use of those strategies. Destructive friction occurs, when a teacher, for example takes over student learning activities that they are used to managing themselves. This friction may result in a decrease in students' use of learning and thinking activities. Friction of a destructive nature may also occur when the distance between the level of self-regulated learning that the teacher expects from the students, and the self-regulatory skills these students possess, is too great (Vermunt & Vermetten, 2004:363, Rodríquez & Cano, 2006:621).

The two *self-directive components* of learning consist of conceptions and orientations students have of learning. A *conception of learning* is a coherent system of knowledge and beliefs about learning and related phenomena which include knowledge and beliefs about oneself as a student, learning objectives, learning activities and strategies, learning tasks, learning and studying in general, and about the task division between students, teachers and fellow students in the learning process (*ibid.*:362). *Learning orientation* refers to the whole domain of students' personal goals, intentions, motives, expectations, attitudes, concerns and doubts with regard to their studies which include their motivation to learn, namely whether they are personally interested or certificate-orientated or vocation orientated in their learning (*ibid.*:360).

Vermunt (in Vermunt and Vermetten, 2004:369) further uses the term "learning pattern or style" as a super-ordinate concept in which the four learning components are united. The *four learning patterns* are coined meaning-directed, reproduction-directed, undirected and application-directed learning patterns. A *meaning-directed learning pattern* is typified by relating, structuring, and processing the subject matter critically, self-regulating learning processes and contents, constructing knowledge as learning conception, and personal interest as learning orientation. Meaning-directed learning patterns are characteristic of learning environments that emphasize relations in subjects and promote deep approaches to learning. They are also student-centred, with a relativistic view of knowledge which may lead to better achievements and study success in higher education. A *reproduction-directed leaning pattern is* typified by memorizing and rehearsing, analyzing, external regulation of learning, certificate and self-test directed-learning orientations, and a learning conception in which learning is viewed as the intake of existing knowledge. Reproduction-directed learning patterns are characteristic of learning environments that emphasize memorization of facts, provide a few incentives for active participation, with an absolutistic/dualistic conception of knowledge. This learning pattern is often typical of students in "second chance" type of education, who have experienced failure in their educational career (Severiens in Vermunt & Vermetten, 2004:369). An *undirected-learning pattern* is typified by a lack of regulation, an ambivalent learning orientation, and a learning conception in which great value is attached to cooperation with fellow students and to stimulating education. Undirected-learning patterns are characteristic of a learning environment which adheres to an absolutistic view of knowledge. An *application-directed learning pattern* is typified by concrete processing, a vocational learning orientation and a learning conception stressing the use of knowledge. Application-directed learning patterns are characteristic of an adult-student learning environment, especially in vocational education (*ibid.*:206,364-382).

According to Vermunt and Vermetten (2004:371), the adaptation to a new learning environment may further cause temporal diffuse patterns of relations between learning strategies, learning conceptions and learning orientations employed by students. More specifically, a period of friction is spontaneously induced when students enter a new type of education. This probably triggers a change in students, which is reflected in unstable learning patterns and learning conceptions. Students may find that their ideas of knowledge and how to go about learning are no longer adequate. Being in a traditional curriculum a discrepancy (dissonance) between meaning-directed conceptions of learning and reproduction-directed activities may also be found which may have affective consequences. Vermunt and Vermetten (2004:371) note that if there is an inner contradiction between beliefs and behaviour it can lead to a high level of dissatisfaction and tension among the students concerned. It may indicate that these students are going through a process of change in their study practices. Their learning environment forces these students to study in a way that does not match their conceptions of learning.

From the viewpoint of high quality learning, the meaning- and application-directed learning patterns are more desirable than reproduction-directed and undirected learning patterns (Vermunt & Vermetten, 2004:362). Rodríquez and Cano (2006:623) also mention that epistemological beliefs and learning approaches predict academic achievement: the more simplistic a student’s epistemological beliefs (referring here to the use of surface approaches), the poorer his academic performance.

The theoretical links between PBL and self-directed and self-regulative learning theory

There are various principles that govern the design of PBL based on self-directed and self-regulated learning theory. Newman (2004:15) emphasizes the following concept underpinning the key feature of PBL from within self-directive and self-regulative learning theory, namely, that successful learning requires adoption of particular attitudes and strategies.

Since most students are not homogeneous in background, knowledge, or experience, or the same in their learning abilities or learning styles the SDL activities which are inherent in every PBL phase make them suitable for students’ diverse learning needs (Siaw, 2000). According to Williams (2001a:95) the development of monitoring skills is an important part of developing the skills associated with meta-cognition which contributes to the students’ ability to be continuing professional learners. These skills are developed in PBL when students reason aloud through discussion, identify what they do and do not know, formulate hypotheses, clarify understanding through negotiation, critique classmates’ comments, establish educational goals and create action plans to meet those goals and test their hypotheses. These activities, when facilitated effectively, assist the students to develop self-monitoring skills necessary to identify learning needs by revealing their internal thinking processes. Next, within the PBL classroom, students activate their plans by engaging in self-directed study. Students determine how they will learn the knowledge and skills that they have identified and what resources they will use to assist them. This process assists students to develop the self-directed learning skills (SRL), which are a critical component of continuous professional learning. Students then apply the information acquired during self-study to the discussion of the real-life problem reaffirming some hypotheses, while rejecting others. Finally, students may summarise what they have learned and consciously recall and reflect on learning that occurred, elaborate on the learning and integrate it into their existing cognitive structures. According to Barrows (in Williams, 2001a:95) this process of situational analysis, learning needs determination, self-study, application of knowledge, critiquing of resources and personal research methods, and reflection of what was learned during the activity develops the student's ability to be self-directed in their learning. In the process of learning in this way, students learn to identify what they need to learn to solve the problem, and in pursuing the necessary learning via the very best resources effectively. With practice and the support of a group of peers, students gradually develop confidence in their ability to successfully learn from identification of their own deficits, rather than relying on teachers to tell them what to learn. They therefore develop simultaneously the appropriate knowledge and skills along with independence and motivation as students (Miflin, 2004a:50). The emphasis placed on self-directed learning within the PBL philosophy therefore encourages students to reflect upon and control their own learning activities; skills which are conducive to lifelong learning (Johnston & Tinning, 2001:161).

2.2.3 Conclusion

The goal of this section was to investigate the contribution of recent constructivist learning theory underpinning PBL which illustrates the complexities of learning at different stages throughout life (Bolhuis, 2003:343; Newman, 2004:16). It became clear that it is important to consider the life experience of the individual student, the social context, and self-direction or autonomy in lifelong learning (Bolhuis, 2003:329, Rodríguez & Cano, 2006:618). This section formed the conceptual basis for PBL as an educational approach to be adopted within a higher education institution in South Africa. The following section will provide a general overview of PBL as an educational approach.

2.3 GENERAL OVERVIEW OF PBL

2.3.1 Introduction

Newman's (2004:15) conceptual model presented an opportunity to reflect upon the many theoretical perspectives underpinning PBL. In an effort to integrate discussion of theory and practice this section will focus on the discussion of the constituent parts or key features of PBL.

2.3.2 Problem-based learning (PBL)

PBL is an educational philosophy to learning (Bouhuijs, 1993a:28; De Graaff & Newman, 2004:6; Poikela & Poikela, 1997:16; Savin-Baden, 2000:13) and an innovative approach to curriculum design and implementation (Hattingh & Killen, 2003:39-40) that has been designed using theory and research evidence about the nature of learning (Savin-Baden, 2003:2; Yamada & Maskarinec, 2004:86). PBL describes a student-centred learning environment in which problems drive the learning. Learning begins with a problem that needs to be solved and the problem is posed in such a way that students working cooperatively in groups need to gain new knowledge before they can solve it (Dunlap, 1997:1; Miflin, 2004a:50; Savin-Baden, 2000:15; Sonmez & Lee, 2003:1). This prepares students to think critically, to find and use appropriate learning resources of their own accord and challenges them to "learn how to learn" (Watson, 2005:11).

2.3.2.1 Where did PBL come from?

The origins of PBL can be traced back as far as the works of philosophers like Socrates, Aristotle and Plato who demanded from their students the kinds of problem solving and problem management that emerge in PBL curricula (Savin-Baden, 2000:3). Although problem-based learning draws on ideas that have been around for quite some time, as an *educational approach* it was first developed only in the late 1960's at the medical school of McMaster University in Hamilton, Canada (Barrows, 1996:3; De Graaff, 1993:9; Dochy, Heylen, & Van de Mosselaer, 2000:39). Research conducted by Howard Barrows (a neurologist) and James Anderson (an antropologist) revealed a lack of reasoning abilities of medical students (Savin-Baden, 2000:14; Schmidt, 1993:442). Both Barrows and Anderson critiqued all the time spent on didactic teaching and set out to design a medical school curriculum based solely on small-group, student-centred learning whilst giving students problems from their first day (Dochy *et al*., 2000:39).

Stimulated by the McMaster approach, other newly-created medical schools in Maastricht (the Netherlands) (Barrows, 1996:3; Dochy *et al*., 2000:39) and in New-Castle (Australia) also developed PBL curricula. By the early 1980's, the PBL approach was sufficiently well researched and developed to be used as the basis for a complete undergraduate medical programme (Barrows, 1996:3; Hattingh & Killen, 2003:39-40). Since then PBL as an approach to learning has grown in breadth and depth throughout other parts of the world (Dochy *et al*., 2000:39; Savin-Baden, 2000:2) and has spread not only through North America, the Netherlands and Australia but also throughout the USA (Barrows, 1996:3) the UK, Brazil, Chilli, Egypt, the Philippines, Hong-Kong, Indonesia, Malaysia, Nigeria, Taiwan, Sweden and Switzerland (Dochy *et al*., 2000:22).

Although PBL has been implemented mainly in the context of health education like medicine, nursing, physiotherapy, dentistry, and occupational therapy (De Graaff, 1993:11; Lam, 2004:374) it has also been adapted and used in different disciplines including business administration, education, architecture, industrial design, law, engineering, social work, counselling, psychotherapy, geography, leadership education, mathematics, science, chemical and mechanical engineering, zoology, and even high school education (Barrows, 1996:1; De Graaff, 1993:11; Charlin, Mann & Hansen, 1998:323-330; Lam, 2004:374).

Following suit, new debates about professional education in South Africa have been influential in putting PBL high on the agenda within higher education which have led to the introduction of PBL as a teaching approach in many of the professional degree programmes in South African higher education institutions. Four out of the eight medical schools in South Africa have already adopted PBL curriculum. According to Meel (2003) the Faculty of Health Sciences at the University of Transkei (UNITRA) is currently the leading institution in Southern Africa with regard to PBL. It introduced PBL in the medical school during 1992 as a way to foster effective learning among students with weak academic backgrounds. The University of Pretoria also implemented a new problem-oriented, vertical and horizontally integrated MBChB curriculum at first year level. The University of the Witwatersrand (Wits) implemented PBL through simulation games in the International Relations foundation course

(Ala & Hyde-Clarke, 2006:121). The University of Kwa-Zulu Natal's Nelson R. Mandela School of Medicine has also implemented PBL (McLean, 2004:301-303). At the Medical School of the University of Stellenbosch, PBL is currently high on the agenda as a teaching approach to be considered in order to enhance professional education.

2.3.2.2 What is PBL?

The introduction of PBL within disciplines with their own traditions and characteristics has led to the emergence of several varieties of PBL (Savin-Baden, 2000:16). According to De Graaff (1993:11), the ongoing expansion of PBL will lead to even more diversity. Since PBL has many guises and differences (Savin-Baden, 2000:16) it is difficult to define exactly what PBL is (Barrows, 1994:1). This also became apparent considering the many terms used to refer to PBL such as "problem-focused", "issue-based learning", "enquiry and action learning", "learning in a functional context", "task-dependent learning", or "problem-generated learning" (Lam, 2004:374). Barrows (in Savin-Baden, 2000:18) concluded that the term PBL must be considered a genus from which there are many species and subspecies

General features of PBL

PBL derives from theory that learning is a process of constructing knowledge and not a receptive process, that cognitive processes affect the use of knowledge and that social and contextual factors influence learning (Engelbrecht, 2001:12). On this basis, PBL approaches in different curricula in different settings share the following key features outlined by Newman (2004:14-15) and others such as Barrows (1996:3-6) and Boud (in Savin-Baden, 2000:17-18) as illustrated in Figure 2.3.

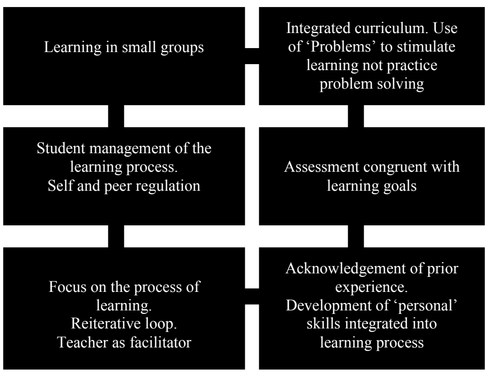


Figure 2.3: The constituent parts or key features of PBL (Newman, 2004:15)

- **PBL is an educational approach**, not just an isolated teaching technique (Charlin *et al.*, 1998:323-330; Limerick & Clarke, 1997:259-274; Newman, 2004:17; Savin-Baden, 2000:19). PBL offers an attractive alternative to traditional education by shifting the focus of education from what staff members teach to what students learn (Burch, 2001:194; White, 2001:69). Content remains important, but there is more emphasis on the process of learning (White, 2001:70).
- **Learning is student-centred** with an emphasis on students taking responsibility for their own learning. Students take the role of active problem-solvers rather than passive students waiting to be spoon-fed (Baker, 2000:258; Charlin *et al.*, 1998:323-330; Mierson, 1998:16; Newman, 2004:115; Savin-Baden, 2000:17-18).
- **PBL involves a shift in the curriculum** which typically involves a shift in three curriculum areas, namely content coverage to problem engagement; role of lecturing to role of coaching; and students as passive learners to that of active problem-solvers. The move towards using PBL in many educational institutions can be illustrated as shown in Figure 2.4 (Finucane *et al.,* 1998:445-448).

Figure A: Traditional teaching model

Figure B: The conventional PBL curriculum model (C-PBL)

Figure 2.4 The two curriculum models (Neo & Neo, 2005).

- **Problems form the organizing focus and stimulus for learning.** The principal idea behind PBL is that learning should be organized around conceptually ill-defined problems, rather than around subjects or academic disciplines (Charlin *et al.*, 1998:323-330; Limerick & Clarke, 1997:259-274; Raine & Symons, 2005:6; Van den Bosch & Gijselaers, 1993:31).

- **Lecturers are facilitators or guides** rather than disseminators of knowledge. The role of the tutors can be understood in terms of meta-cognitive communication which implies that the tutor role models asking the kind of questions that students should be asking themselves to better understand and manage the problem until students are eventually ready to take on this role themselves (Baker, 2000:261; Engelbrecht, 2001:12).
- **Learning occurs in small groups.** PBL is a collaborative form of learning (Limerick & Clarke, 1997:259-274) in which students work cooperatively in small groups of five to nine students (Dochy *et al*., 2000:25; Raine & Symons, 2005:6) to seek solutions to real-world problems (Mierson & Freiert, 2004:15).
- **Interdisciplinary connections are made.** The use of problems to introduce concepts at increasing depths also provides a natural mechanism to highlight the interconnections among disciplines whilst de-emphasising separate subjects (Allen, Duch & Groh, 1996:45; Newman, 2004:17).
- **New information is acquired through SDL.** Through PBL students are provided with a learning environment where they are stimulated to become more involved and take on more responsibility for the learning process (Dochy *et al*., 2000:25).
- **Assessment is congruent with learning objectives.** Moving to a student-centred, cooperative learning format requires rethinking how to assess student learning in such an environment. In PBL a change in focus from staff assessment of outcomes of learning to student self- and peer assessment is evident (Boud in Savin-Baden, 2000:17-18). The basis of self-assessment in the learning process is reflection which means assessment and learning has to be integrated in such a way as to support rather than measure learning (Poikela & Poikela, 1997:19).
- **Prior experience is acknowledged.** In working on problems through small-group discussions students' prior knowledge and experience are activated (Schmidt *et al*., nd:23).

In short PBL in its pure form treats teaching and learning as a problem-centred, collaborative, integrated, interdisciplinary process with students working in small groups on open-ended problems rooted in real-life (Van Kampen, 2005:38).

2.3.2.3 Why PBL?

PBL is regarded as a valuable attempt to improve the quality of higher education (Van den Bosch & Gijselaers, 1993:31). PBL fulfils distinct educational objectives by not only developing content-oriented (subject-specific) but also process-oriented (global) skills (Groh & Duch, 2003:4). Content-orientated skills focus on what students should *know* (Duch & Groh, 2001:97-98) whilst process-oriented skills focus more on what students should be able to *do* which are not necessarily linked to a specific content (*ibid.*:99). Some of the skills on offer through PBL are as follow:

- PBL develops effective problem-solving skills. PBL focuses on introducing concepts to students by challenging them to solve a real world problem. PBL therefore utilizes an interactive approach and uses the student's current knowledge base as a springboard for the development of new concepts and reasoning (Bechtel, Davidhizar & Bradshaw, 1999:183). During this process students learn complexity and realize that there are no straightforward answers to problems, but that learning and life takes place in contexts, which affect the kinds of solutions that are available and possible. Learning such as this is therefore not just a straightforward method of solving problems, but it helps people to learn how to learn (Watson, 2005:27) and to link learning with their own interests (Savin-Baden, 2000:5) whilst developing critical skills for the workplace (Watson, 2005:28).
- PBL enhances the acquisition, retention and use of knowledge. It seems that traditional teaching often produces inert knowledge in students which seem to be related to the narrow needs of tests and examinations only (Campbell, 1999:13). PBL produces more transferable knowledge that support understanding, emphasise application, and integrate theoretical and practical knowledge (Tynjälä, 1999: 373).
- PBL integrates knowledge and skills from different domains. Many students fail to appreciate how the pieces of the curriculum can be pulled together, and continue to view their subjects as a sequence of distinct units rather than as an integrated whole (De Vita, 2004:79). The PBL approach focuses on the integration of knowledge and skills from different relevant domains and disciplines (De Graaff, 1993:10; Finucane, *et.al.*, 1998:445-448).
- PBL enhances self-directed, lifelong learning skills. PBL fosters student independence and responsibility for learning or self-directed and lifelong learning (Dahle, Brynhildsen,

Behrbohm Fallsberg & Rundquist, 2002:280; Lam, 2004:375; Mierson, 1998:16; O'Grady, 2004:2; Savin-Baden, 2000:15). Lifelong learning skills include, as a minimum identifying what one knows and does not know, locating sources of information and organizing bodies of information (Mierson, 1998:17).

- PBL provides motivation for learning. The perceived relevance of work with real life problems and the challenge of solving problems in PBL, therefore, provide strong intrinsic motivation for learning (Lam, 2004:375).

2.4 DIFFERENT APPROACHES TO PBL

2.4.1 Introduction

Although there are general characteristics of PBL the implementation of PBL in different institutions and faculties is not only affected by the theoretical background that supports its implementation but also by the structural and pedagogical context into which it is placed, in terms of the discipline or subject, the organization and the staff concerned (Poikela & Poikela, 1997:8; Savin-Baden, 2000:19). This accounts for the numerous different PBL approaches that exist.

There are many different kinds of approaches to PBL. According to Savin-Baden (2000:8) these different forms need to be made explicit as each offers different advantages to the students, staff and to the world of work (Poikela & Poikela, 1997:8). Within the scope of this study the PBL approaches are divided into three categories, namely:

1. Structural PBL approaches which provide a structure for the carrying out of each problem unit.
2. Instructional PBL approaches which describe the organisation of class sessions and so forth.
3. Operational PBL approaches which focus on how PBL is conceptualised and manifested (in other words how PBL operates) within different curricula (Raine & Symons, 2005:10).

2.4.2 Structural PBL approaches

Medical schools mainly implemented PBL in the context of major curricular reform (Finucane *et al*., 1998:445-448) and are some of the best exemplars of approaches focusing on providing a structure for the carrying out of a problem unit. The best-known PBL-models, mostly based on cognitive approaches, have been developed in medical education in Canada and the Netherlands. These approaches are usually presented in the form of *stages or phases* of learning and emphasize the meaning of individual construction of knowledge and a rationalist way of problem solving (Engelbrecht, 2001:14; Poikela & Poikela, 1997:8). In practice this means that teachers pay attention to students' problem solving processes at the individual level. This easily leads to underestimating the cooperative nature of problem solving and the processes involved in the group dynamics. The approaches used in Australia and Sweden, on the other hand, present the learning process in a form of a *cycle,* which emphasizes the meaning of students' own experiences and the holistic nature of learning. In this case, the students' own experiences, group dynamics and communication in learning are taken into account (Poikela & Poikela, 1997:9).

2.4.2.1 The PBL approach of Howard Barrows (McMaster University)

The features of the original PBL method developed at McMaster University still remain the most widely recognized (P. Bouhuijs, personal communication, March 16, 2006). Barrows' (1996:5) approach include the following characteristics: a) learning is student-centred; b) learning occurs in a small student group; c) teachers are facilitators or guides; d) real-life problems form the organizing focus and stimulus for learning; e) problems are a vehicle for the development of clinical problem-solving skills; and f) new information is acquired through self-directed learning (Savery & Duffy, 1994:2-5).

2.4.2.2 The Seven jump approach (University of Maastricht)

In 1974, PBL was introduced in the Netherlands by the teaching staff at the then new medical school of the University of Maastricht. The approach was adopted from the Health Sciences programme of McMaster University (Engelbrecht, 2001:15; Smits, Verbeek & De Buisonje, 2002:153-156). The Maastricht medical school was among the first to adapt the principles of

PBL and in the Netherlands PBL has become known chiefly in the Maastricht version (De Graaff, 1993:10).

The theoretical approach to PBL at Maastricht as a method of instruction stands (in opposition to Barrows' views) firm within the rationalist tradition, and is strongly influenced by cognitive psychology, based on the information processing approach to learning (Albanese, 2000:729-738; Schmidt *et al*., nd:28). While Barrows viewed PBL as a tool to learning how to solve professional problems, Schmidt (1993:442) viewed PBL as a special way to acquire and organize knowledge.

The PBL process referred to in many medical school programmes is largely derived from the seven jump approach developed at Maastricht (Newman, 2004:122). In the seven jump approach PBL can be seen as divided into several phases or stages spread over periods of group work and individual study (De Grave, Boshuizen & Schmidt, 1996:321). The procedure starts when a collection of carefully constructed problems is presented to small groups of students that challenge their knowledge and experience (Smits *et al*., 2002:153-156). The important premise of this approach is that the students' prior knowledge of the problem is in itself insufficient to understand it in depth (Schmidt, Dolmans, Gijselaers & Des Marchais, 1995:83). In this approach students work together in small groups each with individual roles following seven defined steps (Raine & Symons, 2005:10; Van de Wiel, 2002).

Step 1: Clarifying and agreeing on working definitions of unclear terms or concepts. During this step students discuss with each other difficult concepts or terms.

Step 2: Producing an exact definition of the problem. During this step students define the problem(s), agree which phenomena require explanation and decide which issues need further discussion (Dochy *et al*., 2000:40; Schmidt in Newman, 2004:122).

Step 3: Analysing the problem components, implications, suggested explanations and developing working hypothesis (through brainstorming). During this step students study the text carefully in order to gain a clear impression of the situation described, which results in ideas and hypothesis about the structure of the problem. These are either based on students' prior knowledge or are the result of rational thought.

Step 4: During this step ideas are clustered together and a summary is produced of the various explanations of the problem, which is then prioritised. Students try and determine what they already know about the problem and the ideas referred to in the summary are more extensively studied (Barrows, 1994:1; Dochy *et al*., 2000:40; Schmidt in Newman, 2004:122).

Step 5: Generating and prioritising learning objectives. During this initial analysis, dilemmas will arise and questions will come up. Students discuss with each other what they are going to study by determining what they don't know, only know vaguely, or may have conflicting ideas about. This is then formulated into questions (also referred to as learning issues) which are prioritised and can be used for subsequent, individual, self-directed study.

Step 6: Students research the learning objectives independently through self study. References, audiovisual aids, occasional lectures, and skills training may be included as learning resources relevant to the understanding of the problem(s) (Barrows, 1994:2; Dochy *et al*., 2000:40; Engelbrecht, 2001:20; Schmidt in Newman, 2004:122; Schmidt *et al*., 1995:83; Smits *et al*., 2002:153-156).

Step 7: Synthesising a comprehensive explanation of the phenomena and reapplying and integrating synthesised newly acquired information to the problem(s). During this step the students inform one another about their individual findings, supplement this knowledge, and correct it where necessary.

The medical school models, which are largely derived from the seven jump approach developed at Maastricht are very student-centred (group discussion is usually the primary class activity) and is according to Duch, Groh and Allen (2003) a good choice for highly motivated, experienced students where tutorials take place in small, upper-level seminar classes. However, the medical school model does have shortcomings. For instance, it makes no specific mention of the requirement of students to reflect on their development of learning and process skills (Dolmans & Schmidt in Newman, 2004:122).

2.4.2.3 The Eight, Nine and Ten step approach

Due to its shortcomings, the seven jump approach was modified to an *eight, nine and ten step PBL approach*. The *eight step approach* incorporates a role for reflection on what has been learnt and the process of learning (Wolff in Newman, 2004:123).

Woods and Barrows (in Poikela & Poikela, 1997:15) went one step further as both presented assessment as a last stage in the learning process. Woods (in Newman, 2004:115-116) proposed a *nine step approach* focusing specifically on the development of Problem-based curricula rather than the PBL process as such to guide the process of curriculum development. Woods' nine step approach to problem-based learning programme development includes the following stages: 1. Decide how to start. 2. Visualise the timing and duration of the meetings. 3. Create the environment for learning the subject knowledge. 4. Create the environment for the process skills. 5. Create the environment to develop expertise. 6. Organise student groups. 7. Create the resources. 8. Assess students' performance. 9. Evaluate programme effectiveness.

In September 1987, the Sherbrooke School of Medicine in Quebec, Canada implemented a full-scale preclinical PBL curriculum (Des Marchais & Chaput, 1997:66). The seven step approach was extended to *a ten step approach* adding the steps of generating research questions, small group and tutorial process evaluation, and personal evaluation.

2.4.2.4 PBL-CD and Leuven approach

A recent version of PBL is called the *problem-based learning as co-development (PBL-CD) approach which* also incorporates a role for reflection on what has been learnt and the process of learning. This version views problem solving as a progressive skill. It is a series of cycles consisting of four fundamental thinking processes, namely understanding and planning, acting, reflecting and rethinking and revisioning. These cycles are applied to both teachers developing curriculum and students engaged in problem solving (Drake, 1998:94).

Similar to the approaches of Wolff, Woods and Barrows the Leuven approach tries to compensate for the disadvantages of the seven jump approach of Maastricht and McMaster, namely the lack of reporting the problem solving process that led to it. The Leuven approach differs further from McMaster and Maastricht in the way that it is more product-orientated (Dochy *et al*., 2000:47; Newman, 2004:115-116; Poikela & Poikela, 1997:15).

2.4.3 Instructional PBL approaches

Within this study instructional PBL approaches describe the different instructional procedures (in other words organisation of class sessions, group size and class size) that can be followed during a PBL session (Raine & Symons, 2005:10).

2.4.3.1 The Medical School Model or Fixed Facilitator Model

In many of the medical schools where PBL is used as a teaching technique a fixed facilitator model is employed. A fixed facilitator model implies that a facilitator is assigned to a group for the duration of a PBL unit(s). Adopting a fixed or dedicated facilitator model may hold the following benefits: the facilitator may get to know all the students well in a group; the facilitator may be more likely to be aware of the group dynamics of the particular group; there may be more opportunities to model the types of questions that would help a group probe for a deeper level of knowledge; the facilitator can more easily challenge the group to deepen their understanding of a particular topic; the facilitator may have many opportunities to become alert to conceptual errors a group is making about the content and the facilitator can reinforce desirable behaviour in the group (Mierson, 1998:21).

The instructional PBL process at the University of Maastricht employs a fixed facilitator model. In the Maastricht process the tutorial group is composed of a dedicated faculty tutor who is assigned to a group to guide the students through their discussions of the problem. Groups consist of eight to ten students with a student acting as a chairperson and another student acting as a scribe (Raine & Symons, 2005:10; Engelbrecht, 2001:21; Duch *et al*., 2003). According to Duch *et al*. (2003) the fixed or dedicated facilitator model is especially a good choice for highly motivated, experienced students and applicable for small, upper-level seminar classes.

2.4.3.2 The Floating or Roving Facilitator Model

Within a floating or roving facilitator model the facilitator moves around from group to group listening to the students and probing their understanding. The floating facilitator model is a more structured format since it provides opportunity for a greater degree of instructor input into learning issues and resources (Duch *et al*., 2003).

The floating or roving facilitating model may hold the following benefits:

- The facilitator can get to know all the students in the class much sooner.
- The student groups may become self-sufficient much earlier as the students may take on more responsibility for their own group dynamics.
- The logistics can be simpler. With all the groups in one room, coordination of groups and materials is more straightforward.
- There are more opportunities for formal exchange of ideas about the content among groups.
- There can be opportunities for short mini-lectures on topics that are confusing to all the groups and for end-of-problem wrap-up discussions involving all the groups.
- Some class time may be devoted to group reporting.
- Time can also be spent in debates and whole class discussions.
- All groups have some access to the facilitator who may be a content expert (Duch *et al*., 2003; Mierson, 1998:22; Raine & Symons, 2005:10).

A group size which is limited to four to six students is advisable when using the floating facilitator model since groups of this size help improve student accountability and provide scope for participation for all group members (Raine & Symons, 2005:10). According to Duch *et al*. (2003) the floating facilitator model is especially a good choice for less experienced students and applicable for small- to large-sized classes or institutions where there is a shortage of experienced facilitators.

2.4.3.3 The Peer Tutor Facilitator Model

Within a peer tutor facilitator model advanced undergraduates serve as facilitators. They help monitor group progress and dynamics and ensure that student discussions are demonstrating a reasonable deep level of knowledge. Since the peer students already have experience of the PBL process, they can serve as a role model for students who are unfamiliar with it (Raine & Symons, 2005:10).

2.4.3.4 Large Class Models

PBL can be implemented in large classes where only lecture theatre accommodation is available or when there are a limited number of additional facilitators (Raine & Symons, 2005:10). A group size of four is advisable since it poses a numbers advantage in dealing with groups versus dealing with individual papers and projects (Duch *et al*., 2003).

In the large class model the role of the course leader will be to ensure that problems given to the students are discussed; that learning issues are prioritized; that students report on the results of their discussions; that students share resources; and suitable questions are asked to ascertain the level of knowledge obtained by the students (Raine & Symons, 2005:10). According to Duch *et al*. (2003) floating facilitator or peer facilitator models are the most appropriate models for large classes.

2.4.4 Operational approaches

Since the PBL approach focuses on the integration of knowledge and skills from different relevant domains and disciplines it is important to understand different problem-based learning approaches in operation in different curricula (De Graaff, 1993:10; Finucane, *et.al*. 1998:445-448). The discussion will therefore firstly focus on what the term curriculum integration entails within the scope of this study. Secondly, the integration ladder of Harden will be discussed, which describes curriculum integration on a continuum of options. Within this study curriculum integration is the process of experiencing and understanding connections within a discipline as well as across disciplines and, because of this, seeing relatively fragmented knowledge in a unified whole (Bhattacharya, MacIntyre, Ryan & Brears, 2005; De Vita, 2004:71; Halbach, 2000:1). This process overcomes the rigid perceptions of subject boundaries and therefore supports the claim that all knowledge is interrelated (Drake, 1998:11).

2.4.4.1 Harden's integration ladder

According to Harden (2000:551) discussions about integration are often polarized with some teachers in favour and others against integrated teaching. Harden proposes that the question to be asked of teachers and curriculum designers is not whether they are for or against integration, but rather where on the continuum they should place their teaching. The integration ladder of Harden has eleven steps from traditional subject-based to integrated teaching and learning (Harden 2000:551; Kysilka, 1998:197). The ladder builds on previous descriptions or models of integrated curricula, notably the work of Jacobs, Fogarty and Drake. Jacobs has concentrated her definitions of integration on what happens specifically with respect to the disciplines. Her options are focused on the *organisational structure* of the curriculum and are less concerned with how the curriculum is taught. Robin Fogarty's models are more focused on the *how* rather than the organizational structure of the curriculum (Kysilka, 1998:197). Drake's (1998:20) model on the other hand indicates six steps on a continuum of integration, namely traditional integration, fusion, integration within one subject, multidisciplinary-integration, interdisciplinary-integration and trans-disciplinary-integration (Kysilka, 1998:202) which Harden (2000:551) has expanded by including five more steps on the integration continuum.

Harden (2000:551) describes the following 11 steps of integration on a continuum between two extremes.

1. Isolation
2. Awareness
3. Harmonization
4. Nesting

'Staircase' model (Ward & Lee, 2004:73)

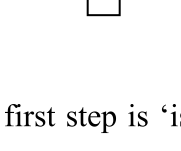
5. Temporal co-ordination
6. Sharing
7. Correlation
8. Complementary
9. Multi-disciplinary
10. Inter-disciplinary
11. Trans-disciplinary

'Spider-web' model (Ward & Lee, 2004:73)

In the first four steps on Harden's ladder, the emphasis is on the subjects or disciplines. This can be likened to the "staircase" or "brick-on-brick" model of curriculum organization which has predominated most of this century (Ward & Lee, 2004:73). The curriculum comprises largely of separate and discrete fragments (usually called subjects) added together to form the curriculum and accumulating in numbers and size as the volume of knowledge increase (Margetson, 1998:199). This model implies a well-defined progression from simple to complex, in which one concept must be attained before the next is achievable (Ward & Lee, 2004:73). Here the control of the curriculum is in the hands of the textbook publishers and subject matter 'experts' (Kysilka, 1998:206). The staircase model further implies lecture-based instruction in which a teacher provides the students with information, usually followed by activities to reinforce student learning. Learning is usually measured through tests that are taken independently by students. Students are passive, mainly observing instead of processing information. As a result teaching and learning become more or less separated, because learning is postponed until after the lecture, or even until some days before the test (Jochems, 1993:65).

The following six steps emphasize integration across several disciplines. As one therefore moves up the ladder, there is less emphasis on the role of disciplines, an increasing requirement for a central curriculum, organizational structure and a requirement for greater participation by staff in curriculum discussions and planning (Ward & Lee, 2004:73). Moving up the ladder the control of the curriculum has accordingly moved to more teacher-facilitated student choice (Harden, 2000:551; Kysilka, 1998:206). Eisner (in Ward & Lee, 2004:73) notes that neither the "staircase" model nor the "spider-web" model for organizing curricula is the "right" or "wrong" way to educate; however, depending on the philosophy of the teacher or educational unit, one model often will prevail. Harden's (2000:551) detailed descriptions of the eleven steps of integration on a continuum are as follow:

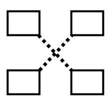
Step 1: Isolation (Synonym – fragmentation, anarchy)



The first step is 'isolation'. Departments or subject specialists (represented by squares in the diagram) organize their teaching without consideration of other subjects or disciplines. This end of the continuum represents the discipline or subject-centred approach to learning, also referred to as the current 'traditional model' (Kysilka, 1998:204). Each discipline therefore looks from the perspective of their own discipline at the curriculum content in terms of areas to be covered, depth of coverage, sequence and timing (Harden, 2000:552). The material is therefore taught through the lens of only one discipline (Drake, 1998:20) where each subject is seen as an entity in itself. No attention is paid to other or related subjects, which contributes to the curriculum. The relationships between subjects are thus not explicitly covered and related topics from two disciplines are not intentionally correlated. Within these traditional approaches students may attend a lecture on anatomy, and then move on to a lecture in physiology, with neither lecturer being aware of what was covered in the other lecture (Harden, 2000:552). Here content is taught in its separate state and any integration that takes place is often haphazard and resides solely within the student. The slots in the timetable are labelled with the name of the subject, which is taught by specialists in the discipline. The objectives are seen as mastery of the subject and these are tested in a subject-based assessment of the student's knowledge and understanding of the subject.

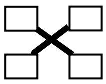
In these traditional educational settings modules are therefore like 'boxes' filled with information. Students are then, at best, invited to self-serve and critically process this information, or at worse, they are spoon-fed bits of content and expected to assimilate, digest and regurgitate. Such models are thus under criticism for placing too much emphasis on memorization of facts and figures and for overloading the students with excessive details, especially in times characterized by unprecedented knowledge expansion and accelerated information input (De Vita, 2004:74; Puri, 2002:52). Within these traditional approaches lecturing is predominantly used as an instructional technique (Dochy *et al*., 2000:14).

Step 2: Awareness



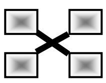
The second step is 'awareness'. As with 'isolation', the teaching is subject-based. Some mechanisms are in place, however, whereby the teacher in one subject is made aware of what is covered in other subjects in the curriculum. This can be achieved through appropriate documentation and communication about the aims and objectives of each course and the content and topics covered in lectures and other teaching sessions. Lecture notes or handouts may be circulated to other course teachers as well as to students. At this step, however, there is no explicit attempt to help the student to take an integrated view of the subject (Harden, 2000:552).

Step 3: Harmonization (Synonym – connection, consultation)



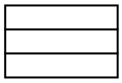
In harmonization, teachers responsible for different courses, or different parts of the same course, consult each other and communicate formally or informally about their courses. This consultation process encourages teachers to adapt their programmes so that each course makes an appropriate contribution to the curriculum and the overall curriculum objectives are more likely to be achieved. Fogarty (in Kysilka, 1998:198-199) has described this stage of integration as ‘connection’. The disciplines remain separate but the teacher may make explicit connections within the subject area to other subject areas. The key to this model is the effort to deliberately relate curricula within the discipline rather than assuming that students will understand the connections automatically (Harden, 2000:552).

Step 4: Nesting (Synonym – infusion, fusion)



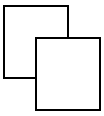
‘Nesting’ is the fourth step of integration. It has been used by Fogarty (in Harden, 2000:552) to describe an integrated approach where the teacher targets skills relating to other subjects. In this form of integration a topic is thus inserted into several subject areas (Drake, 1998:20). Content drawn from different subjects in the curriculum may be used to enrich the teaching of one subject. In nesting, the individual subjects or disciplines recognize the broader curriculum outcomes and relate their teaching programmes to these.

Step 5: Temporal co-ordination (Synonym – parallel teaching, concurrent teaching)



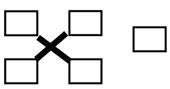
In temporal co-ordination, each subject remains responsible for its own teaching programme. The timing of the teaching of topics within a subject, however, is done in consultation with other disciplines. The timetable is adjusted so that topics within the subjects or disciplines, which are related, are scheduled at the same time. Similar topics are taught on the same day or week while remaining part of a subject-based teaching programme (Drake, 1998:47; Harden, 2000:553). Students study the concepts of the different subjects separately, and are left to uncover the relationships, which is facilitated by the timetable. Programmes described as 'integrated teaching programmes' are often in practice programmes which are temporally co-ordinated. The implementation of a temporally co-ordinated programme introduces some of the advantages of integrated teaching. According to Harden (2000:553), it is a good stepping off point for a more integrated curriculum.

Step 6: Sharing (Synonym – joint teaching)



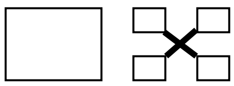
Two disciplines (which usually consist of complementary subjects) may agree to plan and jointly implement a teaching programme. The joint course produced emphasizes shared concepts, skills and attitudes. Unlike temporal co-ordination which may be a step towards a more fully integrated overall programme, shared programmes are often seen as ends in themselves which are not necessarily examples to be followed in other parts of the curriculum.

Step 7: Correlation (Synonym – concomitant programme, democratic programme)



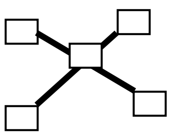
In the 'correlation' step of integration, the emphasis remains on disciplines or subjects with subject-based courses taking up most of the curriculum time. Within this framework, an integrated teaching session or course is introduced in addition to the subject-based teaching. This session brings together areas of interest common to each of the subjects. An example of correlation is a basic medical science programme where students study topics, first from the perspective of each of the subjects, and then meet for an integrated session. The contributions of the different subjects are used to clarify the problem. Another example of correlation is a subject-based programme in which the project, problem or assignment given to students, is designed to integrate the subjects. The students may be required to submit a written assignment or to present a report on the project at an integrated plenary session.

Step 8: Complementary programme (Synonym – mixed programmes)



The 'complementary' approach has both subject-based and integrated teaching. The integrated sessions now represent a major feature of the curriculum. The focus for the teaching may be a theme or topic to which the disciplines can contribute. Running alongside the integrated teaching are scheduled opportunities for subject-based teaching.

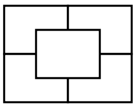
Step 9: Multi-disciplinary (Synonym – webbed, contributory)



A multidisciplinary approach brings together a number of subject areas in a single course with themes, problems, topics or issues as the focus for the students' learning. The term 'webbed' was used by Fogarty to describe this stage of integration. A fertile theme is webbed to curriculum contents, and disciplines or subjects use the theme to sift out appropriate concepts, topics or ideas (Harden, 2000:554). The theme or issue is usually studied during the same time frame, but in separate classrooms. Examples are the medical school PBL models used at Maastricht and McMaster University.

The characteristic of multidisciplinary integration is that, whatever the nature of the theme, it is viewed through the lens of subjects or disciplines. The theme or problem is the focus for the student's learning but the disciplines preserve their identity and each demonstrates how their subject contributes to the student's understanding of the theme or problem (Harden, 2000:554; Hommes, 1997:2). In multidisciplinary teaching, the contributions of the individual disciplines to the theme are stated implicitly in the curriculum documents and the timetables. However, students in general are expected to make the connections among subject areas rather than having them taught explicitly (Drake, 1998:20). In the multidisciplinary step on the integration ladder the subjects and disciplines give up some measure of their own autonomy as connections are made among subjects (*ibid.*:47).

Step 10 Inter-disciplinary (Synonym – monolithic)



In the taxonomy proposed in the ladder, interdisciplinary teaching implies a higher level of integration, with the content of all or most subjects combined into a new course with a new menu. In the interdisciplinary course there may be no reference to individual disciplines or subjects, and subjects are not identified as such in the timetable. Implicit in the move from a multidisciplinary to an interdisciplinary approach may be the loss of the disciplines' perspectives. According to Drake (1998:46) science and mathematics programmes often take this approach to make their courses more relevant to the student. They usually connect the subject area to a real-life context rather than to a textbook.

Step 11 Trans-disciplinary (Synonym – fusion, immersion, authentic)

Transdisciplinary means 'beyond the disciplines' (Drake, 1998:93). Here the disconnection of subjects is eradicated. The focus is on one subject matter for education, namely life in all its manifestations. In transdisciplinary, as in interdisciplinary integration, the curriculum transcends the individual disciplines and is found in many different forms (Drake, 1998:21-22; Harden, 2000:555). The focus of learning, is not on a theme or topic selected for this purpose, but on the field of knowledge as exemplified in the real world (Harden, 2000:555). It therefore differs from the other approaches because it does not begin with the disciplines in the planning process; rather, the planning begins from a real-life context.

Kysilka (1998:206-207) believes there is no one best organizational structure for curriculum integration. Kysilka thus emphasises that the integration continuum should not be viewed as a means of forcing teachers to reorganize their curriculum but rather more importantly be viewed as a vehicle to help them rethink what they are currently doing and provide some guidance in determining how they might do things differently.

2.4.4.2 Hybrid to Full PBL approaches

There are clearly some variations in the extent to which PBL approaches are used and different species of PBL is therefore prevalent within curricula. The way the PBL curriculum is designed can be broadly categorized on a continuum ranging from 'hybrid' (or 'adapted') approaches, also referred to as transitional semi-problem-based curricula to the 'full' (or 'pure' 'rigorous' and 'authentic') PBL approaches (Margetson, 1999:359,364; Newman, 2004:13; O' Grady, 2004:3). Margetson (1998:193), who focuses specifically on PBL for professional practice in the field of medicine, distinguishes between these two main conceptions of PBL as Conception 1 or C1 (which typifies the hybrid approach to PBL) and Conception 2 or C2 (which typifies the full PBL approach). Conception should be understood here as the ideas and ways of thinking one comes to have (Margetson, 1999:360).

A central difference between C1 and C2 lies in the difference between atomistic addition and holistic integration. Atomistic addition in a traditional curriculum is similar to the 'staircase' or 'brick-on-brick' model whereas holistic integration is similar to the 'spider-web' model referred to earlier (Ward & Lee, 2004:73). According to Margetson (1998:194) C1, which is an improvement on the traditional fragmented curriculum, still compartmentalizes knowledge under discrete subject headings although some integration does take place. Within the 'hybrid' approach PBL is accordingly implemented in shorter cycles and there is generally less integration of disciplines. The 'hybrid' groups generally have at most two subjects in collaboration for the PBL approach and many involve single-subject PBL (Newman, 2004:13).

The view taken of problems in C1 (Hybrid PBL approaches) is that they are obvious and are not themselves problematic but are used simply as a device for a further purpose, namely as 'convenient pegs' on which to hang the coat of knowledge-acquisition (in other words 'basic' science knowledge). The main task for students is therefore knowledge-acquisition in relation to the problem. In this conception, the convenience in using a problem lies simply in its motivating effect (Margetson, 1998:196). According to Duch *et al*. (2003) Hybrid PBL approaches can accordingly be characterized by a non-exclusive use of problem-driven learning in class which include a mixture of separate lecture segments, tutorials or other active learning components (Newman, 2004:13). Floating or peer facilitator models are commonly used within these Hybrid PBL approaches (Duch *et al*., 2003).

In contrast the full, authentic PBL approaches (C2) have fuller integration of disciplines which can last through repeated weekly cycles as is the case of Maastricht and other medical school models (Das & Das, 2002:162). The view taken of problems in C2 focuses on a 'growing web' of understanding in practice where medical practice is conceived of as an integrated, coherent activity where the practice is developed as a whole (Margetson, 1998:199). In its "pure" or "authentic" form relevant problems are thus introduced at the beginning of the instruction cycle and used to provide the context and motivation for the learning that follows (O' Grady, 2004:3). The role of a problem in C2 is thus to provide the focus within the rich context in which medical issues arise (Margetson, 1998:197). The conception of the growing web therefore acknowledges that action and practice are necessarily related to understanding. Problems are thus more than they seem on the surface. They are not simple 'givens' but may depend on the contexts in which they occur (*ibid*.:196,359).

According to Margetson (1998:196) Hybrid PBL approaches (C1) can be seen as being a transition case, lying between a traditional conception and a transformed education represented by C2 and must therefore be valued as transitions and not as something they are not. Although the traditional curriculum is improved significantly through C1, it is however still partly trapped in a discredited conception of learning. However, there are contexts in which C1 Hybrid PBL approaches prove to be the better approach such as is the case of The University of the Witwatersrand. The University of the Witwatersrand (Wits) created a Hybrid PBL approach by combining formal lectures with small discussion groups. They argue that due to the poorer academic skills of the foundation year students the Hybrid PBL approach proved to be appropriate since the students still need to be provided with a good knowledge base (a 'convenient peg' approach) at this level while simultaneously being required by the simulation games to develop and display the acquired skills encompassed in PBL (Ala & Hyde-Clarke, 2006:123). They propose that PBL can be an excellent teaching and learning tool at the foundation course level if the course is well conceptualised and scaffold and that it has the capacity to impart essential skills to first-year students who are under-prepared for tertiary study (*ibid*.:121).

Williams (2001b:254) takes a similar approach to that used at Wits. She has not fully embraced the "full" medical school approach to PBL because the students that she teaches lack the necessary ability and confidence in their problem-solving and physics and mathematical skills. Williams uses condensed mini-presentations that introduce physics principles and integrate the learning units. After acquiring increased confidence in their conceptual understanding of the physics principles, the students then use the PBL process as described by Barrows to work through and solve the real-world problem encountered in each learning cycle (*ibid*.:256).

2.4.5 Conclusion

It is clear that integration can come in many forms, and that there is no universal PBL approach (Drake, 1998:95; Van Loggerenberg-Hattingh, 2003:53). Similar to Newman (2004:14) the researcher could find no single unanimous position about the theoretical basis for, or practice of, problem-based learning. There is not even agreement about whether there is or should be one type of problem-based learning or many variants. PBL can therefore be implemented within one discipline or at any of the levels of integration (Van Loggerenberg-Hattingh, 2003:53) as identified by Harden (2000:551) depending on the theoretical background for its implementation and the structural and pedagogical context into which it is placed (Poikela & Poikela, 1997:8; Savin-Baden, 2000:19). Kysilka (1998:206-207) also highlighted the fact there is no one 'best' organizational structure for curriculum integration and that the integration continuum should not be viewed as a means of forcing teachers to reorganize their curriculum to a 'best' approach but that it should rather be viewed as a vehicle to help teachers rethink what they are currently doing in order to improve their current teaching practices to foster learning. It also became apparent that when choosing between PBL approaches such as Hybrid or Pure approaches factors such as class size, the intellectual maturity of students, student motivation, the course learning objectives, the instructor's preferences and in some institutions, the availability of peer facilitators need to be considered (Duch *et al*., 2003). Since the success of any curriculum restructuring effort lies within the teacher's acceptance of that particular curriculum (Ensor, 2001) it is important to pay special attention to all the factors that are involved in the design and implementation of a PBL curriculum.

2.5 PLANNING AND IMPLEMENTATION OF A PBL CURRICULUM

2.5.1 Introduction

Although ample descriptive literature exists on curriculum development in general as well as on general aspects of PBL, Wiers, Van de Wiel, Sá, Mamede, Tomaz and Schmidt (2002:45) believe there is a more specific description of the design of problem-based curricula. Wiers *et al*. (2002:45) mainly based their ideas of curriculum development on the classical works of Tyler (1949) who is often cited in curriculum development literature. Tyler advocates that four fundamental questions be answered in developing a curriculum, namely: what is the purpose of the curriculum? What educational experiences can be provided to attain these purposes? How can these educational experiences effectively be organized? And how can we determine whether these purposes are being attained? A chief criticism of the more traditional approach has been that it describes curriculum development as an overarching, timeless and unchanging process which is strongly prescriptive and de-contextualised which disempowers the people who are involved with the day-to-day implementation of the curriculum (teachers and students) in terms of active involvement in the teaching and learning process (Engelbrecht, 2004:341).

This study moves away from the more traditional behaviourist approach towards a more democratic, descriptive, critical and transformative view of curriculum development. A socio-constructivist view of learning, where learning is increasingly seen as a social process, and knowledge about the curriculum, as socially constructed by students, teachers, researchers, programme managers, among others, is thus adopted. The programme itself is therefore at the centre of curriculum development (Engelbrecht, 2004:341). A broader definition of *curriculum* is used which includes objectives or outcomes to be achieved, selection and organisation of learning activities, social climate or ethos, and the involvement of teachers, students, and significant others (such as peers) in contributing to the learning content and processes. *Curriculum development* is thus regarded as an umbrella concept for improving or changing learning opportunities, and as a process that is responsive to the socio-cultural context. It is also a vehicle which teachers can use to plan learning opportunities and students can construct new knowledge (*ibid.*:340).

The more prescriptive guidelines outlined by Wiers *et al*. (2002:50) for the design of a PBL curriculum will be discussed in depth. They not only offer a more specific description of the design of problem-based curricula but also provide support especially in circumstances where curriculum development is a local activity not guided by experts (Haberman, 1992:13). The steps outlined are also applicable to the development of a PBL curriculum in a shorter course setting (in other words a one year course) and not only the development of a longer curriculum such as implemented at medical institutions such as Maastricht (Wiers *et al.*, 2002:46).

2.5.2 The rationale for a PBL curriculum

The first step involves giving a rationale for the curriculum and the formation of a curriculum-planning group. The process starts with defining the purpose of the curriculum and deciding what makes the development of this particular curriculum in a programme necessary. This planning group consists of three to eight people from different backgrounds, preferably including both educational and content experts and future teachers of the new curriculum (Wiers *et al*., 2002:46).

2.5.3 General educational objectives of the curriculum

The second step involves generating general objectives of the curriculum within professional degree programmes. This can be done by describing professional competencies of future graduates which describe the typical real-life problems professionals have to deal with (*ibid*.:46).

2.5.4 Assess the educational needs of the future students

In the third step the prior knowledge, skills and misconceptions of future students are considered. This process is called ‘needs assessment’. In this process the general educational objectives generated in step two are compared with the expected prior knowledge of future students (*ibid*.:47).

2.5.5 Apply the educational principles of PBL to the curriculum

In the fourth step the educational principles of PBL is applied to the curriculum. The introduction of a PBL curriculum has implications at all levels of organizations. Some aspects of PBL that are directly relevant for curriculum design are as follow:

- A problem-based course tends to be organized in thematically multidisciplinary units also called educational building blocks rather than discipline based.
- The themes of the units/blocks are often related to real-world problems or problems professionals have to deal with.
- Tutorial groups and self-study is the core of the PBL curriculum. In these groups the ‘problems’ are discussed and learning objectives are generated that guide subsequent self-study. This has implications for scheduling, organization and necessary facilities.
- Other study activities may complement the tutorial groups, such as lectures, a practical or skills training session (Norman & Schmidt, 1992:558; Schmidt & Moust, 1998:135-137).

2.5.6 Structure the curriculum and generate a curriculum blueprint

In the fifth step, the information from the previous step has to be integrated into a preliminary schedule. The general prioritized objectives are therefore organized into units or blocks which can last from six to eight weeks (Schmidt & Moust, 1998:138; Wiers *et al*., 2002:48). In the process of translating the general educational objectives into a curriculum blueprint, several issues therefore have to be considered:

- The structure and sequence of units should be considered. In PBL a vertical structure usually dominates. This implies that the core of the curriculum consists of a sequence of units in which contributions of different disciplines are integrated (Schmidt & Moust, 1998:135-137).
- Both the multidisciplinary contents of a unit and an overarching theme have to be identified for each unit. With regard to the possible themes, it may be useful to make a concept map or topic tree of the core concepts in the curriculum. If the theme is determined, then a multidisciplinary planning group needs to decide how this theme can be projected onto a series of problems (Engelbrecht, 2001:30; Schmidt & Moust, 1998:138).

2.5.7 Elaborate the unit blueprints

When the global structure of the curriculum has been defined during step five, the units can be described in more detail by further elaborating the blueprints or sketches. In a brainstorming session, a list of specific subjects and more specific educational sub goals are generated for each unit. As in step five a concept map or topic tree may be helpful to clarify the interrelations between the subjects and to select the most relevant ones. The sub goals are then related to educational activities (problems, lectures, skills and training) and are put into order (Wiers *et al*., 2002:48).

2.5.8 Construct the units

Only after unit sub goals are related to the planned educational activities is the learning materials developed, with problem writing as the most important aspect. The unit planning group usually starts with a discussion of the problems that have to be written, based on the specific educational objectives outlined in the unit blueprint (generated in step six). For each problem, the type of problem is discussed and relevant literature is selected. Ideas for problem writing are generated through brainstorming with the unit planning group. Here, the anticipated prior knowledge and misconceptions of students are particularly relevant. One or two members of the unit planning group write the draft versions of the problems. The draft problems are discussed critically by the planning group and if possible tested by presenting them to a representation group of students (*ibid*.:48).

2.5.9 Problem design

The idea of using problems in education is not new. Already in ancient times problems were used to stimulate thinking and learning. The idea that the problem should come first was already proposed by Plato and implemented by Dewey around 1900 (Schmidt *et al*., nd: 2, 4).

2.5.9.1 Principles underlying effective problem design

Duch (2001b:47), Schmidt and Moust (1998:73) state that the quality and the type of problem used is a central factor in the successful implementation of PBL. According to Duch (2001b, 47-48) and Schmidt *et al*. (nd:12) typical standard textbook problems do not foster the development of effective problem-solving and analytical skills but tend to reinforce the students' naïve view of learning that problems can successfully be answered through memorization of facts. Figure 2.5 illustrates clearly that the quality of the problem as well as the functioning of the tutor is central since it not only influences the better functioning of the group but also impacts on the amount of time students will spend on self study. And it is self study that ultimately determines how well their achievement will be (Schmidt & Moust, 1998:73).

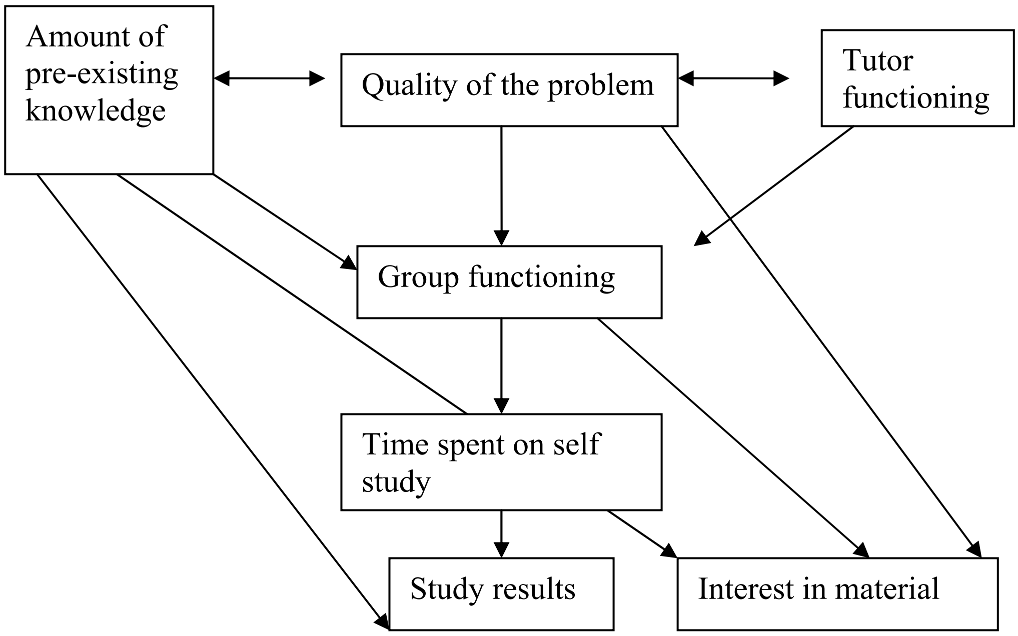


Figure 2.5: Important elements in PBL (Schmidt & Moust, 1998:72; H.Scmidt, personal communication, April 11,2005).

The following essential criteria for effective problem design have been deduced from findings of research on learning and cognition (Charlin *et al.*, 1998:323-330; Raine & Symons, 2005:8).

- **Adapts to students prior knowledge:** An important principle in effective problem design is to ensure that students can relate to it. The problem should provide students access to their personal experience (Dochy *et al.*, 2000:86; Newman, 2004:125). If the contents of the problem adapts well to students prior knowledge, it will help the students mobilize what they already know about the problem (Dolmans, Snellen-Balendong, Wolfhagen & Van der Vleuten, 1997:185-189).

- **Is complex:** The problem should be complex enough to require considerable individual and collaborative effort (Claxton, 1999:32; Dolmans *et al*., 1997:185-189; Eason & Green, 1987:243; Hattingh & Killen, 2003:41) if it is to promote a deep level of thinking and understanding (Raine & Symons, 2005:7). The problem should incorporate stimulants for discussion (Dochy *et al*., 2000:86) where it will be necessary for the group members to cooperate in order to effectively work through a problem. Duch (2001b:48-49) also suggests that the length and complexity of the problem must be controlled in such a way that students realize that a 'divide and conquer' effort will not be an effective problem-solving strategy. For example, a problem that consists of a series of straightforward 'end of chapter' questions will be divided by the group and assigned to individuals and then reassembled for the assignment submission. Students will thus end up learning less, not more.
- **Describes real-world situations:** Schmidt *et al*., (nd: 22-23) describe the use of real world problems as a form of contextual or situated learning. Savery and Duffy (1994:8) provide three reasons why problems should address real issues. Firstly, problems addressing real issues provide opportunity for students to explore different dimensions or perspectives of a problem. Secondly, real problems tend to engage students more since there is greater familiarity with the problem. And finally, students must also take ownership of the problem (Burch, 2001:194; Duch, 2001b:48-49).
- **Is ill-defined:** A distinction can be made between well-defined, moderately defined and ill-defined problems. For a problem to be *well defined* there must be one clearly preferable solution and a small change in the problem would result in only a small change in the solution. Where more than one potentially acceptable solution exists the problem is described as *moderately defined.* For *ill-defined problems*, there may be no solution or there may be one solution and small changes in the problem will require large changes in the solution. The 'authentic' problem-based learning approach described by Barrows' uses ill-defined problems to simulate the conditions that occur in the real environment. 'Problems' by this definition are therefore situations that challenge existing knowledge and expertise (Newman, 2004:125). Ill-defined problems can thus be described as messy problems that occur in the real world, where students have to use reasoning when they are confronted by a complex, novel or difficult problem (Barrows, 1994:6).

- **Creates cognitive conflict:** When problems are ill-defined and challenging, they encourage higher levels of comprehension and skill development than in traditional instruction (Duch, 1996; Van Loggerenberg-Hattingh, 2003:53). The problem is therefore designed in such a way that there is a mismatch or at least a gap between the students' knowledge and the problem. This confrontation with meaningful but poorly understood problems drives the learning since there is an intrinsic need of the organism to reduce the gap or cognitive conflict (Norman & Schmidt, 1992:558). The way the students deal with this conflict in their groups as well as in their self study sessions will be largely due to this discrepancy (De Grave *et al*., 1996:324).
- **Elicits self-directed learning:** When a problem is so relatively unstructured and open-ended (Hattingh & Killen, 2003:41) that it creates cognitive conflict it will elicit spontaneous self-directed learning (De Grave *et al*., 1996:324). During this process students must identify key learning issues, focus their efforts, marshal resources, and collaborate. Since students immediately apply the knowledge they discover and explain it to others, they learn by doing. In the process, students develop new social and cognitive skills, responsibilities, and understandings (Burch, 2001:194; Claxton, 1999:32; Eason & Green, 1987:243; Hattingh & Killen, 2003:41). The problem should therefore sustain discussion about possible solutions and facilitate students to explore alternatives in order to enhance their interest in the subject-matter (Dolmans *et al*., 1997:185-189). Dilemmas that arise and questions that come up during these initial discussions can then be used as learning goals for subsequent individual self-directed learning (De Grave *et al*., 1996:324; Dochy *et al*., 2000:86; Norman & Schmidt, 1992:558; Yeung *et al*., 2003:237).
- **Incorporates programme/course objectives:** In PBL, objectives may exist at the programme, course and problem level. In spite of support in the literature for the narrowing effect of faculty-derived objectives on student learning and the need for self-directedness, most curricula are developed with faculty objectives in mind which, in turn, guide the selection of each problem (Charlin *et al*., 1998:323-330). It is important for the content objectives of the course to be incorporated into the problems, connecting previous knowledge to new concepts, and connecting new knowledge to concepts in other courses and disciplines (Dochy *et al*., 2000:86; Duch, 2001b:48-49; Savery & Duffy, 1994:7). The use of triggers throughout the problem text will keep students close to the desired learning objectives (Raine & Symons, 2005:8). If a problem does not lead students to spend time on the intended course objectives, the

intended learning outcomes are not accomplished, so that gaps in students' knowledge can exist. This implies that problems should direct students to confront one or more of the course objectives (Dolmans *et al*., 1997:185-189).

2.5.9.2 Types of knowledge and problems

According to Schmidt and Moust (1998:111) problems should be based on types of knowledge that must be acquired in a course.

Types of knowledge

There are four types of knowledge that students gain during their studies: explanatory, descriptive, procedural and normative (Schmidt & Moust, 1998:114) which can be categorized under personal and public knowledge (see Figure 2.6).

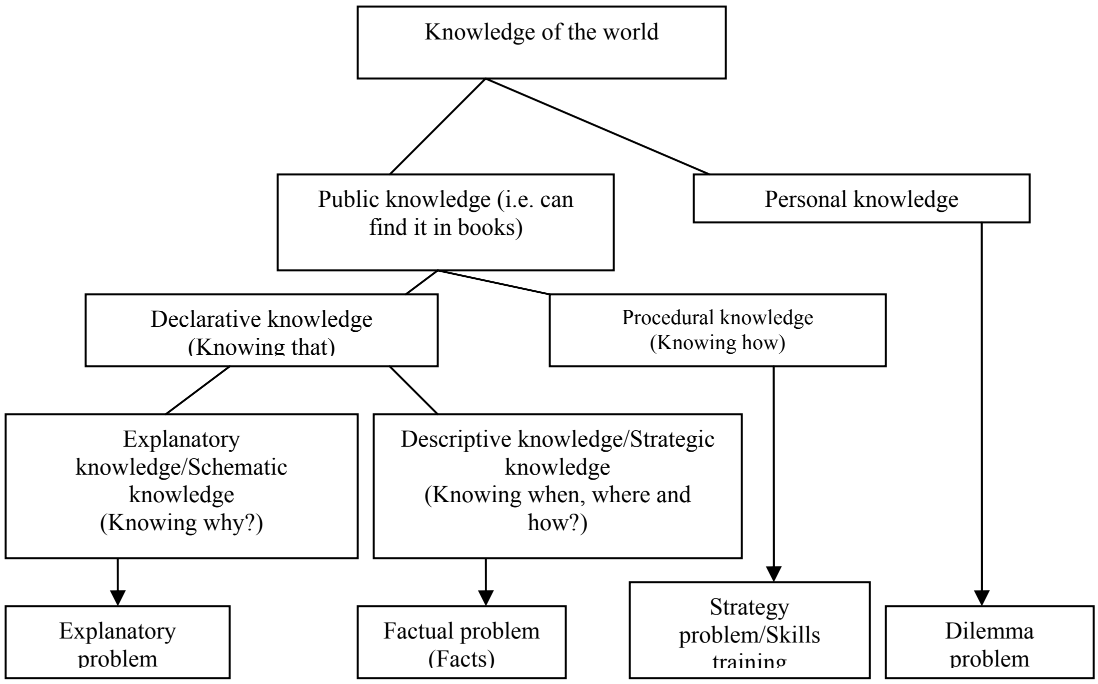


Figure 2.6: Four different kinds of knowledge and the forthcoming problems of students in PBL curricula (Schmidt & Moust, 1998:111; Shavelson, Ruiz-Primo & Wiley, 2005:415).

- **Personal knowledge**

Personal knowledge is seen as the thoughts, attitudes, opinions and values of individuals. Typical problems based on personal knowledge are problems that focus on ethical dilemmas/issues, also named dilemma problems (Schmidt & Moust, 1998:111).

- **Public knowledge**

Public knowledge is knowledge that can be accessed in books, journals and newspapers and is accessible to all (Engelbrecht, 2001:40). Public knowledge can be divided into declarative knowledge (knowing that) and procedural knowledge (knowing how). Declarative knowledge can further be divided into explanatory knowledge (which refers to theories) versus descriptive knowledge (which refers to facts). Descriptive knowledge therefore describes the facts of life whilst explanatory knowledge describes these facts in terms of principles, causal mechanisms and processes (Schmidt & Moust, 1998:113).

Types of problems

There are five types of problems relating to different types of learning objectives namely explanatory, factual, strategy, dilemma and application problems (Schmidt & Moust, 1998:114; Wiers *et al*., 2002:45-51).

- **Explanation problems (Explanatory knowledge)**

An explanation problem is more or less a neutral description of a number of occurrences or symptoms which have to be explained in terms of an underlying process, mechanism or principle (Schmidt & Moust, 1998:73). Explanation problems are suited for the development of understanding of the relations between causes and consequences and the construction of mental models and theories (Wiers *et al*., 2002:45-51).

- **Factual problems (Descriptive knowledge)**

A factual problem is in essence a specific assignment based on a text in which students have to study specific material. The aim of factual problems is to enable students to work on their own. When constructing factual problems it is important to make clear in the formulation that this is a factual problem, as well as indicate precisely what the student needs to focus on when studying the material. A clear question (product) should therefore be asked (Schmidt & Moust, 1998:124-125).

- **Strategy problems/Skills training (Procedural knowledge)**

A strategy problem is more or less a neutral description of an individual, group, organisation who asks a professional for advice. A characteristic of a strategy problem is that students are not asked for factual information, but how they would handle such a situation as a professional. Strategy problems usually start or end with the words "How would you handle…" or "What strategies will you follow…" It is important that strategy problems must be stimulating enough to gain the interest of students, that students be provided with the opportunity to empathize with the characters and that the problems should not be too long (Schmidt & Moust, 1998:119-122).

- **Dilemma problems (Personal knowledge)**

A dilemma problem is closely linked with students' experiences. It describes in more or less neutral terms a societal or professional situation that motivates students to express their own personal opinions, values and norms regarding a specific situation. The aim of dilemma problems is the development of critical thinking regarding ethical issues (*ibid*.:111-117).

- **Application problems**

The aim of application problems is to apply knowledge students already have rather than to acquire new knowledge. Application therefore takes place after the literature has been studied. However, with application problems students combine their mastered knowledge into new entities or deduce new facts from familiar information. Application problems therefore enable lecturers to assess whether students have mastered the knowledge they have studied and also serve as a self-assessment technique for students where students need to know whether they can apply their knowledge, especially the application of principles as is the case in subjects such as mathematics, economics and law. Schmidt and Moust (1998:126-127) emphasize that application problems should be kept short and that they should provide the students with immediate feedback.

2.5.9.3 Guidelines for problem construction

Finding good PBL problems is a challenge in most disciplines. They generally are not found in traditional texts, so the search for material for a PBL course takes a certain amount of creativity (Duch, 2001b:50-53). It is therefore suggested that ideas for problem writing can be generated in a brainstorm session with the unit-planning group (Wiers *et al*., 2002:45-51). Duch (2001b:50-53) and Raine and Symons (2005:9) highlight five steps in writing a PBL problem that can be used as a guide:

Step 1: Choose initial concepts or principles: Choose a central idea, concept or principle that is always taught in a given course, and then think of a typical end-of-chapter problem, assignment or homework that is usually assigned to students to help them learn the concept. List the learning objective that students should meet when they work through the problem.

Step 2: Think of a real-world setting: Think of a real-world context for the concept under consideration. Try to develop a narrative around the problem which will give a real life setting for the concepts to be studied or develop a storytelling aspect to an end-of-chapter problem.

Step 3: Structure the problem: A problem is the basic structural unit of PBL. The problem should be structured so that students can identify the learning issues (Raine & Symons, 2005:7).

Raine and Symons (2005:9) describe the structure of a problem as follow: A problem has a start point (a hook, a trigger, a scenario and/or a problem brief or statement). A *hook* is an object which engages students in the context of the problem and is probably the first thing the student will read. It might be a newspaper story with a provocative headline, an intriguing image, or a poem. Often, the hook does not contain the problem itself or clues to directions to take with the problem. A *trigger* is an object (usually text) which contains indications of how to attack the problem by suggesting possible lines of enquiry of research methods which ensures that students keep to the required learning objectives. A *scenario* sets the context for the problem. Often it tells the student what role or stance they should take when solving the problem (for example you are an environmental pressure group). A *problem brief* is text and objects given to students at the beginning of a problem which contains within it, either explicitly or implicitly, the ‘problem’ (issue, dilemma, or puzzle) which the students should explore. The *problem brief* includes an appropriate combination of hook, trigger, and scenario materials. Problems can also be introduced in stages where information is released to the student bit-by-bit. Many times, PBL problems are designed as multistage or multipage and may take student groups a week or more to complete.

Step 4: Write a teacher guide: It may be useful to write a short guide detailing how to use the problem and how it fits within the course structure. The tutor guide is developed simultaneously with the problems.

Step 5: Identify resources for students: The final step is to identify resources for students. Students may be solely responsible for identifying their own resources. However, it can be helpful if the instructor identifies a few good resources to get them started, especially when the students are newcomers to the PBL process (Wiers *et al*., 2002:45-51).

2.5.10 Decide on student assessment methods

Student assessment in PBL is particularly important because of its influence on the learning process (Wiers *et al*., 2002:49) and in determining what students actually do in the programme (Charlin *et al*., 1998:323-330). Assessment methods that emphasize the learning process itself and encourage students to engage in meta-cognitive and reflective activities are in harmony with the constructivist view of learning (Tynjälä, 1999:365) creating opportunities for deep learning to occur (Bondemark, Knutsson & Brown, 2004:46). Tynjälä (1999:428) therefore suggests that it is very important that assessment is incorporated into the learning process instead of being kept as a separate phase at the end of the course.

Assessment strategies in a PBL course

There are two general types of assessment methods, namely summative and formative assessment (Duch & Groh, 2001:98). Whereas summative assessment entails a formal system of testing in order to make a judgment or establish grades which usually focuses more on the details of the course content (Groh & Duch, 2003:5,97-98) formative assessment methods focus more on broader concepts, skills and processes such as communication skills, self-directed learning skills, problem-solving skills, collaboration and creativity (Duch & Groh, 2001:9; Hansen, 2004:211-212). Both types of assessment thus have a place in PBL depending on the *manner* in which it is used as an assessment tool (Duch & Groh, 2001:98; Raine & Symons, 2005:13).

2.5.11 Consider the educational organization and curriculum management

The design and implementation of innovative programmes is not without difficulty. As soon as innovations outreach the level of individual instructors these instructors become particularly vulnerable to failure and resistant to change. Educational research also shows that new educational practices are often based on past practices. Furthermore, maintenance and sustainability of such an innovation process is strongly influenced by departmental affiliation, the organizational context teachers are working in, their previous teaching experience and a consistent system of quality management (Hommes, 1997:1). According to Cavanaugh (2001:34-35) achieving sustainability is relatively simple and should include the establishment of an ongoing faculty development programme; creating a demand for the new curriculum or pedagogy and generating publicity and recognition by focusing on developing a critical mass of faculty who use PBL.

2.5.12 Evaluate the curriculum and revise it

Other key components that also need to be addressed are evaluating the course itself in order to improve the following year's curriculum (Duch & Groh, 2001:96; Wiers *et al*., 2002:50).

It is clear that problem-based curriculum development is a dynamic process with many interrelated steps. The ten steps described here could be applied to the specific needs of problem-based curriculum development in a particular context, ranging from the development of a relatively short curriculum to the development of the more typical long curricula in universities (Wiers *et al*., 2002:50).

2.6 PREPARING FACULTY AND STUDENTS FOR PBL

2.6.1 Student orientation

Through experiencing PBL many students are challenged to revisit their perceptions of learning and of themselves (Savin-Baden, 2000:93). To support these students in their process of adjustment Dochy *et al.* (2000:65) suggest a two-week introduction course for students. According to Savin-Baden (2000:29) four areas should be included in an orientation programme to facilitate an introduction to PBL and prepare the students for self-directed learning, namely the lecturers' expectations of self-directed learning, the role of the facilitator, the principles and organization skills such as time management and practices of learning in groups such as establishing group roles and group rules.

2.6.2 Preparation of faculty members

According to Irby (1996:69) faculty members who choose to learn about PBL appear to progress through predictable stages of development that include understanding and valuing the rationale for PBL, acquiring general and content-specific tutor knowledge and skills, developing advanced skills in PBL such as facilitation, and developing leadership and scholarship skills.

Creating a climate in the academic programme that acknowledges the efforts of faculty members, encourages their initiative and rewards their accomplishments is crucial to sustaining any PBL initiative (Cavanaugh, 2001:32; Hitchcock & Mylona, 2000:55). Since improving student learning requires deep change the key ingredient is ongoing support of the teachers who have to implement the changes (Drake, 1998:40).

Several training options are available, such as hiring a consultant (Drake, 1998:42; Hitchcock & Mylona; 2000:55) or building an 'in-house' faculty development programme which may include PBL training for faculty, student orientation, consultation for groups developing or revising PBL units, development or conducting of evaluation of PBL students, peer mentoring and group reflections. The major advantage of having an 'in-house' faculty development programme is that support for the developing PBL initiative is ongoing and immediately available. Few programmes have been able to build and sustain PBL initiatives without such a resource (Hitchcock & Mylona, 2000:56). Another reason for supporting in-house programmes is partly because there is less money to bring in experts (Drake, 1998:42).

2.7 CONCLUSION

Times have changed, students have changed, the quantity of knowledge has changed and what has adequately served us in the past simply does not serve the best interests of the majority of students (Kysilka, 1998:208). Problem-based learning seems an appropriate teaching philosophy in order to address some of these changes. In its pure form PBL treats teaching and learning as a student-centred, collaborative, integrated, interdisciplinary process with students working in small groups on open-ended problems rooted in real-life (Van Kampen, 2005:38).

An extensive literature review indicated that although there are general characteristics of PBL the implementation of PBL in different institutions and faculties differs. Implementation is not only affected by the theoretical background that supports its implementation but also by the structural and pedagogical context into which it is placed. This accounts for the different PBL approaches that exist (Poikela & Poikela, 1997:8; Savin-Baden, 2000:19).

Since the success of any curriculum restructuring effort lies within the teacher's acceptance of that particular curriculum (Ensor, 2001) it is necessary to pay special attention to all the factors involved when planning, designing and implementing PBL into the curriculum. For these purposes the more prescriptive guidelines outlined by Wiers *et al*. (2002:50) were discussed. They not only offered a more specific description of the design of problem-based curricula, but also provided support where curriculum development is a local activity (Haberman, 1992:13) with shorter course settings in mind (Wiers *et al.,* 2002:46). It is clear that the restructuring of a curriculum is a complex operation that affects students as well as all members of the staff. The following chapter will describe the design and the implementation of a Hybrid PBL approach for SciMathUS integrating the theoretical stance with the design and implementation of the actual Hybrid PBL approach.

CHAPTER 3: THE CONCEPTUALIZATION, DESIGN AND IMPLEMENTATION OF A HYBRID PBL APPROACH FOR SCIMATHUS

"Do not quench your inspiration and your imagination; do not become the slave of your model" – Vincent Van Gogh

3.1 INTRODUCTION

Since the success of any curriculum restructuring effort lies within the stakeholders' acceptance of that particular curriculum Chapter 3 pays special attention to all the factors that were involved in planning, designing and implementing a Hybrid PBL approach in the SciMathUS programme.

3.2 THE SCIMATHUS PROGRAMME (SCIENCE AND MATHEMATICS PROGRAMME AT THE UNIVERSITY OF STELLENBOSCH)

The SciMathUS programme which is fully sponsored by outside organizations is a one-year full time preparation year during which learners from weak academic backgrounds do coursework on grade 12 level (Michaels, 2005:3). It hopes to address some of the discriminatory practices which have limited the access of mainly black students and women students into fields such as Science, Engineering, Technology and Commerce. The effects of these discriminatory practices have been detrimental to economic and social development (NCHE, 1996). As part of the programme, three groups of about 25 students each (two groups in Mathematics and Physical Science and one group in Mathematics and Accountancy) rewrite the Senior Certificate examinations of the National Education Department at the end of the year. Their holistic curriculum includes practical skills such as research, essay writing, critical reading, thinking, life and computer skills and encourages and empowers these students to become independent thinkers. As the programme manager, Dr. W. Michaels (2005) explains "at SciMathUS we want to develop the multiple facets of each individual to the extent that each person is sufficiently skilled and empowered to become a productive member of the Commerce, Science, and Engineering professions in South Africa which is the reason for the holistic approach of the programme". SciMathUS aims not only at having at least 80% of the students qualify for tertiary programmes in the natural sciences, applied natural sciences and the economic and management sciences after completion their SciMathUS year, but also at having students who are adequately equipped to succeed at their future tertiary studies (Michaels, 2005:3).

3.3 TYPE OF STUDENT AT SCIMATHUS

The SciMathUS students, consisting of 42 adult students ranging in age between 17 and 22 during 2007 had previously largely been exposed to traditional teacher-centred, fragmented, content- and product-orientated approaches for most of their schooling years. For many of them their prior experiences of learning and their view of themselves as learners led them to assume that learning comprises rote memorization of facts (Savin-Baden, 2000:93). Since most of them have a survival mentality and try to do things the easy way it is thus not uncommon to find that they expect the people who teach them to direct their studies, leaving them dependent, passive and often competitive and defensive (Adendorff, 2006; Engelbrecht, 2001:47; Finucane *et al*., 1998:445-448). According to Kosie Smit, the Director of IMSTUS (Institute for Mathematics and Science at the University of Stellenbosch), these students lack the necessary skills to work effectively within a constructivist learning environment and are accordingly ill-prepared to do tertiary study (J. Smit, personal communication, March 16, 2006). They are usually unable to use each other as learning resources; they are unaware of problem solving skills and are less reflective in their learning (Jarvis, 1996:74). They struggle to plan their studies independently and are poorly equipped to take on more responsibility for their own learning (Engelbrecht, 2001:47; Johnston & Tinning, 2001). Their lack of success during their final secondary school years means they are often disheartened and find it difficult to see that their lived experiences and those of others are worth it. They therefore tend to value the knowledge provided by tutors more highly than the knowledge which emerges from their own experiences. For many of them accepting that their own perspective is of value is problematic (Savin-Baden, 2000:93). Peter Bouhuijs (personal communication, March 16, 2006) so fittingly describes the SciMathUS students as "talented but not developed."

At present the South African school system does not equip everyone that has talent to do further study. According to Bouhuijs (personal communication, March 16, 2006), “the time is therefore right for PBL”. The SciMathUS programme has thus embarked on a process to introduce PBL into its existing curriculum in order to enhance the students’ chances of success in higher education. In order to describe and simplify the discussion of the process of introducing PBL into the SciMathUS curriculum the researcher used a combination of the conceptual model of social programmes described by Babbie and Mouton (2001:343) and the curriculum development model described in Carl (2002:54) and adapted it for this specific context.

3.4 THE DEVELOPMENT OF A HYBRID PBL APPROACH FOR SCIMATHUS

The conceptual curriculum development model (see Figure 5.1) was used by the researcher to describe the formulation, design, dissemination, implementation and evaluation of a Hybrid PBL approach for SciMathUS. Within this research *curriculum formulation* is that phase during which programme needs (based on the needs of stakeholders) were identified, programme objectives were developed and a possible solution was formulated. *Curriculum design* entailed the design of the Hybrid PBL approach, which included using Harden’s ‘integrative ladder’ to set up a menu of choices for stakeholders to explore the integration options available; developing the Hybrid model; determining programme and instruction plans and designing problems. This was followed by a *curriculum dissemination* phase during which the teachers and learners were prepared for the intended change and implementation of the Hybrid PBL approach. *Curriculum implementation* is that phase during which the Hybrid PBL approach was applied in practice, whilst *curriculum evaluation* is the phase during which the effectiveness of introducing a Hybrid PBL approach into the SciMathUS curriculum (referred to as curriculum-orientated evaluation) as well as its effect on the learning patterns of the learners (referred to as learner-orientated evaluation), was assessed in terms of measurable outcomes (Babbie & Mouton, 2001:343; Carl, 2002:54; Wood & Mack, 2001:2).

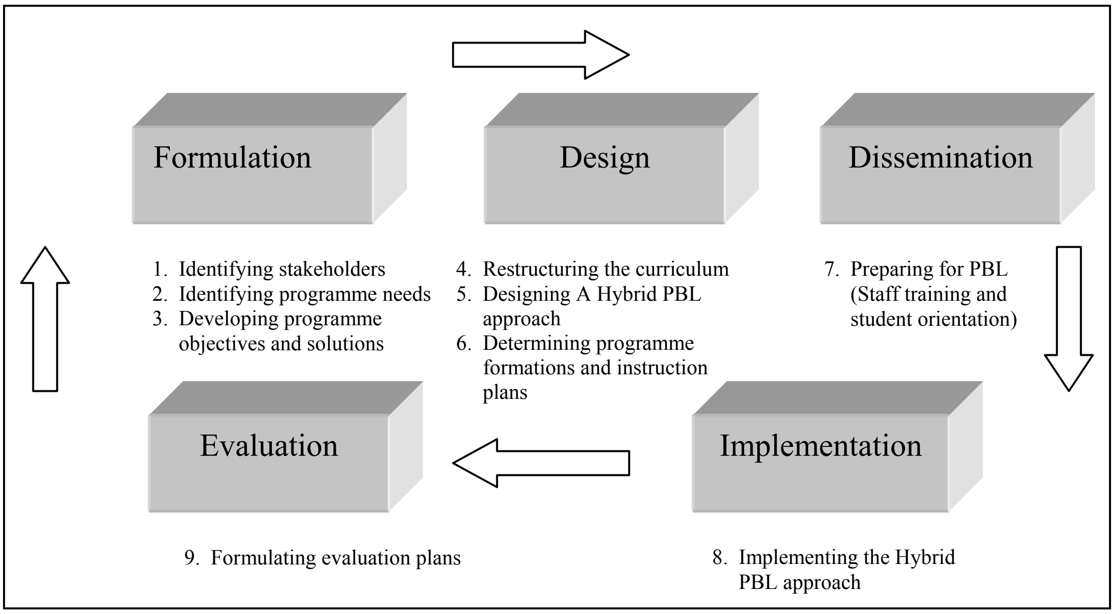


Figure 3.1 The development of a Hybrid PBL approach for SciMathUS (adapted from Babbie & Mouton, 2001:343; Carl, 2002:54).

In order to evaluate the processes involved in the development and implementation of a Hybrid PBL approach for SciMathUS (curriculum-oriented evaluation), the nature of the evaluation was formative and developmental in nature (improvement-orientated) (Babbie & Mouton, 2001:338,345; Mertens, 2005:232; Rossi *et al.*, 2004:44) and took place while the programme was being implemented (so-called ongoing evaluation) (Babbie & Mouton, 2001:xxxi).

For these purposes qualitative evaluation data was obtained from:

- A problem planning session for PBL held on 17 October 2006 which included tutors, management (the Director of IMSTUS and SciMathUS) and two Mathematics consultants.
- A strategic staff meeting held on 27 October 2006.
- Three semi-structured focus group meetings with students and staff directly after completion of problem 1, problem 2 and problem 3 (see Addendum B).
- Class observations during problem 1, problem 2 and problem 3.
- Feedback provided to students after completion of problem 1, problem 2 and problem 3.
- Feedback obtained from Peter Bouhuijs (an expert PBL consultant) regarding problem 2.

- A staff meeting held on 25 April 2007.
- Informal comments obtained from staff after completion of problem 1, problem 2 and problem 3.

3.4.1 The formulation of a Hybrid PBL approach for SciMathUS

Since the main purpose of higher education institutions is not to provide education but to focus on student learning it is always good to analyze the strengths and weaknesses of current curricula (Dochy *et al.*, 2000:69). During the *formulation* phase of the curriculum change process at SciMathUS programme needs (based on the needs of stakeholders) were identified, programme objectives were developed and possible solutions were formulated.

Programme needs

The traditional, behaviourist curriculum at SciMathUS can be categorized as teacher-centred, and content- and subject-based (Puri, 2002:59). Since the conception of the SciMathUS programme in 2001 the coursework depended largely on lectures alternated with some group work, textbooks and some practical work in applicable contexts. Teaching focused mainly on the content of the matriculation curriculum and the quality of the knowledge that the lecturer has and controls. As had happened in the traditional school education system, the students were exposed to a teacher-centred approach which strengthened a closed conception of teaching and a reproductive, superficial conception of learning, encouraging learner dependency and passivity (Battista, 1999:4; De Vita, 2004:70; Drake, 1998:8; Engelbrecht, 2001:6; Finucane *et al.*, 1998:445-448; Michael, 2001:145-158; O'Grady, 2004:2; Ward & Lee, 2004:73).

Furthermore teaching at SciMathUS was organized without real regard to what was being covered by the other subjects; each subject was viewed as an entity in itself. Relationships between subjects were not explicitly made and so related topics from the two main subjects, namely Mathematics and Physical Science were not correlated. Valuable time was wasted on helping learners acquire surface knowledge that was poorly understood, subsequently forgotten or found to be irrelevant (Harden, 2000:551-552). The objectives were seen as a mastery of the subjects and these were tested in a subject-based assessment of the students' knowledge and understanding of the subject. The general teaching approach at SciMathUS was therefore similar to what these students had long been exposed to during their formal schooling years.

With regard to Mathematics and Physical Science specifically, the students at SciMathUS had been exposed to a traditional schooling system which focused on part 2 of Moursund's (2006:1) diagram (see Figure 2.3). Here the teacher usually starts the instructional process from part 2 of the diagram. The students are shown several examples of how to solve a certain type of problem and then have to practice this method in class and in homework leading to "mindless mimicry mathematics" (Battista, 1999:4). Instead of understanding what they are doing, students parrot what they have seen and heard. Students therefore acquire mathematical skills by imitating and absorbing demonstrations by the teacher or the textbooks. Doing mathematics then becomes an academic ritual that has no real-world usefulness (Battista, 1999:4:5). Because the students in traditional curricula learn ideas and procedures by rote rather than meaningfully, they quickly forget them, so the ideas must be re-taught year after year (*ibid*.:2). Instead of teaching mathematical concepts and reasoning, students are thus taught how to solve by rote the specific types of problems that appear on their tests, further encouraging mimicry mathematics. Teachers, who teach students rote procedures for doing these novel items, do not test understanding, but mere memorization (*ibid*:12).

Mathematics and science topics were therefore learnt in self-contained environments where what was being learned had little immediate use in their lives. This behaviourist teaching approach had not allowed students to develop skill at transferring their mathematics and science knowledge and skills into non-mathematics/science disciplines or into problems that they encountered outside of school (Moursund, 2006:2). This became apparent when after the first test during March 2005 most of the SciMathUS students had not maintained the mathematics and science knowledge and skills that they initially developed in their formal schooling years.

Programme objectives

The predominantly behaviourist school system encouraging dependency and passivity as well as the weaknesses identified in the teaching approach utilized at SciMathUS called for a new teaching and learning approach at SciMathUS. To address these needs a strategic planning session for SciMathUS was held on the 14th of March 2005 which yielded the following strategic objectives:

- SO2: "To *empower students* by using an *integrated and focused curriculum* to guide them to *take responsibility and be accountable"*
- SO8: "To *continuously assess and adapt the programme content* in order to stay optimally relevant" (Parsadh, 2005:4).

It was clear that reform was needed in the SciMathUS programme. To address this reform SciMathUS evaluated the potential of problem-based learning as a vehicle which would:

- provide learning opportunities which support the learning processes of active, self-directed, independent learners;
- implement more active, integrated learning approaches where lecturers would act more as facilitators;
- restructure the current curriculum in order to improve learner understanding in the two main subjects Mathematics and Physical Science, where the focus would be more on concepts and increased understanding rather than techniques;
- provide positive learning experiences to students who were often disheartened by the traditional school system by building on their strengths and prior knowledge and improving their skills of 'learning to learn' (Barrows, 1996:5; Burch, 2001:194; Seltzer *et al*., 1996:84; Tynjälä, 1999:427).

Since the SciMathUS programme offers students the opportunity to rewrite the Senior Certificate examinations of the National Education Department in order to improve their chances of access into higher education institutions, curriculum reform was needed, without needing to change the whole system. An adapted version of PBL for the specific group of students or a Hybrid PBL approach also referred to as transitional semi-problem-based curricula (Margetson, 1999:359,364; Newman, 2004:13; O' Grady, 2004:3) was therefore needed which would gradually make PBL an integral part of the existing curriculum.

3.4.2 The design of a Hybrid PBL approach for SciMathUS

After the initial period of situation analysis, a series of workshops was conducted by the researcher during October 2005 to provide stakeholders with the knowledge and skills needed to reconstruct the curriculum via PBL. Focus was on personal, contextual, as well as instructional issues (Terre Blanche & Durheim, 1999:220,223). The *curriculum design* process entailed the following steps: developing a Hybrid PBL approach for SciMathUS, which entailed using Harden's 'integrative ladder' to set up a menu of choices for the stakeholders to explore the integration options available; designing the actual Hybrid PBL approach; determining programme and instruction plans and designing problems.

Before embarking on this mission one of the most important issues in restructuring the curriculum was deciding who would do the actual planning. The following rules of thumb that have been successful in the past was therefore used in this process:

- The planning took into consideration the grade 12 and first-year curriculum for Mathematics and Physical Science.
- The planning team included all the people who would implement the plan, thus the two lecturers in Mathematics, the lecturer in Physical Science, the programme manager and the researcher who is also a lecturer in the Language and Thinking course).
- Students are worth listening to and were included in the planning process (in other words ideas and problems were tested on them during the pilot phase of the study).
- The nature of the subjects to be integrated was not as important as the PBL philosophy among the participants.
- Staff was made aware of the fact that the first efforts in restructuring the curriculum were usually the hardest.
- Management was supportive and on the actual planning teams itself (Drake, 1998:183).

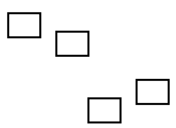
The school syllabi were identified as one of the restraining forces in the programme restructuring process at SciMathUS (Parsadh, 2005:2) which meant that an adapted version of PBL for the specific group of students had to be developed within an existing curriculum. It was therefore inevitable that old and new structures would co-exist for some time (Bouhuijs & De Graaff, 1993:23). A further challenge to the curriculum restructuring process was the 'test-driven' mentality of the Education Department which could hamper the development of more integrated curriculum efforts. If the students failed to achieve good results in the National Certificate Examinations the lecturers would be held accountable. This could lead to the hesitance to try out ideas where there was no guarantee that they would improve students' performance in the required assessment tests, even if ultimately the students' ability to apply their knowledge to real world activities improved. A curriculum that would seem to capture some of the benefits of both the PBL and conventional curricula was therefore needed at SciMathUS.

3.4.2.1 Exploring integration options by using Harden's integrative ladder

Since the stakeholders agreed about the value of integration but differed in their views as to the optimum balance between integrated (more constructivist orientated) and subject-based (more behaviourist orientated) teaching, Harden's integrative ladder proved to be useful in restructuring the curriculum. Harden's integrative ladder (which defines 11 steps between subject-based and integrated teaching) set out a menu of choices for stakeholders to explore the integration options available and to discuss the extent or form of integration most appropriate for SciMathUS. Such informed decision making was preferable to a debate on 'authentic, pure PBL' or 'nothing'. Through an in-depth literature review on introducing PBL into existing curricula, the researcher also noted that in most of the cases where PBL was implemented this usually took place at *the last point* on the 11-step continuum posed by Harden (namely trans-disciplinary or authentic integration). Step 11 on the integration ladder requires far greater participation by staff, organizational structure with appropriate resources and self-directedness from students. This could account for some initial resistance found in the literature (Harden, 2000:556). Since SciMathUS was in no position to introduce PBL on step 11 on the continuum due to the nature and specific needs of the programme the demonstration of the range of options proved to be an invaluable tool in assisting the stakeholders to determine where SciMathUS was currently positioned on Harden's integration ladder and finding a stage on the continuum with which everyone could become comfortable.

SciMathUS' position on the ladder prior to PBL

SciMathUS' positioning prior to introducing PBL into the curriculum could be likened to Step 1, the isolated or fragmented step on Harden's ladder.



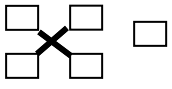
As was explained in 3.4.1, the SciMathUS curriculum subject lecturers (represented by squares in the diagram) organized their teaching without regards to what was being covered by other subjects. Each subject was looked at from the perspective of the curriculum content for that specific subject in terms of areas to be covered, depth of coverage, sequence and timing. The objectives were seen as mastery of the subjects and these were tested in subject-based assessment of the student's knowledge and understanding of the subject. There was no intentional correlation of related topics in the two disciplines. Within this traditional curriculum approach blocks of time were allocated to the individual subjects. Students attended a lecture in Mathematics and then moved on to a lecture in Physical Science, with neither lecturer being aware of what was covered in the other lecture (Harden, 2000:552).

Introducing PBL into the SciMathUS curriculum

The staff at SciMathUS worked hard at finding a stage on the continuum with which all stakeholders could become comfortable and produce a curriculum which could become more meaningful to and connected with the real life experiences of the students. At the first tutor training session held in January 2005 the lecturers and management at SciMathUS felt that step 7 of Harden's integration ladder was an ideal place to start off the restructuring process of the curriculum. This decision was influenced by many factors, namely:

- the existing conventional, behaviourist curriculum (Step 1 on Harden's ladder) employed in the programme;
- the experience and views of the lecturers;
- the organizational structure (including funding and management expectations);
- and the overall aims and objectives of the curriculum.

Due to the importance of the conventional curriculum in the programme, it was decided that PBL would be applied to a part of the curriculum, specifically the two main subjects Mathematics and Physical Science, likened to Step 7, the correlated step or 'democracy programme' (Barrows, 1996:5) on Harden's integration ladder.



Harden (2000:557) recommends starting with something small and manageable such as a few integrated themes using a correlated (Step 7) teaching approach since the move from a traditional subject-based to a more integrated curriculum could involve major changes. This informed the stakeholders' decision to start with Step 7 on Harden's integration ladder with the introduction of subject-integrated problems or projects at the beginning of each semester during the pilot phase of the study, where the focus was specifically on integrating core objectives in Physical Science and Mathematics.

This entailed the development of a transitional semi-problem-based approach or Hybrid PBL approach (Margetson, 1999:359,364; Newman, 2004:13; O' Grady, 2004:3) for SciMathUS which according to Margetson (1998:194) is an improvement on the traditional fragmented curriculum. Although some knowledge is still compartmentalized under discrete subject headings integration is taking place between the main subjects where PBL is accordingly implemented in shorter cycles (Newman, 2004:13). The SciMathUS Hybrid PBL approach lies between a traditional conception and a transformed education (Margetson, 1998:196). This seemed to be a more appropriate approach in the light of the poorer academic skills of the students, typified by a weakened knowledge base and the lack of the necessary ability and confidence in their problem-solving and physics and mathematical skills (Ala & Hyde-Clarke, 2006:123). Exposing the students to PBL would further have the capacity to impart essential skills to the students who are under-prepared for tertiary study (*ibid.*:121).

Initially some of the lecturers were reluctant to engage in the curriculum restructuring efforts due to the amount of time needed for planning and developing themes and problems. However the lecturers soon started to enjoy the process and gathered the necessary information to plan and to work collaboratively. Though markedly different from the conventional, behaviourist, teacher-centred model, the PBL approach implemented at SciMathUS does not fully dissociate with the former; rather, it builds on the strengths of the 'old' and adds new dimensions to it (Puri, 2002:52). Harden (2000:556) also notes that no position on the integration ladder should be deemed better or worse than any other. It is a matter of the best fit for the particular programme. Furthermore, these steps do not function separately since certain characteristics found in one step my also be found (combined) in some of the other steps on Harden's integration ladder. As Lowyck and Vermunt (1997:60) affirm: "Wat de onderwijs- en leeractiviteiten betreft, blijkt dat geen enkele strategie afzonderlijk het brede spectrum van onderwijsdoelen kan bereiken."

3.4.2.2 Design process of a Hybrid PBL approach

In order to effect durable educational change it was necessary to deploy a long-term strategy to create conditions for growth. The purpose of the long-term strategy could be described as trying to adapt the concept of PBL in the specific situation of SciMathUS, or in other words to develop an adapted version of PBL for a specific group of students. The PBL-method from Maastricht or anywhere else in the world was bound to fall short if it was directly applied in a completely different situation. The success of the curriculum restructuring process in the long run therefore depends on the ability of the faculty to adapt PBL to suit its own specific needs (De Graaff & Bouhuijs, 1993b:28). Barrows (1994:1) and Savin-Baden (2000:16) warn that the generic term 'problem-based learning" is vague: anyone describing this method must be quite specific about the design of the particular method (model) employed. In the light of that warning, the researcher will now describe in detail how the SciMathUS Hybrid PBL approach was developed.

The discussion of the SciMathUS PBL model will focus on:

- the process of designing the Hybrid PBL approach;
- the organization of the curriculum, focusing on the course structure and the design of problems with the emphasis on subject integration;
- the PBL process employed and the degree to which students were given responsibility for their own learning;
- the learning environment (education formats) which included the role of the tutors and learners;
- the methods used for student assessment; and
- concern voiced about the Hybrid PBL approach.

In developing the Hybrid PBL approach large blocks of planning time were initially needed with stakeholders who were going to implement the curriculum. The first planning sessions were held outside the work environment providing a conducive environment for change. Additional shorter periods of planning time was needed for ongoing planning while lecturers experimented with new ideas and made modifications as the need arose (Drake, 1998:178).

In designing the Hybrid PBL approach for SciMathUS (see Figure 3.2) a variety of decisions had to be made based on several factors such as the degree to which the conventional teaching methods were going to be mixed with the new innovative PBL method, the nature of and number of subjects that were going to be integrated into the PBL curriculum, the sizes of the classes, the intellectual maturity of the students, the course objectives and the method of learning that best fitted these objectives as well as the preferences of the tutors and other stakeholders (Duch, 2001a:39-40; Barrows, 1994:5-6, 54).

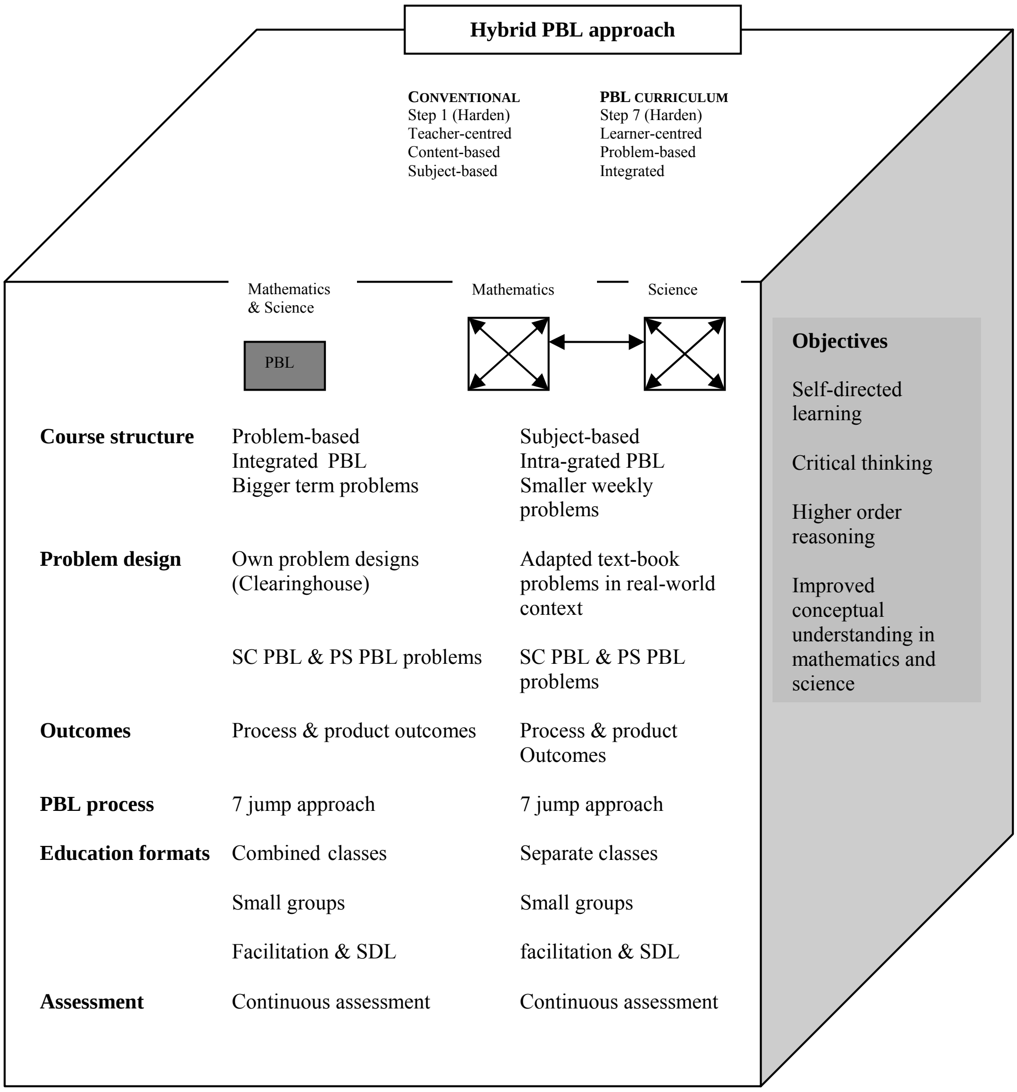


Figure 3.2 A Hybrid PBL approach for SciMathUS

3.4.2.3 The course structure of the SciMathUS curriculum

After introducing PBL into the SciMathUS curriculum at Step 7 on Harden's integration ladder the emphasis remained on the subjects mathematics and science with subject-based courses taking up most of the curriculum time. Within this framework, an integrated teaching session (via PBL) was introduced in addition to the subject-based teaching. The three *integrated bigger PBL problems* and sessions brought together areas of interest common to each of the subjects. In this correlation approach a problem-based approach was therefore used in which the problem designed to integrate mathematics and science was given to students prior to addressing the work in class. During class discussions and feedback sessions the contributions of the different subjects were then further used to clarify the problem. This process was followed by a subject-based approach by providing students *smaller intra-grated problems* (integrating concepts in mathematics or concepts in science separately for each problem) on a weekly basis during normal class hours.

Students' basic science and mathematics frameworks were therefore developed in subject-based teacher-directed study for a portion of the curriculum due to the importance of acquiring a sound knowledge base in these subjects. This was coupled with the integrated problem-based learning thread typified by PBL discussion groups where students worked on larger open-ended problems in a combined classroom, to motivate or introduce topics, to integrate or reinforce concepts, and to enrich the syllabus whilst allowing students to explore cases which commensurate with their developing understanding of these subjects. Support for this type of implementation comes from Barrows' and Tamblyn's study (in Albanese & Mitchell, 1993:52) of the added value of a six-hour PBL segment within a classically taught course. The results from their study combined with findings from the present literature review supported the use of PBL to supplement subject-based, teacher-directed instruction. Although staff experienced the process of covering the curriculum as time-consuming initially this was not the case for long. The explanation may be that the Hybrid PBL approach was used where the traditional as well as the innovative curriculum was implemented concurrently in the programme.

3.4.2.4 Problem design

After the curriculum organization and course structure had been determined the team was ready to design the problems. The process began by establishing desired learning objectives which consisted of the following steps:

- Drawing up a meeting schedule for the entire planning period and determining learning objectives for mathematics and science. The process started with defining the purpose of the curriculum, the prior knowledge, skills and misconceptions of students were also considered. Thereafter staff listed specific desirable outcomes and expectations for their subjects. Both content and process goals were considered.

- Selecting themes for each term relevant to the curriculum.
- Designing a conceptual map or topic tree with keywords indicating the subjects and their overlapping concepts to be covered by the different themes (see Addendum C). Here staff compiled a list of possible topics and why these topics were essential before reaching consensus over the topics.
- Projecting the themes onto a series of problems. Decisions were made on which problems needed to be written.
- Designing problems covering the topics in the themes. Consideration was given to which learning aids would be needed.
- Setting up course schedules and sequencing PBL sessions on the basis of the central theme(s) from a multidisciplinary perspective

To approach the issue of problem design, lecturers asked themselves: “What is it that we want our students to *know* and know how to *do* when they leave our programme” (Stinson & Milter, 1996:35)? It was therefore important that the problems would support major course objectives, not just minor or trivial ones and that the problems should integrate subject content, concepts, and skills in order to enhance understanding. Tying content to PBL activities was an important means of determining whether students had grasped key concepts, where they were still experiencing gaps in their knowledge base and whether they could integrate the concepts between the different subjects. The learning objectives (or areas of expected learning) were then written down which served as a guide to the lecturers in order to help them guide students into areas of discussion that lead to productive learning (Barrows, 1996:8).

In addition the following general points in writing good problems were considered:

- Use problems early and often enough to make problem assignments a significant part of the course grade; thus weekly problems were introduced.
- Give the groups something to do that is challenging enough that they will see obvious benefits in collaboration.

- Give students an opportunity to reflect on what may be a new classroom experience and respond to their input.
- Provide recommended resource lists or provide students access to learning resources based on student needs and levels.
- Have assessment aligned with problem activities (Adapted from Engelbrecht, 2001:42-43).

In the specific writing of the problems the staff made an outline describing the relation between the problems, topics and the subjects. During the problem design stage, it was important for the problems to be presented in a relevant real-life context so that the contents of the problem adapted well to the prior knowledge of the students. It was further important to add a scenario and include several cues in the problem statement that would stimulate discussion, help students generate learning issues and encourage literature searches, sustain discussion and facilitate the exploration of alternatives. It was challenging, in the case of subjects such as Mathematics and Physical Science, to design the problems in such a way that they were not too structured or obvious as learning outcomes but also not too complex to solve. This was especially important since SciMathUS has a broad band of access and a very diverse student population which therefore included stronger and weaker students. This motivated the decision to replace the SC PBL model (student-centred PBL model) where students were totally responsible for generating their learning issues (during the pilot phase of the study) with a combination of the SC PBL model and the PS PBL model (Problem stimulated PBL model, during the case study phase of the study) where lecturers or the problem statement itself provided more learning objectives to students. It was found that students from disadvantaged backgrounds had many gaps in their existing knowledge and needed more direct mediation. This decision supported the view of Kirschner, Sweller and Clark (2006:75, 83) that certain aspects of the PBL model should be tailored to the developmental level of the learners where the advantage of guidance begins to recede only when learners have sufficiently high prior knowledge to provide "internal" guidance. The lecturers felt this to be especially important for subjects such a Mathematics and Physical Science and especially for students with *low prior education levels.*

During the pilot and case study phase of the study the students were provided with the opportunity to assess the quality of the problems after its completion. Some of the questions in the assessment were: What did you like most about the problem? What didn't you like about the problem? Did it challenge you to think and do research? Was the problem appropriate for the proposed course? Do you have any suggestions for improvement? These results were then reported during evaluation sessions and the problems were adjusted accordingly. One significant change that was made after the first evaluation session on 15 June 2006 resulted in the replacement of bigger, once off problems with a combination of bigger and smaller regular problems (in other words the PBL *project approach* during 2006 was replaced with a *problem-based combination approach* during 2007 consisting of a *combination* of three bigger subject integrated problems and smaller subject intra-grated weekly PBL problems). The rationale behind this decision was that the PBL project approach was experienced as an add-on by the students and the lecturers whereas the combination approach, or subject inter- and intra-gration approach formed a more integral part of the academic programme and provided lecturers with a way of analyzing misconceptions before starting with new work. During October 2006 the Mathematics and Physical Science lecturers thus planned their curricula together and searched for overlapping themes that lend themselves for integration. The science lecturer also wrote four smaller PBL problems for the first term in 2007 which the Mathematics lecturers reviewed. Duplications between subjects and connections and content that covered the same general ideas were explored.

Since the lecturers did not feel equipped to design bigger integrated problems without support they were registered at Clearinghouse in order to view existing PBL problems available on the network and adjust them for their context. Although many science problems were available, no problems were available for mathematics. The book "Problem-based learning problems for Mathematics and Science" was therefore ordered to address this need. In designing the smaller weekly intra-grated problems, the lecturers doing Physical Science and Mathematics adapted their textbook or classroom problems by placing them in real-world contexts. The bigger integrated problems that were designed were titled Pedestrian fatalities, Crossed-circuits, Palmiet power plant, The amazing race and The two oceans marathon.

Scheduling of problems

During the initial part of the pilot phase of the study, students experienced PBL as an add-on. They simply viewed the PBL exercises as doing Mathematics in the Physical Science class or Physical Science in the Mathematics class rather than making the links between the different subjects. It was therefore important to pay special attention to the scheduling of problems. The following scheduling options were presented to the lecturers during the staff planning meeting in October 2006, namely shorter in-class problems during the first and second terms and a bigger integrated problem during the third term, no bigger problems (only shorter PBL problems during class times for all three terms) or a combination of bigger integrated and smaller inter- and intra-grated problems throughout the three terms. The third option was chosen by the lecturers since, like Drake (1998:95) and Dochy *et al*. (2000:63-64), they felt that PBL exposure must occur with enough regularity for students to gain the necessary skills and to be able to make the connections among subject areas without getting mixed signals. Another question that arose was whether it was wise to provide students with a new problem just after completion of the examinations. The fear was that this could impede student motivation and lead to PBL not being experienced as forming an integral part of the curriculum. The scheduling options for the bigger integrated PBL problems (usually at the beginning or ends of terms) were therefore reconsidered to offer more flexibility for staff and to make the implementation of these problems most effective for all those involved.

3.4.2.5 The PBL process

The PBL process employed at SciMathUS combined the seven jump approach of the University of Maarstricht (Albanese, 2000:729-738; Schmidt, 1993:422-432) with the Howard Barrows PBL model (Barrows, 1996:5) since both models provided a more structured way of developing self-directed learning skills in the students. The same process was followed for the bigger term problems as well as the smaller weekly problems.

The classic PBL process employed at SciMathUS usually consisted of three to five meetings, namely a problem presentation meeting, one or two problem discussion meetings, and an evaluation session. In the *problem presentation meeting* students approached the problem by organizing information into three categories: facts, hypotheses, and learning issues. A fact was the piece of given information; a hypothesis was a hunch or proposed explanation of the problem and a learning issue was the information needed to solve the problem (Baker, 2000:260). During the *problem discussion meetings* students analyzed the problem, identified questions (learning issues) and considered resources for investigating those questions. After seeking the needed information, a second problem discussion meeting was convened in which students shared their new knowledge, analyzed the information in relation to the learning issues and the hypotheses, created concept maps, critiqued resources, and assessed the reasoning processes used in specifying hypotheses and learning issues. Here students drew on their existing knowledge to identify which aspects of the problem they did or did not understand. Thereafter they presented their findings to each other and the class (Burch, 2001:195). The final meeting, the *evaluation session*, took place after the problem had been solved and the concepts were mapped. In order to evaluate the product outcomes the learning objectives were used as the basis for evaluating the student's learning, focusing on their solution to the problem and their analyzing of how they might have better managed the problem whereas process outcomes focused on the information resources they used and their experiences of the group processes (Baker, 2000:260).

In short the basic steps of the PBL process thus involved encountering the problem first; identifying learning issues in an interactive process, self-study, applying newly gained knowledge to the problem, and summarizing what had been learned. The process concluded with students evaluating the experience. Student's self-directed learning time was the period between the problem presentation and problem discussion meetings. Here individual students or small groups sought information to satisfy the identified learning issues and then restructured the problem based on their new knowledge.

3.4.2.6 Educational formats

It was decided that the bigger subject integrated problems would be addressed in a combined classroom (where class groups A, B and C, consisting of 47 students would work in one class in separate groups of six). Smaller PBL problems would be addressed during normal class hours in separate classes (with a maximum of 20 students per class). After completion of the weekly problems whole-class wrap-up sessions were a natural occurrence in which concepts that may still not be understood by some students or groups were explained either by the tutor or by a student volunteer and during which connections to past problems or to major principles were identified. These wrap-up sessions further provided opportunities for the tutors to model the problem solving process for the students (Allen *et al*., 1996:43).

After working on the problems a spiral approach in teaching the course was used during class sessions, where tutors frequently returned to a number of recurring threads, such as graphs, distance and velocity and multiple representations of functions. These threads were a source of continual review. On the other hand, many aspects of the course were quite typical. When students were not doing activities or working in groups, the tutors lectured fairly interactively and answered the questions from students. Lectures were especially valuable when an overview was needed, difficult subject matter or misconceptions needed to be addressed or refresher material needed to be presented. They further assigned homework daily, gave tests regularly, and gave one examination a term (Seltzer *et al*., 1996:84).

Small groups

The students usually worked in groups of six bringing together collective skills at acquiring, communicating, and integrating information. Miflin (2004b:446) suggests that the small-group character of PBL is desirable: guidance for students in their first experiences of learning in a new arena will be facilitated more readily when there is a tutor–student ratio of 1:6 as opposed to 1:280. Thus, small-group work is a welcome feature of the initial stages of any educational experience, but especially in a curriculum model such as PBL that, for most students, is very different from the style to which they were accustomed. The students remained in the same group the first term, with new groups formed the second and third term. Combined classes usually consisted of seven or eight groups whereas the separate classes usually consisted of three to four groups. Several strategies were developed which a single tutor could use to effectively guide four groups through problems. One of these strategies was making use of a floating facilitator model. When the multiple groups met in one room one to four roving facilitators were usually available (Mierson, 1998:17).

Facilitation

The problems had natural break points at which the tutors often intervened when needed without hindering students' initiatives. During these breaks, whole-class discussions led by a tutor were used to clarify common misconceptions and encourage groups to compare notes on their progress. Between these breaks, the tutors rotated among the groups, ideally spending five to ten minutes with each to prevent over-engagement in one group's activities to the exclusion of others who may be having difficulties. If common roadblocks were perceived, the class was brought back together spontaneously to receive pointers and clarifications. In this 'floating facilitator' model, optimal group functioning was aided by the small group size and role assignments (Allen *et al*., 1996:47).

The floating or roving facilitating model proved to hold the following benefits:

- Tutors came to know all the students in the class much sooner (especially during the first term).

- The student groups became self-sufficient much earlier. The students took more responsibility for their own group dynamics.
- The logistics were simpler. With all the groups in one room, coordination of groups and materials was more straightforward.
- There were opportunities for short mini-lectures on topics that were confusing to all the groups and for end-of-problem wrap-up discussions involving all the groups.
- There was more opportunity for formal exchange of ideas about the content among groups.
- All groups had some access to the tutors who were content experts (Mierson, 1998:22)

According to Raine and Symons (2005:15), floating facilitation does not always work well with combined groups because the tutors cannot engage with all the members. This was one of the objections expressed by one of the tutors. It was therefore suggested that a fixed facilitator model (implying that a facilitator is assigned to a specific group for the duration of a PBL unit) be used. Although this was suggested, it did not happen in practice since the students sometimes needed their Physical Science or Mathematics tutor to address a specific need (Mierson, 1998:21).

The role of the students and self-directed learning

Students attended a two-week orientation programme during February 2007 facilitated by the researcher. In order to prepare students for self-directed learning, the orientation programme included an introduction to PBL, the PBL process and learning cycle, the tutors' expectations of self-directed learning, the role of the facilitator, the principles and practices of learning in groups, understanding group work (including group rules, group roles and group dynamics), organization skills such as time and conflict management, and self-assessment and peer assessment (Savin-Baden, 2000:29).

Students were assigned to groups randomly in the beginning of the year, and later heterogeneously by personality features and academic ability. Once formed, each group constructed its own ground rules. Typical ground rules included dealing with attendance, completing assigned work on schedule, ways of dealing with group assignments and consequences for members who violated the rules. Equal participation was further assured through roles assigned by group members such as chair, scribe, reporter, and time keeper.

Sometimes students rotated these roles weekly if the need arose. In order to perform their roles effectively students were given written guidelines about the different roles and tasks in order to equip them during the PBL process. The students were also provided with guidelines for giving feedback. At the end of each session students were asked to evaluate their performance as a learning group during the session and to identify goals for improvement (Newman, 2004:129).The basic steps of the PBL process encouraged the development of self-directed learning skills since it involved encountering the problem first; identifying learning issues in an interactive process; self-study; applying newly gained knowledge to the problem, and summarizing what had been learned. Student's self-directed learning time was especially the period between the problem presentation and problem discussion meetings. Here individual students or small groups sought information to satisfy the identified learning issues and then restructured the problem in the light of their new knowledge.

The role of the tutor

One of the exciting features of PBL was the empowerment of teachers to become active designers of the curriculum and facilitators of learning. As a curriculum designer, the typical teacher's role changed from implementing externally-made curriculum decisions to being an active decision maker in the curriculum planning process. As a PBL tutor, the teacher's role changed from that of a disseminator of information to a facilitator of learning. The facilitation skills of the teacher were therefore central to the success of PBL (Baker, 2000:261; Drake, 1998:42; Ismat, 1998:1-4; Johnston & Tinning, 2001:162; Lizzio & Wilson, 2005:377).

In an effort to make the transition to a more student-centred approach, the SciMathUS lecturers tried to involve students as participants in a shared situation where the teacher performed the role of facilitator. In order to perform the facilitative role some of the following suggestions provided during teacher training were adopted by lecturers, namely not expressing their own opinions or giving students too much information, not using their knowledge of the content to ask questions that would lead the students to correct answers. The tutors were therefore encouraged to guide the students with questions such as "Why?" "What do you know about that?" "How do you know that's true?" "What does that mean?" "What are the implications of that?" "What more do you need?" PBL therefore led to a redefinition of relationships: required staff members to assume new roles and develop new skills (Hitchcock & Mylona, 2000:52) in order to assist the students to become more self-directed and teacher-independent in their learning, and be cooperative learners (Allen *et al*., 1996:44; Barrows, 1992:12; Dolmans *et al*., 2002:173).

3.4.2.7 Methods used for student assessment

It was decided to introduce a continuous assessment approach during 2007 to facilitate the integration process at SciMathUS. This meant that the final marks on report cards at the end of each term consisted of 50% conventional examination results and 50% class work results (which included PBL activities, homework and other assignments). Both formative and summative evaluation was used to assess the performances of the students, the groups, the tutor, the PBL process, and the learning resources. The learning objectives provided one perspective for summative evaluation at the conclusion of the problem analysis (Baker, 2000:261). Students' justification of decisions and solutions were assessed on the basis of use of mathematical and scientific support, cited sources, and logical and critical reasoning. Students were given a variety of tasks. Examples are written assignments, a poster, presenting a report on the project, answering questions orally or participating in discussions (Jochems, 1993:67). Formative assessment entailed evaluating the performance of students and groups. Here focus was on how students worked on their own (self-directed learning), how they made use of the problem-solving process and the PBL notes as a template for solution design and decision making, and also how effectively they worked as team members and as a team.

Assessment usually occurred within a short time span to ascertain quickly whether or not students had grasped the course content and whether they were applying the appropriate skills to provide a viable solution to the problem. Feedback on assignments was very detailed at this level. It included written comments by the different tutors and panel discussions to help students when they had not understood the material or had not applied the appropriate skills to the problems. In order to assist tutors during this process, assessment checklists were provided with additional guidelines.

3.4.3 Preparation and dissemination

Faculty training

Expecting staff members to change their practice is very difficult when they firstly, do not understand what specific changes are being suggested, secondly, do not make sense of the rationale behind these changes and thirdly, do not believe that the changes could be implemented in their existing teaching situations. A series of training workshops and planning sessions were held before PBL was implemented in the existing curriculum. These were facilitated by the researcher. The training workshops and planning sessions aimed at familiarizing staff with the principles of PBL and the processes involved in curriculum restructuring at SciMathUS. The workshops comprised the following:

1. Workshop 1: Developing an understanding and valuing the rationale for PBL (Workshop held on 10 November 2005).
2. Workshop 2: The processes involved in curriculum restructuring and setting up course calendars and schedules (Workshop held on 23 January 2006. Planning session held on 24 January 2006).
3. Workshop 3: The writing of problems (Workshop held on 25 January 2006. Planning session held on 26 January 2006).
4. Workshop 4: Acquiring general tutor knowledge and facilitation skills, assessment in PBL and critical perceptions and reflections on PBL (Workshop held on 27 January 2006).
5. Informal reflection and follow-up meetings during 2006 and 2007.

The first workshop, 'Developing an understanding and valuing the rationale for PBL' offered the participants a powerful learning experience to challenge their assumptions about teaching, knowledge and learning and developing understanding of PBL. Here staff members were confronted with assumptions and beliefs that were learned from experience. Since holding on to these assumptions might cause resistance to change it was important to introduce them to newer theories of learning and a strong evidence-based rationale regarding PBL. The aim here was to make them rethink what and how things were done at SciMathUS. It was important to provide them with opportunities to respond from within their own visions, insights and concerns, to listen to them and their concerns in order to use it constructively in the changing process (Dochy *et al.*, 2000:71-72; Pang, Wong, Dorcas, Lai, Lee, Lee, Mok & Wong, 2002:233).

Not only did staff members need to be prepared for change, but they also needed to be equipped with the skills to implement these changes. The aim of the second workshop: 'The processes involved in curriculum restructuring and setting up course calendars and schedules' therefore focused on the curriculum restructuring process and on organizational aspects during the implementation thereof. As part of the PBL curriculum restructuring process, the workshop provided clear directives on PBL innovation and what it entailed (Pang *et al.*, 2002:234). The planning groups which included teachers representing the two main subjects were formed. During the planning session these teachers first had to formulate learning objectives and themes, select subject matter and reorganize their course schedules.

The third workshop: 'The writing of problems' was offered to develop teachers' competence in writing PBL problems. The fourth workshop: 'Acquiring general tutor knowledge and facilitation skills, assessment in PBL and critical perceptions and reflections on PBL' was offered to faculty in order to value the PBL tutorial process, focus on generic tutor skills, and to assist staff to lead PBL tutorials. The general tutor skills included setting expectations, developing questioning techniques, encouraging equal participation, giving feedback and evaluating learner performance.

Informal reflection follow-up meetings were held spontaneously during 2006 and 2007. The aim of these meetings was to provide opportunities for teaching staff to reflect on the general themes, group dynamics, facilitation and other needs experienced. Here tutors could discuss emerging problems and experiences. It created an opportunity for them to share common problems and lend support to each other. The focus here was thus less skill orientated and more a process of reflection on experience. After gaining experience tutoring, faculty members were then provided literature on learning and PBL, to develop their own explanatory theories of learning and instruction, and gain from the experience of fellow tutors in dealing with difficult situations.

Student orientation

A two-week student orientation programme was completed during 2006 and 2007 for the new intake of students which was described by the students as adequate preparation for PBL. The aim of the student orientation programme was to give students a thorough introduction to the specific characteristics of PBL since SciMathUS students coming directly from secondary schools were not accustomed to studying in a PBL environment (Van Driel, 1993:44). Student orientation for PBL was also important to make the process teacher proof. Bouhuijs (personal communication, March 16, 2006) explained it as follow: "Even the teacher with a negative attitude must not be in a position to destroy the PBL process. Thus, prepare the students to make it teacher proof since in PBL most problems are experienced with the teachers".

As with introducing innovative teaching and methods within any course, this new way of learning needed to be clearly articulated to the students so that they were able to derive maximum benefit from the PBL experience. Two weeks was therefore devoted to explaining PBL to the students and providing them with practice opportunities. One objective was to stress the importance of developing self-directed learning skills. In order to prepare the students for self-directed learning the following areas were included within their orientation programme. These were the lecturers' expectations of self-directed learning, the role of the facilitator, the principles and practices of learning in groups and issues of time- and conflict management.

Even with clear instructions it took some students several sessions before they fully understood this new teaching and learning environment (Ala & Hyde-Clarke, 2006:129.) It was thus important to find out how students understood PBL and open discussions were held about it. In order to provide students with practice opportunities the students immediately started to work on the 'buy a car training problem' where they practiced working in groups, their roles as group members and time, organization and conflict management skills. Practice items were therefore based on content relevant tasks but with more emphasis placed on process skills and less on content. Lastly the evaluation methods and peer assessment was discussed.

3.4.4 Implementation of a Hybrid PBL approach in SciMathUS

Implementing the Hybrid PBL approach in an existing programme was an exciting but also a challenging experience. Old ways of thinking about teaching and learning science and mathematics had to change. Ultimately however, the change in pedagogy gave an opportunity to build a new, vibrant science and mathematics curriculum. The core staff at SciMathUS collaborated with their colleagues in planning and implementing these new ideas. The science and mathematics staff came together as a team rather than separate individuals within faculties. There was, however, interplay between driving and restraining forces throughout this implementation process. The core staff members were the primary driving force initiating change. The uncertainties, challenges and anxieties experienced were the restraining forces that had the potential to impede change if problems were not fully acknowledged and remedied at an early stage of the implementation process (Pang *et al.*, 2002:233). The continuous evaluation of the implementation phase was therefore imperative in order to effect continuous programme improvement.

Restraining forces

The following challenges were experienced during the implementation of the Hybrid PBL approach at SciMathUS. Initial resistance was expected due to the fact that PBL consumed much of the staff's time and it was felt that learners progressed at a slower pace through the syllabus. It was initially feared that the learners were acquiring less content information which introduced the age-old debate of depth versus breadth of curriculum content coverage. Furthermore changing into a facilitative role was unfamiliar to the staff and led to feelings of uncertainty. The tutors appeared to find the role more difficult than they had anticipated and not surprisingly their level of performance in this regard varied from week to week. The students who were used to more teacher-centred methods also felt uncertain and insecure with the PBL process during the first term (Finucane *et al*., 1998:445-448; Miflin, 2004a:44; Van Loggerenberg-Hattingh, 2003:52).

Driving forces

Even though there were some initial challenges and difficulties, they were short lived. The long-term effects of this process meant that due to careful planning and continuous evaluation efforts structures were put in place. These enabled staff to reflect on what they had done and mould the curriculum to best suit the students' learning needs. Surprisingly, teachers did not raise concern about the increase in workload for long rather they commented on the opportunities that it offered the students in catering for all levels and encouraging independent and higher-order thinking. The move to working on real-life tasks also pleased the tutors who observed an improvement in student motivation and participation. They noted that some of the students were achieving success and engaging for the first time in science and/or mathematics. During this process students were not only developing mathematical and scientific reasoning but learning how to apply mathematics and science. Furthermore tutors covered content that they had not planned to, which changed the order of the syllabus.

During the implementation of PBL in the Mathematics and Physical Science classes, the curriculum was reorganized in themes. The process for Mathematics, for instance, consisted of starting with a real world problem, moving to a mathematical model, followed by solving the mathematical model, re-interpreting the real-world problem and lastly analysing the solution in the real world context. The goal was to create a need for specific mathematics and science topics as well as sensitizing students that the real world is not always simple. Students therefore experienced the role that mathematics and science has in the real world. The goal of theory then was to provide more clarity for their uncertainties. As the mathematics tutor commented: “That is when Mathematics starts making sense; when Mathematics comes alive!”

Suggestions made by Donham, Schmieg and Allen (2001:188-189) were used during the process of implementing the Hybrid PBL approach at SciMathUS, namely using problems early and often enough to experience PBL as a significant part of the course and not merely as an add-on, to have problems support major course objectives, not just minor or trivial ones, to align assessment with problem activities, to give the groups something to do that is challenging enough that they will see obvious benefits in collaboration and to give students and staff an opportunity to reflect on their PBL experiences through both formal and informal means. Although implementing these suggestions assisted in effecting a smoother transition to a more innovative PBL curriculum there were still many reasonable concerns raised about the viability of a Hybrid PBL approach for a programme such as SciMathUS.

3.5 CONCLUSION

This chapter paid special attention to all the factors that were involved in planning, designing and implementing a Hybrid PBL approach in the SciMathUS programme. During this process the following phases were undertaken: namely: programme needs and objectives were identified, PBL was posed as a possible solution to address those needs, integration options for the curriculum restructuring of two main subjects Mathematics and Physical Science were explored, a Hybrid PBL approach was developed, PBL learning problems were designed, teachers and learners were prepared for the intended change and the Hybrid PBL approach was applied in practice during 2007.

Because of the conventional curriculum being used in the programme, a decision was made that PBL would be applied to a part of the curriculum, specifically the two main subjects, Mathematics and Physical Science. This outcome led to the development of a Hybrid PBL approach that would bring many of the benefits of PBL while still ensuring that the conventional curriculum would have its place in the programme. It thus became clear that the approach to learning at SciMathUS certainly does fall within the genus of PBL, but that it is a distinct species with specific educational objectives for students that include the development of self-directed learning skills, critical thinking, higher order reasoning skills and improved conceptual understanding in the two main subjects (Barrows, 1994:6). Introducing the Hybrid PBL approach into the programme offered a `middle way' for curricular change which falls between true PBL and traditional styles (Miller, Schwartz & Loten, 2000:51); however, the question arose whether introducing a Hybrid PBL approach within a shorter one-year foundation programme could create and support conditions for learners to develop and sustain self-directed learning skills. This pointed to a need to evaluate the curriculum and its outcomes. Chapter 4 will provide the theoretical foundation for the methodology of the evaluation study.

CHAPTER 4: RESEARCH DESIGN AND METHODOLOGY

4.1 INTRODUCTION

This study falls under the broad heading of evaluation research, sometimes referred to as programme evaluation (Rossi, Lipsey, & Freeman, 2004:2). This chapter will provide the theoretical foundation for the methodology of the evaluation study in terms of research design, sampling, data construction methods, analysis and interpretation. A conceptual evaluation model of how the evaluation was approached and what was evaluated will be provided. This will include concrete and specific descriptions. The researcher will then explain how the research design was structured to verify reliability and maximize the credibility and the trustworthiness of the research findings.

4.2 EVALUATION RESEARCH AND THE PURPOSE OF THE EVALUATION

Evaluation research has become an area of specialization within the broader terrain of applied social research (Babbie & Mouton, 2001:335). By the end of the 1950s, evaluation research or programme evaluation was commonplace. During the 1960s the number of articles and books about evaluation research grew dramatically whilst in the early 1970s evaluation research emerged as a distinct specialty field in the social sciences (Rossi *et al*., 2004:9).

Evaluation in its more general sense means the general process of weighing or assessing the value of something (Babbi & Mouton, 2001:335; De Vos, 2002:374). Since there is no one ‘correct’ way to define or conduct an evaluation (Terre Blanche & Durrheim, 1999:210) evaluation research within this study entails the use of social research methods to systematically investigate the conceptualization, design, implementation and outcomes of a programme in ways that are adapted to the political and organizational environments, in order to improve a programme (Babbie & Mouton, 2001:335; De Vos, 2002:374; Mertens, 1998:219; Rossi *et al*., 2004:16,18).

As explained in Chapter 1, *the purpose of the evaluation* in this study is formative and developmental in nature focusing on programme improvement (Babbie & Mouton, 2001:338,345; Mertens, 2005:232; Rossi *et al.,* 2004:44) as well as summative (judgement-orientated) (Babbie & Mouton, 2001:357) and takes place while the programme is being implemented (so-called ongoing evaluation) (*ibid*.:xxxi).

The primary purpose of the evaluation relates to the development and implementation of a Hybrid PBL approach (an adapted PBL approach for a specific group of learners) as a tool for overall programme improvement through curriculum restructuring. The secondary purpose of the evaluation is to determine whether exposure to a Hybrid PBL approach in a one-year foundation programme can produce change in the learning patterns and specifically the self-regulation of learning processes of learners and whether the skills attained are sustainable.

It must further be pointed out that the *purpose of the evaluation* needs to be distinguished from the *purpose of the programme* (Mertens, 1998:232) which is to establish integration between the two main subjects Physical Science and Mathematics. The researcher formed part of the whole programme improvement and evaluation process from the very beginning. Babbie and Mouton (2001:342) see this as the ideal.

4.3 RESEARCH PARADIGM AND DESIGN

4.3.1 Research paradigm

The research paradigm that underpinned the methodology in this evaluation research was an interpretive-constructivist approach with a pragmatic focus (Creswell, 2003:4,9; Denzin & Lincoln, 2000:20; Morgan, 2007:48) also referred to as qualitative, naturalistic or fourth generation evaluation (Babbie & Mouton, 2001:356; Quinn, 2003:66). Theorists such as Guba and Lincoln, Patton, Stake, and House have played a significant role in bringing the interpretive-constructivist paradigm along with qualitative methods into evaluation (Mertens, 1998:224). Researchers such as Morgan (2007:48-76) focus more on the combination of qualitative as well as quantitative methods.

The key features of this interpretive-constructivist pragmatic study were as follow:

- *The insiders' perspective was emphasized*

An attempt was made to understand and make sense of phenomena from an insider perspective, in other words to view the world through the eyes of the participants involved (Babbie & Mouton, 2001:271; Merriam & Associates, 2002:38; Mertens, 2005:12). This meant that the researcher not only strove to *understand the meaning* people had constructed about their world and their experiences (verstehen) (Merriam & Associates, 2002:5; Greene & McClintock, 1991:13; Weber, 2004:vi) but also moved beyond 'verstehen' or understanding to yield results useful for programme improvement in order to inform action (Rossi *et al*., 2004:20). According to Guba and Lincoln (2005:202), this shift towards action came in response to the fact that evaluation findings had little impact. The aim was to create forms of evaluation that would inspire participants to act on recommendations by implementing meaningful action plans.

- *The research was conducted in the natural setting of social actors*

The researcher had a preference for describing and understanding events within the concrete, natural context in which they occurred. It is only if one understands events against the background of the whole context and how such a context confers meaning to the events concerned, that one can truly claim to 'understand' the events (Babbie & Mouton, 2001:272). The individuals' 'own' stories were therefore situated, in other words it was historically and contextually framed (Garrick, 1999:148).

- *The researcher was seen as the 'main instrument' in the research process*

The very nature of interpretive-constructivist research meant that the researcher herself in effect became the measurement instrument. The researcher interpreted (measured) the phenomenon observed. In this regard, the interpretive researcher understood that her research actions affected the research objects she was studying. She also understood that the research objects in turn affected her. The researcher and the research object are therefore interdependent (Weber, 2004:vii). Since the goal of the research was to reach sufficient understanding to inform action, the human instrument, which was able to be immediately responsive and adaptive, seemed to be the ideal means of collecting and analyzing data (Merriam & Associates, 2002:5).

- *The product of the inquiry was richly descriptive*

The primary aim of this interpretive-constructivist pragmatic study was in-depth (thick) descriptions and understanding of actions and events (Babbie & Mouton, 2001:270). Detailed descriptions were made of the context, the participants involved, and the activities of interest and qualitative as well as quantitative data were included in support of the findings of the study (Merriam & Associates, 2002:5).

- *The research process was primarily abductive*

Morgan (2007:73) finds it helpful to think of qualitative research as research that emphasizes an inductive approach, whereas quantitative research emphasizes a deductive approach. According to Morgan, problems are encountered when researchers treat these broad tendencies as absolute, defining characteristics for these two different approaches, and these problems become even worse when they deny the possibility of working back and forth between the two extremes. Fortunately, the pragmatic approach, with its emphasis on the abductive aspect of research, offered an effective alternative. Morgan (2007:70-71) points out that any experienced researcher knows that the actual process of moving between theory and data (induction and deduction) never operates in only one direction. That is why findings from a pragmatic approach relies more on a version of *abductive reasoning* that moves back and forth between induction and deduction – first converting observations into theories and then assessing those theories through action.

4.3.2 Research design

Figure 4.1 illustrates the overall shape of the research, including the time frames in combination with the phases of the research. The researcher found that using various headings to identify developments was necessary to provide a sense of structure in recording the research. However, it must be stressed that there was overlapping between stages, and that the analysis and interpretation of data was an ongoing process (Cocklin, 1996:88).

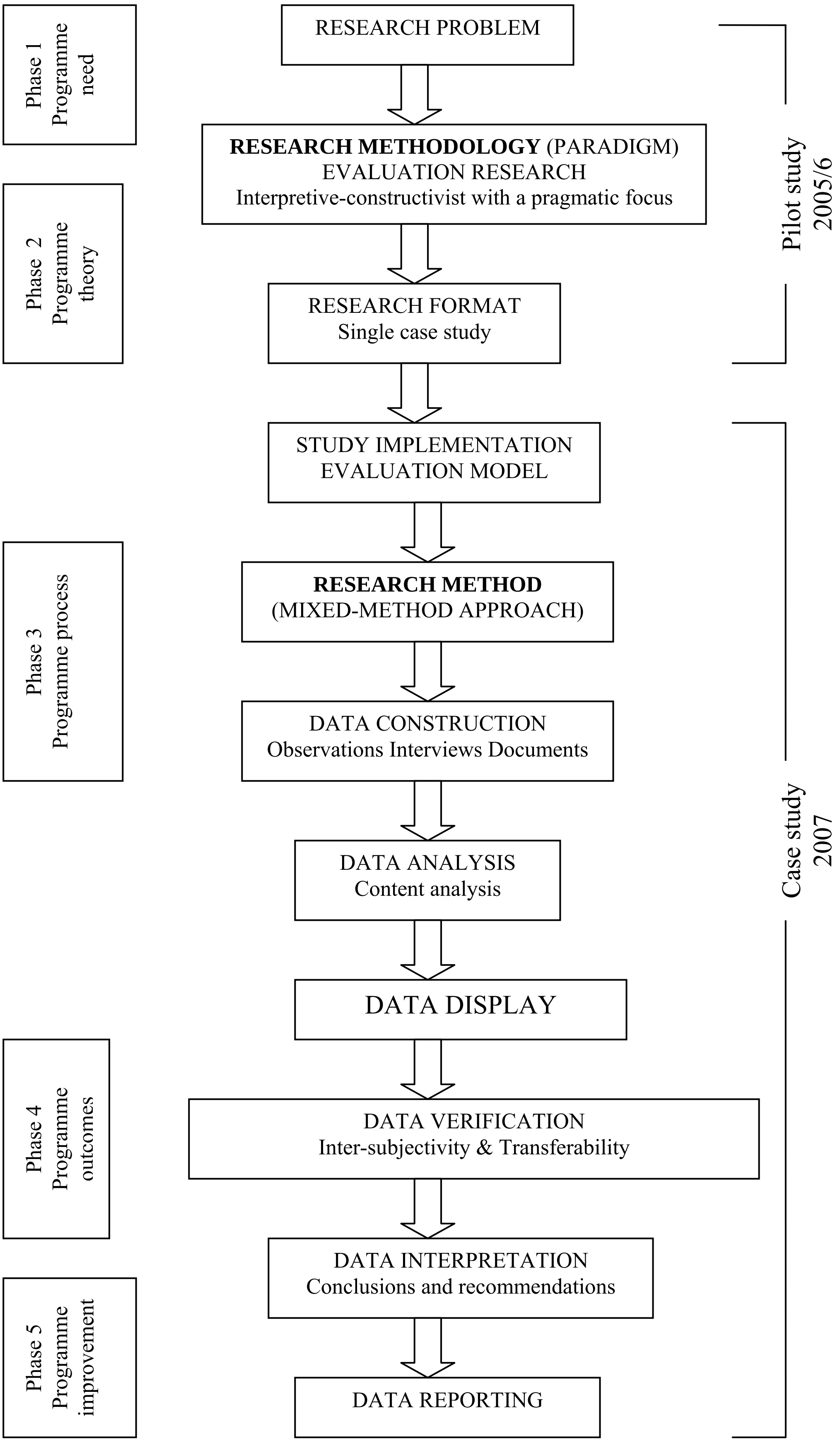


Figure 4.1 The overall shape of the research

Given that this was an emergent design the researcher started off with a broad plan and adapted it as the research progressed (Terre Blanche & Durheim, 1999:224). Knowing the dynamic nature of programmes the researcher had to be prepared to modify the evaluation if it became apparent that the original plan was no longer appropriate to the circumstances (Rossi *et al*., 2004:23).

This evaluation study could be seen as a single case-study (Green & McClintock, 1991:14). A case study is a choice of *what* is to be studied. The 'what' is a bounded system, a single entity, a unit around which there are boundaries (Merriam & Associates, 2002:178). In this single case-study the researcher explored in depth the process of conceptualizing, designing, implementing and evaluating a Hybrid PBL approach in a single programme at the University of Stellenbosch. The case was therefore bounded by time and activity and the researcher collected detailed information using a variety of data collection procedures over a sustained period of time (Creswell, 2003:15).

The next step in the design of the study was to select a sample from which to collect data. It was important for the researcher to select a sample (which included the site, participants and documents) from which the most could be learned. This is called purposive or purposeful sampling (Merriam, 2002:11). To begin purposive sampling, the researcher decided to observe the participants involved in the SciMathUS programme during 2007: forty-two adult students (ranging between the ages of 17 and 22) and three lecturers (two mathematics lecturers and one physical science lecturer).

4.3.3 Study implementation

The study commenced in 2006 with a pilot study phase and the case study phase was in 2007. The pilot phase focused on the conceptualization and development of the Hybrid PBL approach, and the case study phase focused on the implementation of the Hybrid PBL approach and the outcomes achieved.

Since programme evaluation requires that the steps of a particular process be implemented in order to execute the evaluation (De Vos, 2002:376) the following conceptual evaluation model was used by the researcher to describe the evaluation process (see Figure 4.2). According to Caffarella (1994:8) models make the planning and evaluation process easier since they provide a continuing guide for action. However, it must be noted that although the planning and evaluating process appeared to be a fairly logical and orderly process on the surface, it was sometimes a haphazard endeavour too (*ibid*.:1).

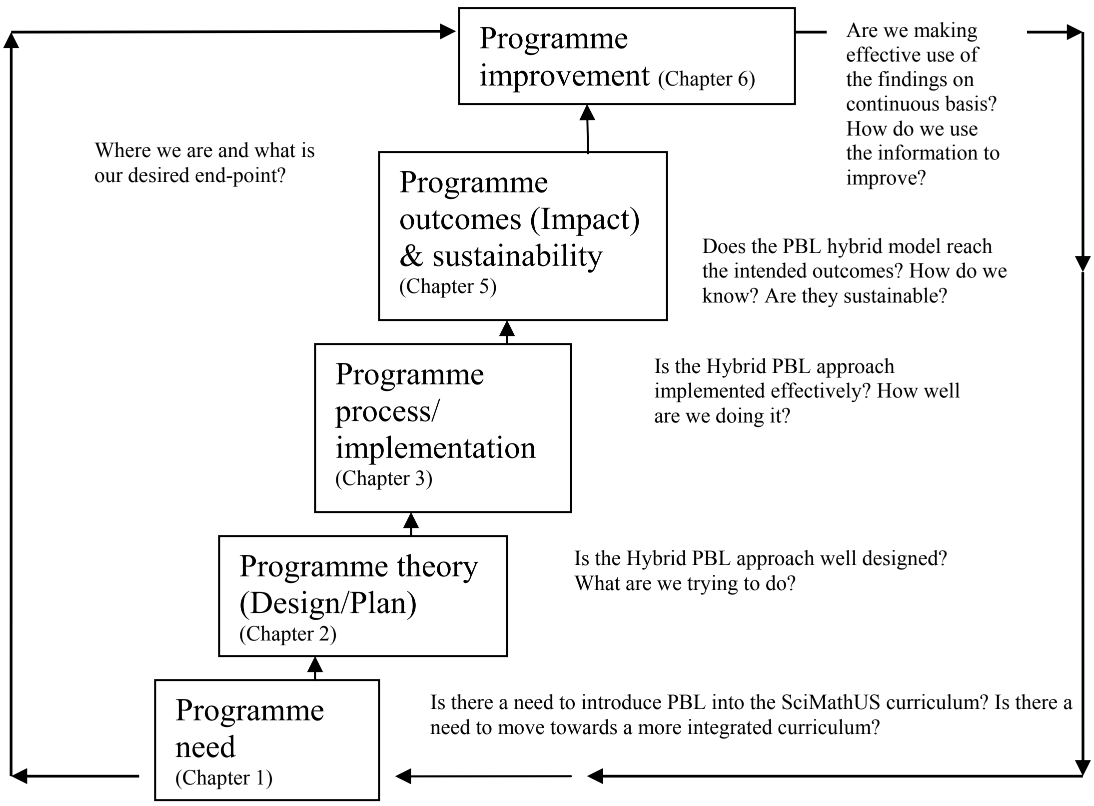


Figure 4.2: Conceptual planning and evaluation model (adapted from Custer, 2003:24-29).

The researcher viewed this model as a cyclic process which could be used to continuously evaluate and improve the programme as the needs kept on changing. It is important to note that although the Hybrid PBL approach was developed in 2006 during the pilot phase of the study the improvement of the model proved to be a continuous process during the case study phase of the research. Since the Hybrid PBL approach needed to be designed, implemented and tested, all the above phases were important in this research. Babbie and Mouton (2001:341) substantiate this view by pointing out that without measuring need, programmes cannot be planned rationally; without effective implementation, successful outcomes cannot result from the programme; and without valued outcomes, there is no reason to continue an intervention. The evaluation therefore commenced at the same time as the Hybrid PBL approach was being developed and designed. It therefore commenced prior to implementation and ended after the completion of the programme. According to Babbie and Mouton

(2001:365), this constitutes the ideal timing of programme evaluation research. It must also be noted that informal and unplanned evaluation opportunities sometimes occurred which also delivered useful results (Caffarella, 1994:124).

The following steps in the evaluation process namely programme need, programme theory (or design and plan) during the pilot phase, programme process (implementation), programme outcomes (impact), and programme improvement and sustainability (maintenance) during the case study phase will now be discussed briefly.

Programme need (conceptualization) – Phase 1: Pilot phase (2005)

The importance of assessing needs is viewed as a precondition to effective programme planning and programme evaluation (Babbie & Mouton, 2001:341; Caffarella, 1994:17). An early step in planning an evaluation therefore is a thorough inquiry into the motivation of the stakeholders (Terre Blanche & Durheim, 1999:224), the intended purposes of the evaluation, and the uses to be made of the findings **(**Rossi *et al*., 2004:20). Stakeholders were identified at the outset with the emphasis on those closest to the programme and who hold high stakes in it. Stakeholders were involved early (as soon as they have been identified because many critical decisions that affect the evaluation occur early in the process). Stakeholders were involved continuously. To ensure that the input of key stakeholders was part of virtually all the phases of the evaluation, regular group meetings were scheduled. The primary stakeholders the evaluator considered in this study were:

- decision makers (persons responsible for deciding whether the programme is to be started, continued, discontinued, expanded or restructured),
- target participants (the consumers of the programme such as the teachers and the learners),
- programme managers (those responsible for overseeing and administering the intervention programme) and
- programme staff (those responsible for delivering the programme services) (Rossi *et al*., 2004:48-49).

The stakeholders were therefore key actors in the planning and evaluation process and not the mere objects thereof (Capeling-Alakija *et al*., 1997). All were part of the collaborative process of creating a new story at SciMathUS, so all the voices were heard (Drake, 1998:11). Participation by the stakeholders ensured that evaluation results would more closely address their concerns and be useful to them. Moreover, it created a sense of ownership in the development and implementation of the Hybrid PBL approach within SciMathUS. This amplified the significance of findings and reduced the potential for engendering resistance (Rossi *et al.,* 2004:52).

Topics for discussion with stakeholders included why there was a need to introduce PBL into the existing curriculum, what the programme goals and objectives (measurable attainments that were theoretically plausible) were and what the most important questions for the evaluation to answer were (Babbie & Mouton, 2001:365; Rossi *et al*., 2004:88,89). It was therefore important that the evaluation be tailored to the particular programme and its circumstances in order to yield credible and useful answers to the questions at issue (optimizing the situation for research purposes) and at the same time to minimize the disruption caused to normal operations (Rossi *et al*., 2004:22).

After an initial period of situation analysis where internal and external factors were considered, a series of workshops was conducted by the researcher to ensure staff support for and active involvement in the development of the Hybrid PBL approach and evaluation design. The focus was on personal, contextual, as well as instructional issues (Terre Blanche & Durheim, 1999:220,223). It was expected that the researcher would have fairly regular daily interactions with the stakeholders in order to share preliminary results and consult on the use of the findings for the purposes of programme modification, as well as to be given directions for further data collection and analysis (Mertens, 1998:239).

Programme theory (design/plan) – Phase 2: Pilot phase (2006)

If stakeholders do not have a clear idea about what a programme is supposed to be doing (programme theory), it will be difficult to evaluate how well it is doing it. In the planning stages of designing the Hybrid PBL approach, the researcher therefore strove to provide information concerning what PBL can do, as well as what it cannot do (Rossi *et al*., 2004:44). Intended effects (stated before intervention) as well as unintended effects (stated during and after intervention) were therefore considered in order to enlarge the knowledge base of the stakeholders and decision-makers (Caffarella, 1994:102; Chen & Rossi, 1980:111,119).

The assessment of programme theory therefore focused on the following questions relating to the way the Hybrid PBL approach was conceptualised and designed: What PBL approach would be suitable to be adapted for the SciMathUS context? What is to be achieved, in other words what is supposed to be happening (considering intended as well as unintended effects) (Rossi *et al*., 2004:55, 93) and is the Hybrid PBL approach designed well?

The purpose of the pilot study was to become more familiar with PBL and to test the viability of different PBL approaches as well as ascertain whether relevant data could be obtained from respondents via the different data collection methods employed in the study. By testing the PBL approaches and the nature of questions in the interviewing and focus group schedules the researcher was able to make modifications to be implemented during the main investigation during 2007 (Strydom & Delport, 2002:337). This resulted in the replacement of the *PBL project model* with a *Hybrid PBL approach* during the pilot phase of the study in June 2006. This was tested and modified during July to October 2006. However, like Bloland (1992:537) the researcher realized that no design can be faithfully followed because local conditions over a period of time affect how it will be implemented.

The success of the innovation process in the long run depended on the ability of the faculty to adopt and adapt the Hybrid PBL approach to suit their own specific needs. The development process during 2006 that involved stakeholders in the programme before actually implementing innovation (during 2007) was therefore employed during the pilot phase of this study (De Graaff & Bouhuijs, 1993a:17). Since SciMathUS is an organization with the freedom to make their own decisions (De Graaff & Bouhuijs, 1993a:17), the researcher believed this to be an ideal approach to innovation. See also Addendum D for and outline of what the Pilot phase of the study consisted of.

Programme process (implementation) – Phase 3: Case study phase (2007)

The case study phase during 2007 focused on the implementation of the Hybrid PBL approach, the programme operations and service delivery (Rossi *et al*., 2004:62). The assessment of programme process focused on the following questions: Is the Hybrid PBL approach implemented effectively? What challenges during implementation can be expected when integrating the Hybrid PBL approach into the current SciMathUS curriculum? What would be effective ways of addressing these challenges?

Data for documenting the implementation of the Hybrid PBL approach included the roles of all the stakeholders, the training of the staff and student orientation, the time and resources allotted to PBL, the programme schedule, the distribution of information concerning PBL, the design of PBL instruction plans and challenges and modifications experienced. All aspects of the implementation of the Hybrid PBL approach were documented, from the point it was put into practice, the times and nature of any changes to the completion of the programme (Bloland, 1992:537).

Programme outcomes (Impact) & sustainability – Phase 4: Case study phase (2007)

Although it is essential for all the stakeholders involved to understand how well a programme has been implemented, it is also important to demonstrate whether, how, and to what degree the programme has affected the participants. The assessment of programme outcomes in this study therefore focused on the following questions: Did the Hybrid PBL approach meet its objective of encouraging students to use more favorable learning patterns with an emphasis on the gradual transfer of control over student learning processes from external regulation to self-regulation? And if so, how do we know? Such an evaluation was critical to determine whether the programme should continue in its current form (Frank & Barzilai, 2004:49). The researcher's role was not to judge the merit or worth of the Hybrid PBL approach but to let such judgements emerge naturally from the process of information-sharing in which stakeholders also became engaged in the course of the evaluation (Terre Blanche & Durrheim, 1999:217).

The major difficulty in assessing the impact of a programme however is, that usually the desired outcomes can also be caused by factors unrelated to the programme. In order to establish with some degree of plausibility that this particular intervention had made a positive change, or had positive effects the researcher needed to show that there had been a positive change over time, as well as that such a change was in fact due to the intervention of the Hybrid PBL approach and not due to other extraneous factors (such as other training programmes focusing on the development of self-directed learning skills and normal developments in the environment). In evaluation studies the first condition is met through the use of pre-and post evaluation measures, in other words through collecting some baseline data which is followed with similar measures later on in the project. The pre-post evaluation design was therefore used to establish whether the learners had improved their learning patterns during the course of the programme. The ILS questionnaire of Vermunt (2004a; 2004b) was used for these purposes.

The second condition however is met through the introduction of experimental and control groups (Babbie & Mouton, 2001:348) which was not a possibility in this research. Relying therefore on the qualitative data obtained from students as well as staff during and after completion of problems 1, 2 and 3 the researcher deduced from the voices of the participants that there was a strong probability that the Hybrid PBL approach could be contributing to the changes occurring in students with regard to the development of meaning-directed learning patterns. Evaluation reports were prepared on a regular basis in order to communicate the value of the interventions and challenges to stakeholders. The researcher further attempted to be proactive with regard to the timing of the release of the evaluation reports (Caffarella, 1994:22).

Although it is essential to demonstrate whether, how, and to what degree the programme has achieved the objective towards changing the learning patterns of students in a more favourable direction it is also important to determine whether the impact is sustainable. In broad terms sustainability can be defined as the ability to maintain the positive impact of a programme, once that programme has achieved its objectives (Ismail, Immink & Nantel (2002). In order to determine the sustainability of meaning-directed learning patterns in the learners, data was obtained from randomly selected 2006 students during August 2007. A focus group meeting was planned during a certificate ceremony session in August 2007 for these students. However, this fell through due to time constraints and the researcher therefore had to rely on e-mail correspondence and questionnaires with the 2006 students. The basic tenet was whether learners could apply what has been learned after exposure to the PBL approach within the university environment, in other words could the learners therefore integrate what they had learned back into their personal, academic or public lives, often referred to as the ‘so what’ or ‘now what’ phase. Often some of what has been learned cannot be applied unless changes are also made in current practices or learning institutions. Numerous reasons have been identified to explain why participants either do or do not apply what they have learned as a result of being exposed to new approaches or programmes. Examples include the perceptions of participants about the value and practicality of the skills, the presence or absence of follow-up strategies and organizational attitudes toward changes required to apply what has been learned (Caffarella, 1994:108,110).

The 2006 students, after a period of eight months, served as the primary judges of whether exposure to the PBL approach had worked for them or not. Allowing the students the freedom to form their own criteria for judging the quality and sustainability of the PBL approach meant the researcher and stakeholders had to accept multiple ways of saying the PBL experience was or was not worthwhile (*ibid*.:141).

Programme improvement – Phase 5: Case study phase (2007)

Within this study the focus was on the improvement of the Hybrid PBL approach within the SciMathUS programme. The focus on improvement of the Hybrid PBL approach concluded with a discussion of examining challenges and the formulation of recommendations for current and future programmes (see Chapter 6). Achieving further improvements can be achieved in a variety of ways, namely: continue the programme, institutionalize components of the programme in other subjects and assess the programme's ability to respond to future needs. Some of the factors that contributed and promoted sustainability within this study were real commitment from stakeholders, support from management and institutionalization of PBL within the programme (through demonstrated ownership and participation from all staff members) (Caffarella, 1994:141).

4.4 RESEARCH METHODOLOGY

A mixed-method approach to programme evaluation that involved collecting and analyzing both qualitative and quantitative data (Babbie & Mouton, 2001:368; Cresswell, 2003:14; Greene & McClintock, 1991:19) was used in this study. The combination of qualitative and quantitative methods emphasized the largely pragmatic approach adhered to in this study (Morgan, 2007:48,53) which moved beyond technical questions about mixing or combining methods to focus on a more integrated methodology for the social sciences (Morgan, 2007:73). Although Guba and Lincoln (2005:200-201) as well as Mertens (2005:231) identify qualitative methods as the preferred methods for researchers working in the interpretive-constructivist paradigm they too recognise that quantitative methods can be used within this paradigm when it is appropriate to do so. Many different terms are used for the mixed-method approach, such as integrating, synthesis, qualitative and quantitative methods, multi-method, and multi-methodology, but the recent writings use the term mixed-method (Creswell, 2003:210).

There are many reasons for using a mixed-method approach. Bloland (1992:537) and Creswell (1998:101) note that the use of qualitative research approaches (which provide detailed views, meanings and patterns) in combination with quantitative methods (which provide broad numeric trends) in the same study can greatly expand the breadth and depth of understanding the research problem. Potter and Kruger (2001:197-198) confirm that there is value in evaluation approaches that are able to take different frames of reference into account. This explains the growth of interest in multi-method approaches that combine qualitative and quantitative data which assumes that all methodological approaches are limited and need to be supplemented by others. Within this study the main rationale for using the mixed-method approach was therefore to converge or confirm outcome findings from different data sources (Creswell, 2003:210) which could enhance the validity of the findings (Merriam, 2002:12).

The decisions that went into selecting a mixed-method strategy of inquiry for this study were based on the following questions proposed by Creswell (2003:211): What is the implementation sequence of the qualitative and quantitative data collection in the proposed study? What priority will be given to the quantitative and qualitative data collection and analysis? At what stage in the research project will the quantitative and qualitative data and findings be integrated? Creswell (2003:16) illustrates three general strategies and several variations within the mixed-method approach, namely sequential procedures, concurrent and transformative procedures. Within this study the researcher selected a *concurrent nested mixed-method strategy* which seeks to elaborate on or expand the findings of one method with another method. Figure 4.3 illustrates the concurrent nested strategy that was used in this study in combination with the conceptual planning and evaluation model.

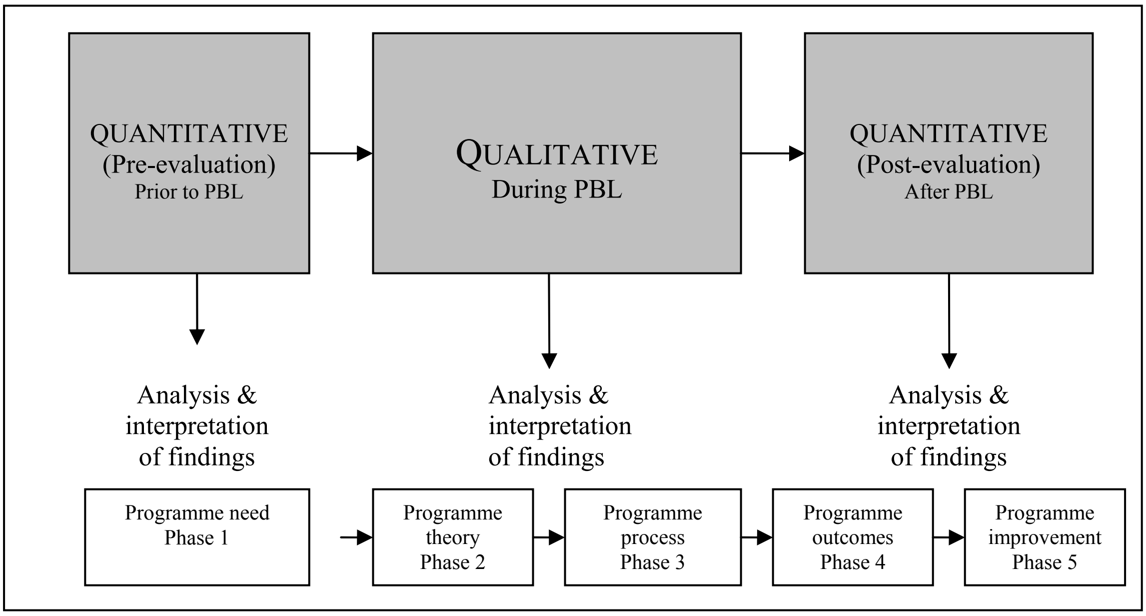


Figure 4.3: The concurrent nested strategy employed by the researcher (adapted from Creswell, 2003:214)

The concurrent nested strategy within this study can be identified by its use of one data collection phase (the pre-evaluation phase at the beginning of the study), during which both quantitative and qualitative data were collected simultaneously followed by a predominantly qualitative data collection phase during the implementation process of PBL followed by a post-evaluation phase at the end of the study where both quantitative and qualitative data again were collected simultaneously. A nested approach has a predominant method that guides the research. Given less priority, the quantitative method in this study was embedded or nested within the predominant qualitative method. This nesting meant that the embedded method sought information from different levels. The data collected from the two methods were mixed during the analysis and interpretation phase of the research (*ibid.*:214).

The concurrent nested model used in this research served a variety of purposes. This model was used so that the researcher could gain broader perspectives as a result of using the different methods as opposed to using the predominant qualitative method alone. Qualitative data was used to describe aspects that could not be quantified. The concurrent nested model was also employed when the researcher chose to use different methods to study different groups, namely the learners as well as the tutors. Tutors as well as students were interviewed and observed resulting in qualitative data while students' comments and experiences were compared with the quantitative results obtained from the completion of the ILS questionnaire for pre- and post-evaluation purposes (*ibid.*:218-219). The results from one method thus helped develop and inform the other method and provided insight into different levels or units of analysis (*ibid*.:16).

By combining qualitative and quantitative methods the researcher capitalized on the strengths of each method by gaining perspectives from the different types of data and from different levels within the study (*ibid*.:218-219) which ensured higher quality data (Babbie & Mouton, 2001:348). The combination of multiple methodological practices and perspectives in this single study added rigour, breadth, complexity, richness, and depth to the inquiry (Denzin & Lincoln, 2000:5).

However, there were also limitations to consider when choosing this approach. The data needed to be transformed in some way so that it could be integrated within the analysis phase of the research. There is still little written at this time that could guide the researcher through this process. In addition, there was little advice on how the researcher should resolve discrepancies that occurred between the two types of data. Because the two methods were unequal in their priority, this approach also resulted in unequal evidence within the study, which was sometimes problematic when interpreting the final results (Creswell, 2003:218-219). Furthermore, this form of research posed additional challenges for the researcher such as a need for extensive data collection, the time-intensive nature of analyzing both text and numerical data, and the need for the researcher to be familiar with both quantitative and qualitative forms of research (*ibid*.:210). The next section describes the procedures that were used in the study to collect, analyse, verify, interpret and present the data.

4.4.1 Data construction

Mason (in Greeff, 2002:299) mentions that it is more useful to talk of data generation or construction than data collection since the researcher is neither objective nor detached, but rather engaged when trying to unfold the participants' views and therefore forms part of the meaning creation process. Multiple data construction strategies were used (Mertens, 2005:16) most of which resulted in qualitative data that were generated from the programme evaluation (during phases I to V) of the study whilst quantitative data were generated during the pre- and post evaluation stages (phases I and IV) of the study. Within the mixed-method approach the researcher based the inquiry on the assumption that collecting diverse types of data provided a better understanding of the research problem (Creswell, 2003:21).

Data was collected at key points over a sustained two-year time period. Different sources of information were used. One important source was the students who provided insights and judgments on the PBL educational activities and outcomes. It was important for the researcher to ask the students (the major stakeholders in their educational experiences) for their perceptions about the Hybrid PBL approach since students have unique insights into the academic challenges they encounter. Students can also tell which component of the particular Hybrid PBL approach had the most impact on them and which components still needed improvement (Simpson, 2002:4). The tutors on the other hand were a good source of information regarding the design and implementation of the Hybrid PBL approach, emphasizing the quality of the problems, tutor preparation, the amount of ‘steering’ that was needed as well as outcomes achieved. An in-depth literature survey provided an understanding of PBL theory and the curriculum’s more general objectives (Simpson, 2002:4; Wiers *et al*., 2002:17-18).

Table 4.1 illustrates the data construction process used in this study. Note that when referring to participants the researcher is referring to both the students and tutors.

When and why data were collected	***Type of data collected***	***How and where data was collected***
	PILOT STUDY PHASE – 2005/6	
	(Programme need)	
Prior to the PBL programme • Determining programme need • Testing of PBL project and Hybrid PBL approach	• Data on need for PBL (staff) • Data on the quality of the design and implementation of the project PBL model (Jan – June 2006) and Hybrid PBL approach (June – Oct 2006) • Data on participants' learning and functioning in a PBL environment • Participant reactions to project PBL model & the Hybrid PBL approach • Data on whether PBL has addressed the needs stated by participants	• A strategic staff meeting held 14 March 2005 • Problem planning session for PBL (17 October 2006) • A strategic staff meeting held on 27 October 2006. • Classroom observations • Semi-structured focus group interviews with participants (focusing on quality of problems, quality of student & tutor preparation, quality of schedules with both models). • Semi-structured focus group interviews on PBL experience with both models (participants)
	CASE STUDY PHASE – 2007	
	(Need for SDL)	
Prior to the PBL programme • Need for development of self-directed learning skills in 2007 students	• Baseline data on students' present level of self-directed learning skills, values/attitudes.	• ILS questionnaire (pre-evaluation) on 25 Jan 2007 prior to being introduced to PBL. • Semi-structured focus group interviews with participants
	(Programme theory)	
During the PBL programme - 2007 • Evaluating the quality of the design of the Hybrid PBL approach	• Data on the quality of the design of the Hybrid PBL approach focusing on continuous improvement	• Semi-structured focus group interviews (focusing on quality of problems, quality of student orientation, quality of tutor preparation, quality of schedules, etc.). • Data from training sessions

(Programme process)		
During the PBL programme – 2007 • Evaluating the implementation of the Hybrid PBL approach	• Data on the implementation of the Hybrid PBL approach and participants' learning and functioning in a PBL environment • Participant reactions to the Hybrid PBL approach while in progress focusing on continuous improvement	The following data were obtained after completion of P1 (Jan/Febr 2007), P2 (March 2007) & P3 (July 2007): • Three focus group meetings with staff on PBL experience directly after completion of P1, P2 & P3 • Semi-structured focus group interviews with 8 student groups directly after completion of P1, P2 & P3. • Systematic classroom observation during P1, P2 & P3. • Feedback provided to students after completion of P1 & P2 (1 Feb. and 25 April 2007). • Feedback obtained from Peter Bouhuijs (an expert consultant) regarding P1 & P2). • A staff meeting on 25 April 2007. • A staff meeting on 18 July 2007. • Informal comments obtained from staff members after completion of P1, P2 & P3. • Post-evaluation via the ILS questionnaire on 29 July 2007.
THE FINAL ANALYSIS & PRESENTATION PHASE – 2007		
(Programme sustainability)		
Well after the PBL programme Follow-up of 2006 students	• Data demonstrating the sustaining effects of the Hybrid PBL approach and the participants' experiences in higher education	• Data further supported by randomly selected 2006 students via e-mail correspondence during August 2007.

Table 4.1: Data construction process (Bloland, 1992:537; Caffarella, 1994:135; Terr Blanche & Durheim, 1999:216, 218).

4.4.2 Data construction methods

Each research question was investigated using different data construction and data analytic methods (Merriam & Associates, 2002:38). The major concern was choosing data construction methods that provided answers to the evaluation questions within the constraints of the evaluation study that would satisfy the information needs of the different stakeholders. It was thus important for the researcher to stay flexible and responsive to emerging data construction needs (Mertens, 1998:238).

Primary data were collected through the application of the ILS questionnaire, semi-structured focus group interviews and classroom observations, whilst secondary data were collected through document analysis (including a literature review) and records of meetings in order to satisfy the information needs of stakeholders (Babbie & Mouton, 2001:76; Capeling-Alakija *et al.,* 1997; Claessens & Jochems, 1993:51; Mertens, 2005:71, 390). The primary and secondary data that were collected formed the case study data base and will be discussed in more depth.

4.4.2.1 Literature review and document analysis

An extensive literature review was conducted prior to data construction to guide the study in order to define the research problem more clearly and to develop a framework of reference within which to interpret the findings (Prince, 2004:228). The extensive literature review not only demonstrated that the researcher was thoroughly knowledgeable about related research and the intellectual traditions that surrounded and supported the study but assisted the researcher in identifying some gaps in previous research (Fouché & Delport, 2002a:266-267). It further provided opportunities to compare the experiences of introducing PBL into existing programmes with the experiences of other programmes. These comparisons were useful ways to find solutions to problems common to all the programmes. It also helped to determine whether challenges experienced were a function of the Hybrid PBL approach itself or whether the problems were due to local conditions (Frank & Barzilai, 2004:49). Other documents that were accessed included in-house memos, transcripts and records of strategic and other staff meetings, timetables and activity rosters (Babbie & Mouton, 2001:347). These documents provided a basic source of information about the programme activities and processes which further gave the researcher ideas about important questions to pursue (Patton, 1986:152).

4.4.2.2 The Inventory of Learning Styles (ILS) in Higher Education

The Inventory of Learning Styles (ILS) on students' regulation of learning processes in higher education (Vermunt & Vermetten, 2004:364) was used in this study as a pre- and a post evaluation instrument. The ILS questionnaire was constructed by Jan Vermunt (2004a) in the context of a research project at Maastricht aimed at measuring four components of student learning, whilst providing an integrative learning theory focusing on the interplay between self-regulation and external regulation of learning processes (Vermunt & Vermetten, 2004:359). The four components of student learning are cognitive processing strategies, meta-cognitive regulation strategies, conceptions students have of learning and their learning orientations. The four learning components were interpreted and discussed by means of the following four learning patterns, namely meaning-directed learning patterns, reproduction-directed leaning patterns, undirected learning patterns and application-directed learning patterns (*ibid.*:364-382).

Since there are only a few studies that provide empirical evidence concerning the effectiveness of PBL on students' self-regulation (Sungur & Tekkaya, 2006:308) the researcher used the ILS questionnaire as a pre- and post evaluation tool to investigate the effectiveness of PBL on various facets of students' learning patterns, specifically focusing on self-regulated learning, learning orientation and learning strategies. These findings were further supported by qualitative data.

The final version of the ILS consisted of 120 statements that cover the four learning components. For the strategy items, students were asked to indicate on a 5-point scale the degree to which they *used* the prescribed *learning activities* in their studies. For the items on learning conceptions and learning orientations, students were asked to indicate on a 5-point scale the degree to which the described views and motives *corresponded to* their *own views and motives* (Vermunt & Vermetten, 2004:364).

Prior to administering the ILS questionnaire the researcher checked for ambiguous and vague terms, especially since many of the students in the SciMathUS programme spoke English as a second or third language. To improve questions that may be experienced as unclear or difficult to understand, simple explanations were provided in brackets which were tested during the pilot phase of the study in order to reduce any negative impact on the quality of the responses (Mouton, 2005:104; Rosnow & Rosenthal, 1996:113). The ILS questionnaire was then translated into Afrikaans.

Forty-seven students at SciMathUS participated in the study but only thirty-five students completed the pre-evaluation ILS questionnaire. The reason is that it was the beginning of the year where late entries to the programme are a common occurrence. The mean ages of the students varied from 17 to 22. Students came from middle to lower-class families. The ILS questionnaire was administered as a pre-evaluation and a post-evaluation tool in the group to determine their learning patterns before and after being exposed to the Hybrid PBL approach. On both occasions the researcher administered the ILS questionnaire to the group and advised students to complete the questionnaire in its entity, not to discuss their responses with others near them and to be as sincere as possible.

4.4.2.3 Semi-structured focus group interviews

An interpretive-constructivist study relies heavily on qualitative methods, especially interviews and observations, which place the researcher in direct interaction with the phenomena under study (Greene & McClintock, 1991:13). The researcher conducted extensive interviews and observations over a two-year period of time. During this time semi-structured focus group interviews were used as one of the primary methods for information collection. Focus groups are used in multi-method studies that combine two or more means of gathering data in which no one primary method determines the use of the others (Greeff, 2002:306). The fundamental principle behind the semi-structured focus group interviews was to provide a framework within which participants could express their own understandings and experiences of PBL in their own terms in a permissive, non-threatening environment (Patton 1986:205). It also helped shed light on the quantitative data already collected (Greeff, 2002:305-308).

Focus group interviews can range from highly structured and focused to open-ended, unstructured conversations. In this study semi-structured focus group interviews (between structured and open-ended) were used. The semi-structured focus group interviews therefore contained a mix of more and less structured questions (Merriam, 2002:12-13) allowing considerable flexibility in scope and depth. Although the researcher had a set of predetermined questions on an interview schedule which was pilot tested first, it guided rather than dictated the interview (Greeff, 2002:298,302; Merriam, 2002:12-13; Mertens, 2005:16). The qualitative focus group interview was therefore essentially a guided conversation in which the researcher established a general direction for the conversation and pursued specific topics raised by the participants (Babbie & Mouton, 2001:289). Very often, therefore, the interview resembled a chat, during which the groups sometimes forgot that they were being interviewed (Greeff, 2002:297).

When using focus groups enough participants were chosen (usually six to eight per group) so that the focus group did not fall flat if some members chose to remain silent (Babbie & Mouton, 2001:292). A crucial concern was also not the amount of data, but rather the richness of data. In order to obtain rich data open-ended questions were used based on a review of the literature. The questions were asked in such a manner as to allow the participants to express themselves freely (Greeff, 2002:203-315). Questions were also asked when the researcher did not understand the participants' responses and during the sustainability phase to determine whether students had transferred and modified the targeted self-regulated learning strategies to their other academic tasks (Simpson, 2002:4). The researcher simply took notes to record the discussions. At the end of the sessions the researcher briefly summarised the main points of view in order to seek verification and to express gratitude for participation (Greeff, 2002:317). It must also be noted that the researcher differentiated between the content and the process of the interviews. The content focused on what the participants were saying whereas the process involved reading between the lines of what the participants were saying (noticing how the participants talked and behaved during the interviews) (Babbie & Mouton, 2001:289).

The main advantage of the semi-structured focus group interviews was the opportunity to observe a large amount of interaction on a topic in a limited period of time. These group discussions also provided direct evidence about similarities and differences in the participants' opinions and experiences (Babbie & Mouton, 2001:292). Furthermore the synergy of the groups proved to be a catalytic factor in bringing information to the fore therefore creating a fuller, deeper understanding of the phenomenon being studied in the 'security of being in a crowd'. It was, however, important that the researcher be skilled in group processes otherwise the expressions of only the active participants would be voiced (Greeff, 2002:319).

4.4.2.4 Questionnaires

Follow-up questionnaires (see Addendum E) targeting the 2006 students eight months after they had been introduced to the Hybrid PBL approach were used to demonstrate the sustaining effects of the programme and the participants' general experiences in higher education. The data collected through the questionnaires provided descriptive information about the learners' self-directed learning skills, attitudes, group functioning and achievements in higher education (Bloland, 1992:537).

4.4.2.5 Classroom observations

According to Merriam (2002:13), observation is the best technique to use when one wants to observe an activity, event, or situation firsthand or when a fresh perspective is desired. However, observation is not a matter simply of opening one’s eyes and ears to people in real-life situations but rather to train one’s eyes and ears. The researcher therefore needed an attitude of curiosity and a heightened attention as well as observational skills in order to attend to those very details that most filter out automatically in day-to-day life (Ely, 1991:42).

During the course of the two years the researcher took copious field notes (written accounts of the things she heard, saw, experienced and thought) in the course of collecting or reflecting on the data observed during the study (Greeff, 2002:317-318). Keeping extensive field notes were essential in order to capture the context of observations (Mouton, 2005:108). Since the researcher was concerned to get as rich descriptions as possible, she always sat down immediately after an observation session and jotted down her impressions. The field notes included both empirical observations as well as interpretations. Empirical observations included what participants were saying and doing in relation to working on actual PBL tasks and the skills and attitudes they displayed. The researcher further wrote down how the class atmosphere was experienced, how the problems were approached and completed and described the interactions between the learners and learners and tutors. Interpretations also included the emotions, preconceptions, expectations and prejudices of the researcher (Merriam, 2002:13; Ely, 1991:54). The researcher’s reflective journal was therefore an immense help where plans, questions, enthusiasms, doubts and ruminations were jotted down. This was an attempt to separate what was observed from thoughts. Every effort was made to keep observations and interpretations separate.

4.4.3 Data analysis

Data analysis is the process of bringing order, structure and meaning to the mass of collected data. It does not proceed in a linear fashion and is not tidy (De Vos, 2002:339-340; Merriam, 1988:127). At whatever point the evaluation data were collected, it was important to have set procedures for analyzing the data because according to Mertens (1998:239) one of the most frequent flaws in the evaluation process is the inadequate planning of data analysis procedures. This is specifically significant when different kinds of data and multiple data sources are used (Capeling-Alakija *et al.,* 1997, Cresswell, 2003:14). In choosing data analysis procedures the researcher considered the evaluation questions, approaches, data collection techniques, and kinds of data collected (Caffarella, 1994:138).

Data collection and data analysis occurred simultaneously as an interactive, continuous and on-going process (Cocklin, 1996:94; De Vos, 2002:341) and was only separated for convenience. The data analysis within this mixed-method research occurred both *within* the quantitative approach and the qualitative approach, and also *between* the two approaches (Creswell, 2003:220). Although the quantitative and qualitative data were sometimes presented in separate sections, the analysis and interpretation combined the two forms of data to seek convergence among the results, which coincided with the very nature of a concurrent study (*ibid*.:222). The quantitative and qualitative data generated from the evaluation research required vastly different competencies of the researcher in the analysis process (Caffarella, 1994:136).

Analysis of the quantitative data

It is important to identify the variables that the ILS questionnaire measured before explaining how the *quantitative data* were analysed. Variables are an event or condition that the researcher observes and measures or plans to investigate which is liable to variation or change. The dependent variable (Y) was the 'effect' (or outcome) in which the researcher is interested, namely whether the learning patterns, (in other words the self-regulation patterns) of students have changed. Students' scores on each of the four subscales constituted the dependent variables. The independent variable (X) was the presumed 'cause' which led to changes in the dependent variable, namely exposing students to the Hybrid PBL approach (Rosnow & Rosenthal, 1996:44). The ILS questionnaire was therefore used to measure the relationship between the dependent variable (Y), namely student learning patterns (in other words self-regulated learning) and the independent variable (X), namely introducing the students to the Hybrid PBL approach. At the same time the student learning patterns were explored using qualitative semi-structured focus group interviews and classroom observations with the participants at the research site (Creswell, 1998:101).

The pre-post evaluation design involved observations and measurements before commencement or implementation of the PBL intervention (O1) followed by the PBL intervention (X). After completion of the PBL programme, another set of post-evaluation observations and measurements was administered (O2). Standard quantitative analyses, such as a comparison of mean scores between O1 and O2 and a t-test (a test of significance used to judge the tenability of the null hypothesis of no relation between the two variables X and Y) and analysis of variance (or ANOVA – the subdivision of the total variance of a set of scores into its components) then indicated whether there was a statistically significant difference between the pre-evaluation and post-evaluation participants. A statistically significant difference means that any differences that are observed between a mean pre-evaluation score and a mean post-evaluation score is not due to chance factors but (most likely) indicate 'true difference' (Babbie & Mouton, 2001:349; Rosnow & Rosenthal, 1996:416). A p-value (probability value or level obtained in a test of significance) also called alpha and significance value was therefore used (Rosnow & Rosenthal, 1996:412). The key question, namely did the learning patterns of the programme participants change, was answered through this pre-evaluation-post-evaluation design (Babbie & Mouton, 2001:349). Follow-up analyses were used as needed to evaluate the mean differences between each dependent variable (Rosnow & Rosenthal, 1996:4).

Analysis of the qualitative data

The *qualitative data* consisted of observations made by the tutors, the researcher and students themselves on the extent of change in students' learning patterns and self-regulated skill levels, values and beliefs. These observations combined with data obtained from the focus group interviews focusing on the participants' experiences of the whole PBL process resulted in over 150 pages of transcripts and comments (Caffarella, 1994:136). The researcher could identify with Cocklin (1996:93) when confronted with the sheer depth and breadth of qualitative and quantitative material gained through the extensive period of the research. It was in this period that the researcher experienced considerable anxiety wondering if there was enough of the right data and how to bring together the qualitative and quantitative results. To analyse the qualitative data and develop themes the researcher used the four components and patterns of student learning identified on the ILS questionnaire (Vermunt & Vermetten, 2004:359) since it provided a useful tool in both the insight being sought and in managing and organizing the extent of data being gathered (Ely, 1991:88). The components on the ILS questionnaire therefore guided data-construction and data-analysis, and provided an explanatory framework for the interpretation of findings (Babbie & Mouton, 2001:366).

To assist in the analysis process the researcher applied a combination of the processes proposed by Mertens (2005:423), Miles and Huberman (1994:9), Ely (1991:87), De Vos (2002:340) and Cocklin (1996:88-115) as guidelines since all qualitative data analysis is in a sense idiosyncratic. After data were collected and recorded in a systematic manner the data was organized into computer files. The researcher then read the transcripts in their entity several times in order to get a sense of the whole before breaking it into parts (De Vos, 2002:343). The parts consisted of data being divided into semantic units, such as paragraphs, lines and phrases (Berg, 1995:178). Each unit was subjected to a pre-determined set of questions. Did the data comply with the descriptive components on the ILS questionnaire? Did it comply with the original objective of the research study? This initial criterion provided useful categories to sift the data (*ibid*.:181). The researcher therefore studied and re-studied the raw data to develop detailed intimate knowledge of it (Ely, 1991:150; Mertens, 2005:423). Because data is just raw data and not information, raw data had to be coded, weighed, collated, processed, analyzed and synthesized to produce information that could be used to make decisions (Anderson, 1992:233). This meant that the data collected was not immediately accessible for analysis, but required some processing (Miles & Huberman, 1994:9). In the concurrent strategy the researcher qualified quantitative data. Here the researcher created factors and themes from the quantitative data that could then be compared with themes from the qualitative data. The researcher also quantified qualitative data. This involved creating codes and themes qualitatively, then consulting the number of times they occurred in the text data (Creswell, 2003:221).

The qualitative data from the various sources were then analysed using the thematic and content analysis procedure of open coding as described in Berg (1995:185) and Frank and Barzilai (2004:46). The researcher took the text apart and data was grouped under the components and patterns (themes) of student learning identified in the ILS questionnaire (Ely, 1991:150). These patterns were given names (codes) and were refined and adjusted as the analysis proceeded (Mertens, 2005:423; Merriam, 2002:14; Miles & Huberman, 1994:9). The coding process was frequently interrupted by the researcher writing a theoretical note. The researcher therefore engaged in a continuous process of reflection and analysis which included writing initial impressions and reflections in the margins of the pages (Ely, 1991:87; Miles & Huberman, 1994:9).

4.4.4 Data display

According to Miles and Huberman (1994:11) "a display is an organized, compressed assembly of information that permits conclusion drawing and action." Miles and Huberman (1994:120) argue that humans are not very powerful processors of large amounts of information. The researcher therefore decided to assemble the organized information into an immediately accessible, compact form by using data descriptive display formats designed to answer the research questions. The formation of data displays was a process of systematically summarizing the data. The different components of the ILS questionnaire proved very helpful in designing the displays because it provided an existing theoretical structure to illustrate the interactive and multi-dimensional aspects of learning patterns of learners. The researcher, therefore, used this questionnaire as a guideline to deciding which of the clustered themes and categories that emerged during the open coding process of data analysis to include. Examples of coded data were then organized onto the displays (see Addendum F) and from them conclusions of a descriptive nature were drawn of possible changes that may have occurred in student learning patterns. Designing these displays had clear data reduction implications and formed part of the analyzing process. As the data displays subsequently filled, preliminary conclusions were drawn (*ibid.*:11-12,307).

4.4.5 Data interpretation (synthesis)

Interpretation involved the synthesis of data into larger coherent wholes. Interpretation meant relating results and findings to existing theoretical frameworks or models, and showing whether these were supported or falsified by the new interpretation. Interpretation also meant taking into account rival explanations or interpretations of data and showing what levels of support the data provided for the preferred interpretations (Mouton, 2005:108-110). From the ongoing interplay of data collection and analysis the researcher developed an emergent understanding of how different participants viewed the PBL experience and whether their learning patterns have changed significantly during the course of the year after being exposed to the PBL approach. Data were interpreted by using the four components of student learning, namely cognitive processing strategies, meta-cognitive regulation strategies, students' conceptions of learning as well as students' learning orientations. These four learning components were interpreted by means of the following four learning patterns, namely meaning-directed, reproduction-directed, undirected and application-directed learning patterns or styles (Vermunt & Vermetten, 2004:364-382).

4.4.6 Drawing conclusions

Basic tactics for drawing conclusions from the displays were noting differences in pre- and post-evaluation patterns and making contrasts and comparisons. The conclusions were checked against the qualitative and quantitative data whilst additionally clarifying how they tied into the theoretical framework derived from the literature survey (Miles & Huberman, 1994:11). This further ensured that all relevant data would be presented. Adequate recommendations were finally made from the data interpretations. In the writing of semi-final texts explaining the conclusions, the researcher attempted to remain objective by providing a detailed report of the data (Mouton & Marais, 1989:199). The final report thus contained a mixture of narrative text with 'thick' descriptions and quantitative displays and associated analytic texts (Miles & Huberman, 1994:243). Specific exemplars presenting the participants voices were used (*ibid*.:11).

It must further be noted that the conclusions drawn from a particular piece of data depended very much on the frameworks through which it was interpreted. The data collected seemed to contain many potential meanings and the relationship between theory and evidence was not cut and dried. The 'facts' were selected and arranged in many different ways and the researcher used her own judgement to construct the most satisfying account of the data. Criteria were available to assist in this process but these, again depended upon the frame of reference of the researcher (Connole, 1990:13-14).

4.4.7 Reporting the findings

After data interpretation and the processing stage of the evaluation the results were reported in a format that was convenient for all the stakeholders (Claessens & Jochems, 1993:51) since in any write-up of research, the audience needs to be considered (Merriam, 2002:15). Given that the researcher had constant daily interaction with all the participants the evaluation results were processed and communicated to staff and programme managers on a regular basis. Preliminary results were shared at two evaluation meetings and consultations were held on the use of the findings for the purpose of programme modification, as well as for directions for further data collection and analysis (Mertens, 1998:239). The two evaluation reports contained only a synopsis of the programme characteristics and findings (Bloland, 1992:537). Great care was taken not to use jargon. Testimonials about the advantages and experiences of PBL were provided (Simpson, 2002:10). In presenting the results of the analysis the staff needed to consider the possible explanations of the outcomes (or lack of outcomes). New results obtained by evaluation research indicated if, and to what extent these decisions have led to improvements (Claessens & Jochems, 1993:51).

4.4.8 Data verification

Within the pragmatic approach another aspect of data analysis was the series of steps taken by the researcher to verify both the quantitative and the qualitative findings. Morgan (2007:72) believes that an emphasis on abduction (discussed previously), inter-subjectivity, and transferability creates a range of new opportunities for thinking about classic methodological issues in the social sciences (see Table 4.2).

	Qualitative approach	**Quantitative approach**	**Pragmatic approach**
Connection of theory and data	Induction	Deduction	Abduction
Relationship to research process	Subjectivity	Objectivity	Inter-subjectivity
Inference from data	Context	Generality	Transferability

Table 4.2: The pragmatic approach to research (Morgan, 2007:71)

4.4.8.1 Inter-subjectivity

Within the pragmatic approach the usual arbitrary dichotomy between subjective and objective is viewed as an artificial summary of the relationship between the researcher and the research process. Although one often hears arguments about the impossibility of 'complete objectivity', it is just as hard to imagine what 'complete subjectivity' would be (Denzin & Lincoln, 2000:5; Morgan, 2007:71-72). According to Morgan (2007:71-72) any practicing researcher therefore has to work back and forth between various frames of reference, and the classic pragmatic emphasis on an *inter-subjective* approach captures this duality. A prerequisite is that the researcher needs to achieve a sufficient degree of mutual understanding with not only the people who participate in the research but also the colleagues who read and review the products of that research. Thus this dimension represents the emphasis on processes of communication and shared meaning that are central to any pragmatic approach. Pragmatists, therefore, treat issues of inter-subjectivity as a key element of social life.

In order to establish a process of communication and shared meaning the researcher aimed to achieve a sufficient degree of mutual understanding with the participants by giving them regular updates on the findings and using thick descriptions in order to make the participants' voices heard (Miles & Huberman, 1994:11). Multiple examples of direct quotations were therefore provided to support the inferences drawn from the data (Mertens, 2005:15). The final report thus contained a mixture of narrative text with 'thick' descriptions and quantitative displays and associated analytic texts (Miles & Huberman, 1994:243). Prolonged engagement in the field characterized by persistent observation where the researcher constantly pursued interpretations in different ways searching for multiple influences enhanced this process (Babbie & Mouton, 2001:277).

To acknowledge the subjectivity the researcher brought to the research reflexivity was used as a way to address the implications of her subjectivity (Creswell, 2003:221; Weber, 2004:ix). Reflexivity is the process of reflecting critically on the self as researcher, the 'human as instrument'. In order to establish a sense of credibility the researcher purposefully tried to withhold her preconceptions when seeking to understand the phenomena, tried to remain open throughout the research process to alternative explanations of the phenomena observed, focused first on description and then on explanation, and constantly checked the plausibility of alternative interpretations (Guba & Lincoln, 2005:210).

To a large extent the validity of this study further depended upon the ethics of the researcher and the research process (Merriam & Associates, 2002:28). The following ethical considerations were therefore taken into consideration in this study. Participants were provided with the opportunity to give their consent to participate in the study and to remain anonymous in documentation of the research results. The researcher thus ensured that the evaluation was conducted with honesty and integrity by respecting the dignity and self-worth of all the stakeholders involved. To strive for transparency the purpose, goals and objectives and various supporting or competing agendas were openly discussed whilst everyone had the opportunity to influence and shape events. The researcher thus worked towards a true participatory and democratic relationship with stakeholders in a spirit of collaboration, capacity-building and co-ownership. The planning strategy that was employed provided opportunities for stakeholders to come together early in the process to help provide a context from which collaborative consensus could occur (Babbie & Mouton, 2001:359; Capeling-Alakija *et al.,* 1997; Frank & Barzilai, 2004:49; Mertens, 2005:81; Miles & Huberman, 1994:291-292; Nichols, 2002:4; Tuckman, 1978:16).

4.4.8.2 Transferability

Morgan (2007:72) refers to the distinction between knowledge that is either specific and context-dependent or universal and generalized. Morgan does not believe it is possible for research results to be either so unique that they have no implications whatsoever for other actors in other settings or so generalized that they apply in every possible historical and cultural setting. From a pragmatic approach, an important question is the extent to which one can take the things that were learned with one type of method in one specific setting and make the most appropriate use of that knowledge in other circumstances. Once again, this involves a process of working back and forth, in this case between specific results and their more general implications. Morgan (2007:72) borrowed the idea of *transferability* of research results from Lincoln and Guba, who treated the question of whether the things learned in one context can be applied in another as an ‘empirical’ issue. The classic example is assessing whether the results from one particular programme evaluation has implications for the use of similar programmes in other contexts. This advocacy of transferability thus arises from a solidly pragmatic focus on what people can do with the knowledge they produce and not on abstract arguments about the possibility or impossibility of generalizability (Mertens, 2005:427).

Within this single case study the researcher was therefore not primarily interested in generalizations. All observations were defined by the specific contexts and case in which they occurred. For that reason the researcher did not claim that knowledge gained from one context will necessarily have relevance for other contexts (Babbie & Mouton, 2001:277). Replication of this study will therefore not yield the same results, but this does not discredit the results of this particular study. The more important question for the researcher was rather whether the results are consistent with the data collected. Guba and Lincoln (1985:288) were the first to conceptualize reliability in qualitative research as 'dependability' or 'consistency'. That is, rather than insisting that others get the same results as the original researcher, reliability lies in others' concurring that given the data collected, the results make sense, they are consistent and dependable (Mertens, 2005: 351). With transferability the burden of proof for generalizability lies with the reader. It is the reader, not the researcher, who determines what can apply to his or her context (Merriam & Associates, 2002:179). The following strategies for transferability were employed during this study:

Triangulation

Triangulation is the strategy whereby the researcher used multiple methods and sought out different types of data sources that could provide insights about the same events or relationships (De Vos, 2002:341; Frank & Barzilai, 2004:46) in order to support the strength of the interpretations and conclusions reached (Mertens, 2005:426). By combining methods in the same study observers could thus partially overcome the deficiencies that flow from one method (Babbie & Mouton, 2001:275,358; Greene & McClintock, 1991:19; Merriam & Associates, 2002:26; Terre Blanche & Durheim, 1999: 215). The use of multiple methods or triangulation furthermore reflected an attempt to secure an in-depth understanding of the phenomenon in question. Triangulation was not a tool or strategy of validation, but rather an alternative to validation (Denzin & Lincoln, 2000:5).

Member checks

A second common strategy for ensuring transferability is member checks which entail going back to the source of information and checking both the data and the interpretation. The aim was to assess the intentionality of participants, to correct for obvious errors, and to provide additional volunteer information (Babbie & Mouton, 2001:277). Here the participants were asked to comment on the researcher's interpretation of the data. That is, the researcher took the tentative findings back to some of the participants and asked whether their interpretation 'rang true'. This usually occurred during informal conversations with colleagues after data interpretation prior to compiling the two evaluation reports (Merriam & Associates, 2002:26).

Peer reviews

Peer reviews were yet another strategy employed by the researcher. Here the researcher asked a colleague to scan some of the raw data and assess whether the findings were plausible based on the data (Merriam & Associates, 2002:26). Although colleagues did not necessarily have to agree with the claims made by the researcher, it was important that they should be willing to concede that the researcher's conclusions were plausible, at least from the perspective of the researcher herself (Weber, 2004:viii). Furthermore the researcher reviewed her perceptions, insights and analysis with an expert in the field of PBL who was outside of the context of the study but who had a general understanding of the nature of the study (Babbie & Mouton, 2001:277).

Thick descriptions

Providing rich, thick descriptions involved providing sufficiently detailed descriptions of data in context and reporting them, with detail and precision, to allow judgements about transferability to be made by the reader (Babbie & Mouton, 2001:277). That is, enough description and information were provided so that readers would be able to determine how closely their situations matched the single case study and thus whether findings could be transferred to another setting (Merriam & Associates, 2002:28; Mertens, 2005:427).

Audit trial

An audit trail describes in detail how data were collected, how categories were derived, and how decisions were made throughout the inquiry (Merriam & Associates, 2002:27-28). An audit trial thus indicates the degree to which the findings are the product of the focus of the inquiry and not of the biases of the researcher (Babbie & Mouton, 2001:278). The audit trail was dependent upon the researcher keeping a research journal throughout the conduct of the study. What went into this journal were the reflections, questions, and decisions on the problems, issues, ideas encountered in collecting data as well as a running record of the researcher's interaction with the data whilst engaged in analysis and interpretation (Merriam & Associates, 2002:27-28). The aim of the audit trail was to allow independent readers to authenticate the findings of the study by following the trail of the researcher. While the researcher did not expect others to replicate her accounts, the best she could do was to explain how she arrived at the results.

4.4.8.3 The validity and reliability of the ILS questionnaire

Writers on mixed-methods advocate the use of validity procedures for both the quantitative and qualitative phases of the study (Creswell, 2003:221). To verify the quantitative phase of the study the researcher described the validity and reliability of the scores for the four components of student learning from past uses of the ILS questionnaire as well as the internal consistency scores for the four learning patterns attained from this study. The final version of the ILS questionnaire was constructed, using factor, reliability, item, and test-retest analyses (Vermunt & Vermetten, 2004:364). Cronbach's alpha, also called the alpha coefficient was used to measure internal consistency reliability meaning the degree of relatedness of the individual items (Rosnow & Rosenthal, 1996:404). The items of the test are scored dichotomously, that is, scored '1' if marked correctly and '0' if marked otherwise. The more highly correlated the scores, and the more items there are the higher is the reliability (*ibid.*:126). In several studies with a total of 795 regular university students, the internal consistencies of these scales (Cronbach's alpha) varied between .63 and .85 for processing strategies, from .48 to .79 for regulation strategies, between .70 and .89 for conceptions of learning, and from .57 to .84 for learning orientation, for regular university students (Vermunt & Vermetten, 2004:364,367). In this particular study the internal consistencies of the four learning patterns (Cronbach's alpha) for the pre-test and post-test results varied between .83 and .86 for the reproductive learning styles, from .89 to .88 for meaning directed learning styles, between .77 to .87 for the undirected learning styles and from .41 to .70 for the application directed learning styles for the SciMathUS students.

4.5 CONCLUSION

This chapter provided the theoretical foundation for the methodology of the evaluation study. In this chapter the researcher presented an evaluation diagram that served as a framework for this study. The three primary means of gathering data namely semi-structured focus group interviews, observations and the application of the ILS questionnaire was discussed. Quantitative data analysis consisted of a comparison of mean scores between O1 (prior to exposure to the PBL approach) and O2 (after exposure to the PBL approach), a t-test and analysis of variance whereas the qualitative data were analyzed for patterns and general themes.

This chapter further indicated how the research design was structured and provided important guidelines to verify reliability and maximize the credibility and the trustworthiness of the research findings. Although these guidelines helped the researcher gain the confidence to initiate the study, the researcher soon realized that there was no substitute for experience. Many mistakes were thus made; some things happened that were not anticipated, other things worked out serendipitously in spite of the researcher. The research process involved long periods of uncertainty. It was a long, hard journey with many challenges along the way (Correll, 2002:261; Merriam, 2002:421-422).

In the light of the concerns voiced about the Hybrid PBL approach, the question arose whether introducing a Hybrid PBL approach within a shorter one-year foundation programme could create and support conditions for learners to develop self-directed learning skills and whether such an innovation is worth the effort. Chapter 5 will attempt to address these questions.

CHAPTER 5: THE EVALUATION OF THE HYBRID PBL APPROACH FOR SCIMATHUS

5.1 INTRODUCTION

In order to determine whether introducing a Hybrid PBL approach into a conventional curriculum does promote more favourable learning patterns in students in a particular context and whether these patterns seem sustainable, the effects of this intervention on the learning processes of students in the SciMathUS programme were carefully studied (referred to as learner-oriented evaluation). For these purposes both qualitative and quantitative data were generated (as discussed in Chapter 4). Multiple data construction strategies were used.

Quantitative data generated from 35 students *prior to and after exposure to PBL* consisted of:

- The completion of the Inventory of Learning Styles (ILS) for pre-PBL evaluation purposes before being introduced to PBL during the orientation week (25 January 2007).
- The completion of the Inventory of Learning styles (ILS) for post-PBL evaluation purposes after experiencing the PBL approach via three integrated problems during the third term (19 July 2007).

Qualitative data was generated from students and tutors. **Qualitative data** generated from students *prior to and after exposure to PBL* consisted of:

- The completion of a pre-PBL evaluation questionnaire designed by the researcher before being introduced to PBL during the orientation week (25 January 2007).
- The completion of a post-PBL evaluation questionnaire designed by the researcher after experiencing the PBL approach during the third term (19 July 2007).

Qualitative data generated from students *during PBL exposure* consisted of:

- Data generated from semi-structured focus group meetings with eight student groups and classroom observations during and after working on problem 1 (The Palmiet Problem) and smaller PBL problems during class (1 February 2007).

- Data generated from semi-structured focus group meetings with eight student groups and classroom observations during and after working on problem 2 (The Amazing Race problem) and smaller PBL problems during class (29 March and 25 April 2007).
- Data generated from semi-structured focus group meetings with eight student groups and classroom observations during and after working on problem 3 (The Two Oceans Marathon Problem) (17 – 19 July 2007).

Qualitative data generated from staff during the implementation of PBL comprised of:

- Feedback provided to students after completion of problem 1 and problem 2 (1 February and 25 April 2007).
- Three semi-structured focus group meetings with staff directly after completion of problem 1, problem 2 and problem 3 (29 March, 25 April and 19 July 2007) to explore student learning patterns and the teaching strategies employed.
- A staff meeting on 25 April 2007.
- Informal comments generated from staff members during and after completion of problem 1, problem 2 and problem 3.

Prior to and after PBL exposure the students' comments and experiences generated from the qualitative data were compared with the quantitative results generated from the completion of the ILS Inventory for pre- and post-evaluation purposes to ascertain whether exposure to the Hybrid PBL approach had changed students' learning patterns in a favourable direction. Student leaning patterns were further explored through classroom observations and semi-structured focus group sessions with students and tutors at the research site during exposure to PBL (whilst working on problem 1, problem 2 and problem 3). The qualitative and quantitative data were analysed concurrently. This involved creating codes and themes qualitatively (guided by the learning components on the ILS Inventory), then consulting the number of times they were indicated by students and groups in the text data. This was then compared with the quantitative data. Although 47 students participated in the study only 35 students completed the pre-evaluation ILS Inventory. The qualitative results of the same 35 students were considered in analysing and interpreting qualitative and quantitative data. The findings and interpretations will now be discussed in more depth.

5.2 RESEARCH FINDINGS

5.2.1 Introduction

The qualitative and quantitative data generated from students and qualitative data generated from staff will now be presented and interpreted. The four learning components identified by Vermunt (2004a; 2004b) for each of the four learning patterns (described in Chapter 2) were used:

- Cognitive processing strategies employed by students (their thinking processes, which include deep and surface approaches to learning),
- Meta-cognitive regulation strategies employed by students (their thinking about their thinking, which include self-regulation, external regulation or lack of regulation in their thinking),
- Conceptions students have of learning (their knowledge and beliefs about learning, which include construction of knowledge, intake of knowledge, use of knowledge and cooperative learning),
- Learning orientation (their motivation to learn, which include personally interested, certificate orientated or vocation orientated learning).

In order to present and interpret the findings as objectively as possible, the researcher will report data by means of quantitative and qualitative displays as well as a mixture of narrative text presenting the participants voices for the different learning components. The ILS Inventory proved very helpful in designing the qualitative displays since its theoretical structure could be used to illustrate the interactive and multi-dimensional aspects of learning patterns of learners. The qualitative displays for each of the four learning patterns are presented in Addendum H to K.

The following figure 5.1 illustrates where the data were generated and how they will be interpreted and discussed.

Learning patterns & Learning components	Qualitative & quantitative data Prior to PBL exposure	Qualitative data During PBL exposure	Qualitative & quantitative data After PBL exposure
4 Learning patterns - Meaning-directed - Reproduction-directed - Undirected - Application-directed **Learning components Activities (SRL)** Cognitive processing Meta-cognitive regulation **Beliefs (SDL)** Learning conceptions Learning orientations	<u>Quantitative data</u> from the completion of the Inventory of Learning Styles (ILS) for pre-PBL evaluation purposes prior to PBL exposure <u>Qualitative data</u> from the completion of a pre-PBL evaluation questionnaire prior to PBL exposure.	<u>Qualitative data</u> from students: semi-structured focus group meetings & classroom observations during and after working on problem 1, 2 and 3 <u>Qualitative data</u> from staff: Feedback provided to students after completion of problem 1 & 2 Semi-structured focus group meetings with staff after completion of problem 1, 2 and 3 A staff meeting Informal comments obtained from staff during and after completion of problem 1, 2 and 3	<u>Quantitative data</u> from the completion of the (ILS) Inventory for post-PBL evaluation purposes after PBL exposure <u>Qualitative data</u> from the completion of a post-PBL evaluation questionnaire after PBL exposure

Figure 5.1 Display of final analysis categories in the study and the data construction methods used

5.2.2 Interpretation of the learning components

In the following section the quantitative findings (obtained from the completion of the ILS Inventory for pre- and post evaluation purposes) for each learning pattern will be presented first. Next, the qualitative data for each of the learning components (obtained from students and staff *during* their exposure to the three PBL problems) will be discussed. Finally, a comparison of the pre- and post-evaluation results (obtained from qualitative and quantitative data *prior and after* PBL exposure) for each of the learning components will be made.

5.2.2.1 Meaning-directed learning pattern (F1)

5.2.2.1.1 Overall results

The meaning-directed learning pattern consisted of the following learning components as illustrated in Figure 5.2.

Learning components
Activities (SRL) Cognitive processing: Relating, structuring & critical processing Meta-cognitive regulation: Self-regulation of learning process & outcomes **Beliefs (SDL)** Learning conceptions: Construction of knowledge Learning orientations: Personally interested

Figure 5.2 Learning components of the meaning-directed learning pattern

Quantitative results generated from the completion of the ILS Inventory for pre- and post-evaluation purposes indicate that there is no significant change in the overall meaning-directed learning patterns of students (p = 0.71) (see Figure 5.3).

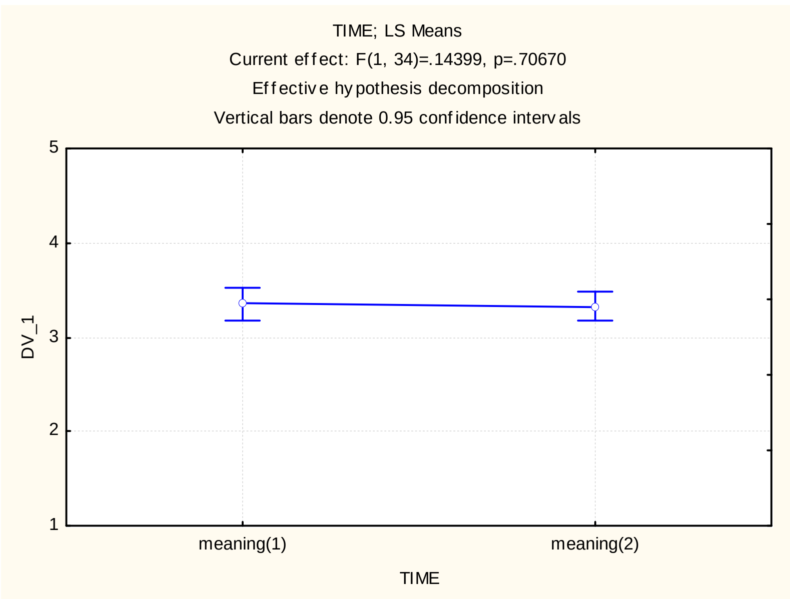


Figure 5.3 Meaning-directed learning pattern

5.2.2.1.2 Learning component results

Cognitive processing (F1)

The integration and analysis of the qualitative data for the cognitive processing learning component (obtained from eight student groups and staff *during* their exposure to the three PBL problems) will now be discussed.

Problem 1

The integration and analysis of qualitative data during PBL exposure indicates that during and after completion of problem 1 all eight groups acknowledged that PBL promoted insight and understanding: *"We enjoy the problems, it gives us insight."*

The tutors confirmed that the groups realized the importance of reasoning logically: *"They realize how important it is to reason logically."*

The following deep processing strategy (critical processing) was performed by students: one group evaluated their own answers to determine whether they grasped the questions: *"Through constructive criticism and by evaluating whether or not we have answered the questions we determined whether we have grasped the problem."*

The following benefits of PBL were noted by tutors: PBL assisted tutors in assessing misconceptions and lack of understanding in students. Tutors further acknowledged that PBL encouraged students to think rather than memorize subject matter: *"I believe in PBL. I notice that the students think rather than memorize. Students are thinking critically about the questions and their answers and not just parroting. This has really made our students think."*

PBL also encouraged deep processing strategies within tutors (encouraging them to look deep within their own subjects): *"It lets you look deep at your own subject."* Furthermore the tutors encouraged critical processing strategies by asking "why?" to improve understanding.

Problem 2

The integration and analysis of qualitative data during PBL exposure indicate that during and after completion of problem 2, four groups expressed the view that PBL expanded and challenged their thinking:

"You think beyond your set boundaries."

"It broadened our minds to think outside of the box."

"It develops your thinking."

The following deep processing strategy (relating & structuring) was noted by students: one group responded to the problem by making use of prior knowledge and noticing the connections and integration between Mathematics and Physical Science:

"We needed old knowledge to solve the problems."

"We noticed some physics words and math concepts."

Two benefits of PBL were noted by tutors. Firstly, PBL assisted tutors in discovering misconceptions and assessing thinking fallacies made by students (such as making assumptions):

"Lots of students struggled with the scale, for example to give their answers in mm."

"On day two it was clear that many still made the mistake of working on assumptions".

Secondly, PBL assisted tutors in discovering misconceptions and thinking fallacies made by themselves: "*We as lecturers also did not look at the problem clearly. We also made assumptions. This (PBL) is excellent."*

Tutors encouraged critical processing strategies by asking "why?" to improve understanding and by challenging students' misconceptions.

Problem 3

During the integration and analysis of the qualitative data obtained from staff and students during PBL exposure the following deep processing strategy (relating & structuring) was noted by students: seven groups noticed the connections and integration between Mathematics and Physical Science which improved their conceptual understanding.

"PBL changed the way we think. We understand math, the calculus part and also physics; the relationship between gradient and velocity, etc."

“PBL shows you how your subjects are related which improve understanding.”
“PBL helped us understand math better...the work becomes easier. For instance in maths we never knew that the whole thing of graphs tighed up with limits because we were only doing math as a subject; not to solve problems outside.”
“PBL gave me the big picture on the chapter on graphs and motions and I can interpret and understand graphs better.”

Two groups indicated how they built on their prior knowledge to address the problem: *“Our old knowledge suited us perfectly to build on, so we first brainstormed what we knew.”*

Whilst working on problem 3 the following deep processing strategy (critical processing) was noted: six groups indicated that PBL encouraged them to express their own opinions, form their own conclusions, and assess their level of understanding whilst building confidence and enhancing their creativity in the process: *“I learnt I have the right to express my own opinions.”*

The groups further became aware that there is more than one way to approach and solve a problem. *“PBL helps us to think critically and how we can go about approaching a problem instead of thinking inside the box. There’s more than one way of solving a problem.”*

One group, however, expressed frustration when they had to compromise their own views for the sake of the teams’ success.

The following benefit of PBL was noted by tutors: PBL encouraged deep processing strategies within tutors (encouraging them to look deep within their own subjects). The tutors encouraged the use of critical processing strategies by asking “why?” to improve understanding and by challenging students’ misconceptions.

Regarding pre- and post-PBL evaluation results for **deep processing (Relating and structuring)** (F1) the data analysis indicates the following:
Quantitative results generated from the completion of the ILS Inventory for pre- and post evaluation purposes indicate a slight increase in the use of deep processing learning strategies (Relating and structuring), although the increase is not significant (p=0.08) (see Figure 5.4).

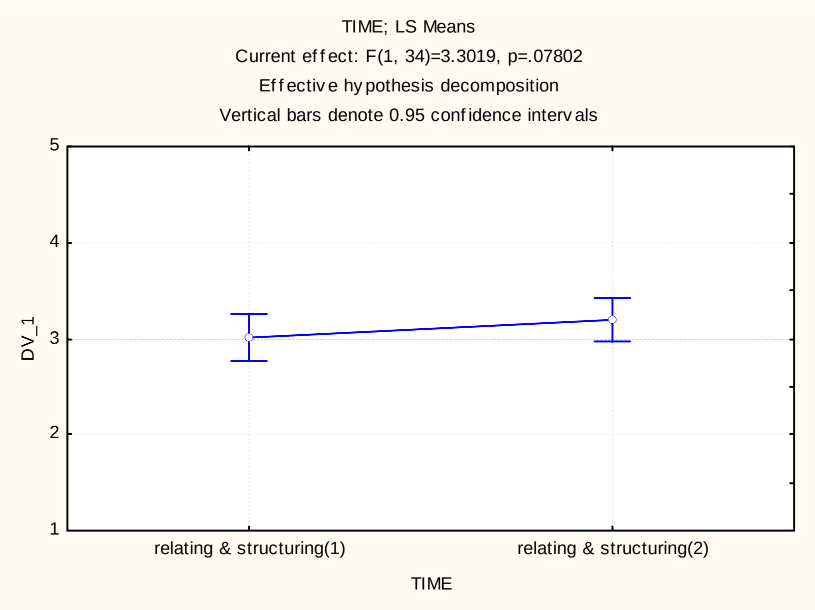


Figure 5.4 Meaning-directed learning pattern (Relating and structuring)

The qualitative results generated from a questionnaire students completed prior to PBL exposure indicate that only eight students acknowledged the importance of understanding and making deductions when studying. No specific deep processing strategies were noted in the qualitative data.

The qualitative results generated from a questionnaire students completed after PBL exposure indicated that eighteen students acknowledged the importance of clear thinking, relating and structuring their work in order to enhance understanding:

"I developed a better understanding of the subject-matter mathematics and mathematical concepts. I think more before answering or tackling a problem."

"I must make sure I understand my work and know what it is about."

"I do all the theory and calculations later so to understand my work better."

"Effective learning is taking responsibility for my studies and making sure that I understand and that I am able to apply my knowledge."

"My thinking has drastically improved and I can apply what I've learned."

"I understand my work much better now."

"I always focused on the right answer which stopped me from answering in class or I said nothing when I didn't understand something. This is slowly starting to change." "PBL helps understanding."

"Rather than memorizing I try to understand the work that stays much longer in my memory. I also try to apply that which I understand and to talk about it which helps me to remember the work."

"Thanks to SciMathUS my thinking skills have improved a lot. The way that I think about a matter before I try to solve it has changed. In math I used to study in detail where the formulas came from."

Students mention the following relating and structuring study strategies employed to enhance their understanding:

"When I study I take out the most important points and I put it onto mind maps."

"I go through my notes, and work through the examples, then I summarize the chapters and try to relate the different chapters by trying to find similarities and differences and sometimes I memorize."

"When I study I make a summary of the section or chapter. I also make mind maps of that whole chapter once I have fully understood the chapter."

"I read to comprehend and when I understand what I've read and have created a picture I make mind maps."

"I think about what the subject matter entails and then I draw a mind map of stuff I know and what I read from textbooks. Then I do calculations and try to see ways of doing the sum quicker or why my solutions are wrong."

The qualitative results generated from the completion of a questionnaire prior to and after PBL exposure thus indicate an increase in the students' use of deep processing learning strategies namely relating and structuring which enhances understanding. This indicates an improvement in students' relating elements of the subject matter to each other, to their prior knowledge and integrating them into a whole.

Regarding **deep processing (Critical processing)** (F1) quantitative results generated from the completion of the ILS Inventory for pre- and post-evaluation purposes indicate that there was no significant change in the use of deep processing learning strategies (Critical processing) ($p=0.80$) (see Figure 5.5).

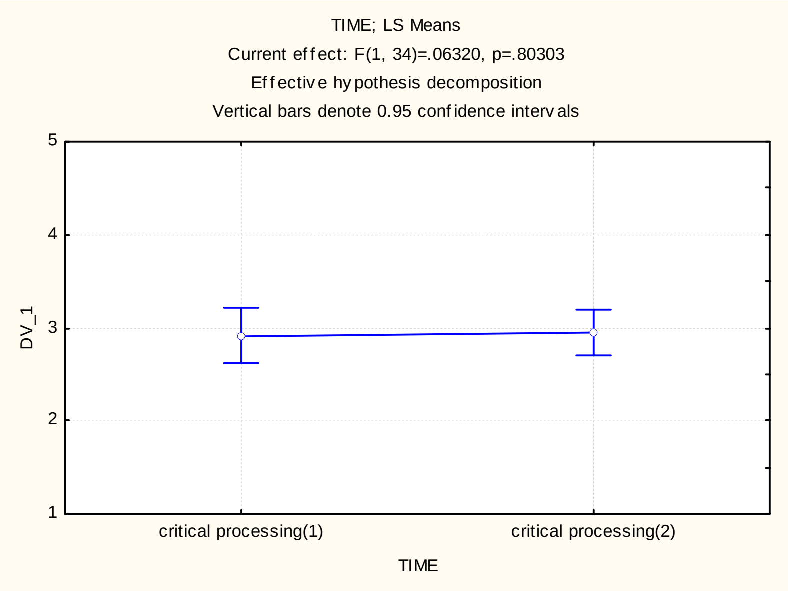


Figure 5.5 Meaning-directed learning pattern (Critical processing)

No critical processing strategies were noted in the qualitative data obtained from a questionnaire students completed prior to PBL exposure.

In the qualitative results generated by the questionnaire, students completed after PBL exposure three students indicated that they are more inclined to think critically, make their own deductions and question things more when studying:

"I question things more and don't just accept things."

"Yes, there is a change. I realized not everything can be taken for granted like we did at school but that I have to work very hard and think well."

"I've learnt to think more critically; not just to accept things that are given to me but also to question it."

Quantitative results do not indicate any significant change in the use of critical-processing learning strategies. The qualitative data does, however, indicate that a minority of students were employing critical processing learning strategies in their studies such as forming their own views, drawing their own conclusions and being critical of conclusions drawn by textbook authors and teachers.

Meta-cognitive regulation (F1)

The integration and analysis of the qualitative data for the meta-cognitive regulation learning component (obtained from eight student groups and staff *during* their exposure to the three PBL problems) will now be discussed.

Problem 1

The integration and analysis of qualitative data during PBL exposure indicate that all eight groups made use of self-regulation activities to address the problem. The following self-regulating activities regulating the learning process were noted: brainstorming first, planning ahead, rereading the questions, identifying the nature of the problem, deciding on key issues, asking their own questions, speculating, monitoring progress and solutions via group feedback, and lastly asking the teachers when needed. The following self-regulating activity regulating learning content was noted, namely doing extra research by consulting extra resources after class. No groups expressed a need for more external control of the learning process.

Tutors noted that PBL expands learners to self-regulate their activities: "*PBL provides students with a positive exposure to self-directedness and encourages us (tutors) to reflect on our own practices and perspectives.*

The tutors encouraged self-regulating by:

- Asking questions where students should think about the viability of their solutions: "*The math lecturer keeps on asking 'why, on what do you base your assumptions, facts or feelings'?" "When a group selects a specific solution to solve the energy resource problem in SA the lecturer asks: 'How… get specific… what will you do differently'?" (Researcher observations).*
- Encouraging students to distinguish between the pros and cons of their different solutions.
- Encouraging students to monitor their thinking by reflecting and adjusting their approaches when necessary: "*During the last 10 minutes of every session students are encouraged to ask the following questions: What did we do right, what did we do wrong, what will we do differently tomorrow?"*
- Encouraging students to monitor their meta-cognitive thinking: "*What are you planning on doing differently next time?"*

Problem 2

The integration and analysis of qualitative data during PBL exposure indicate that five groups made use of self-regulation activities to address the problem. The following self-regulating activities regarding the learning process were noted: brainstorming first, establishing goals, rereading the questions, assessing their own understanding of the problem, prioritizing, monitoring progress, coming up with their own solutions, testing and evaluating their own solutions and lastly consulting textbooks then asking tutors when needed:

"It helps us to develop our own perspectives and to think about it rather than just jumping in impulsively. Sometimes we need to be left alone to figure out what we don't understand and how we can then come up with our own solutions."

"We double checked that we were on the right track."

"We evaluated some possible logical and approximate answers. All of this 'digestion' process reduced the problem itself."

"We thereafter consulted textbooks, lecturers."

"If we really couldn't understand we asked the lecturers or sought help elsewhere."

This was confirmed by tutors: *"Many students said specifically that they learnt so much more when they worked on the PBL problems on their own. They got extra resources and information and then they asked: 'What now?' What do I do with this information now'? When you look for the information then you also realize when you must use this information. Yes they see this is the formula, but I can't do anything with this formula. I can't for instance use trig here"* (Informal feedback).

Students expressed the following needs regarding control of the learning process by expressing a need for more internal control. Three groups wanted less control from tutors and provided the following reasons: a need for independence (not wanting to depend on others for information) and feeling that independence would prepare them for the future. One group took more control of the learning process by tutoring the tutor, indicating to the tutor where she faulted.

Destructive friction occurred when students listened to tutor recommendations but still did their own thing when working on the posters leading to unsatisfactory results.

The tutors encouraged self-regulation by encouraging students to put their questions into their own words.

Problem 3

The integration and analysis of qualitative data during PBL exposure indicate that all eight groups made use of self-regulation activities to address the problem. The following **self-regulating activities to** regulate the learning process were noted:

- Brainstorming first: *"It was important to think before we just leap in."*
- Strategizing and delegating tasks: *"We drew a plan on how we are going to tackle the problem and then gave each other tasks to perform."*
- Identifying the nature of the problem (determining what is given and what is not given) by rereading the questions and discussing it: *"We asked ourselves what we didn't understand and what caused the misunderstanding."*
- Asking own questions.
- Monitoring progress via group feedback: "*We took a step back and rechecked our work and tried to figure out where we went wrong. If there seemed to be no solutions we asked for help."*
- Reflecting and adjusting their approach if necessary. *"We brought all our ideas together. If we didn't understand we used a different way of approaching it."*
- Testing and evaluating own solutions by reaching consensus to see how relevant or logical those solutions were. One group explained their problem and answer in simple terms to someone who knew nothing of athletics. *"If he understood it we knew we could explain this to our clients."* Other groups took turns in explaining their solutions to each other, whilst others tried out various possible answers.
- Lastly consulting textbooks then asking tutors when needed. This was confirmed by tutors.

The following self-regulating activities that were being used to regulate learning content were noted: doing extra research by consulting sources outside the syllabus such as other textbooks, books, and the internet and also approaching outside experts such as athletes or people off the street. One group acknowledged that working with different individuals created a lot of responsibility.

Students expressed the following needs regarding control of the learning process (expressing a need for more internal control). Three groups wanted less control from tutors and provided the following reasons:

- A need for independence: *"We want to stand for ourselves, put our own effort into it. We know we can conquer these challenges with less support … we're supposed to function independently as learners."*
- Feeling that independence will prepare them for the future: *"In the future we will be faced with problem s like this where no-one will give us support."*

Destructive friction occurred when tutors offered support when it was not needed which caused students to take on less responsibility and become lazy in their thinking: "*We get lazy to think because we know our tutors will help us, so we turn to rely on them and not on our knowledge."* Constructive friction occurred when tutors provided support when needed: "*It was encouraging when the tutors gave us a little push in the right direction where we could still find the answers ourselves."*

Five groups experienced the support provided as adequate:
"There would have been nothing to learn if the tutors gave us more support. Though our experience was on unfamiliar ground we learnt more than we could have imagined."
"If we got more help then the PBL problem would have been futile."

Four groups indicated internal control of the learning process. The groups worked on their own first before asking tutors for assistance. The other four groups started by asking the tutors first before attempting the problem on their own.

Tutors encouraged self-regulation by answering the students' questions with more questions: *"The only problem was that sometimes the tutors confused us even more by leaving us with more questions"*…and by looking uncertain themselves: "*There were times where the tutors looked a bit uncertain themselves and expressed their uncertainties to us."*

A particular benefit of PBL was noted by tutors: *"PBL expands learners to self-regulate their activities."*

Pre- and post-PBL evaluation results for **meta-cognitive regulation (Learning process and outcomes)** (F1) indicate the following:

Quantitative results generated from the completion of the ILS Inventory for pre- and post evaluation purposes indicate that there was no change in the students' self regulation of the learning process and outcomes (p=0.84) (see Figure 5.6).

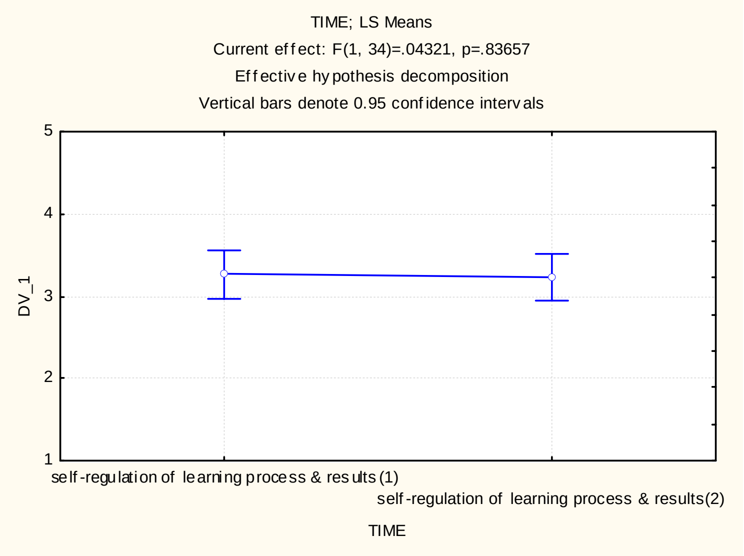


Figure 5.6 Meaning-directed learning pattern (Self-regulation of learning process and outcomes)

The qualitative results obtained from a questionnaire students completed prior to PBL exposure indicate that one student acknowledged the importance of self-regulation activities, setting up your own questions and testing yourself, using your own words, distinguishing important from less important facts and creating your own examples. No other self-regulating strategies were indicated by any of the other students.

The qualitative results generated from a questionnaire students completed after PBL exposure indicated that the activities of nineteen students reflected the importance of being more active and taking responsibility for their own learning:

"My methods of studying is different, I'm more active now."

"I take my work in my own hands now and don't wait for others to spoon feed me."

"I expected to be spoon fed and to literally experience a miracle, see my math mark sky-rocket. SciMathUS did not do that I expected, it did more: it helped me to learn to think for myself; learn to question things in a constructive manner and ultimately become a better person."

"I think I am now able to reason things out by myself. I trust my own thinking and don't rely on other people's brains."

"I have realized it's my responsibility to understand the work and if I don't I ask."

Eight of the nineteen students indicated that they employ one ore more of the following regulation activities in their individual studies:

- Planning their learning activities: *"I learn differently than in the past. I plan now what I need to do and which chapter I have to start with first." "Sometimes I find it necessary to work out a plan in order to do the maximum." "When I study I prefer to start with the difficult stuff first. I first select all the main ideas and concepts."*
- Using their own words: *"First I summarize the work in my own words, then try to summarize it the way it is and try to understand it, what I'm studying and thinking about."*
- Asking their own questions: *"I go through my work and ask myself questions about the work then I break it up until I understand the work"*
- Taking the initiative and going the extra mile: "*To ask questions when I don't understand, to do additional work on my own accord."*
- Solving problems on their own: *"They must provide help but give me permission to solve my problem s on my own."*
- Being self-disciplined: *"To take better responsibility for my academics, self-discipline, to keep motivating myself."*
- Reflecting on their approaches: *"I think why I do what I do and then try my hardest to understand the work, even if I have to ask for help."*

Three students indicated that taking on more responsibility for their studies improved their self-confidence:

"I am now more responsible when it comes to my work. I have more confidence in what I do and I'm more positive when it comes to new challenges."

"I have taken on more responsibility for my own studies and I have more confidence now to attempt things like exams and if I don't work at home I start feeling guilty."

"I must try and understand the work by myself. When I get it right I feel great."

Although quantitative results do not indicate any significant change in the students' self regulation of the learning process and outcomes, qualitative data do indicate that more students were employing regulation activities in their individual studies such as taking more responsibility for their own learning, planning their learning activities, monitoring their progress, diagnosing problems, testing their outcomes, and reflecting on and adjusting their approaches when needed.

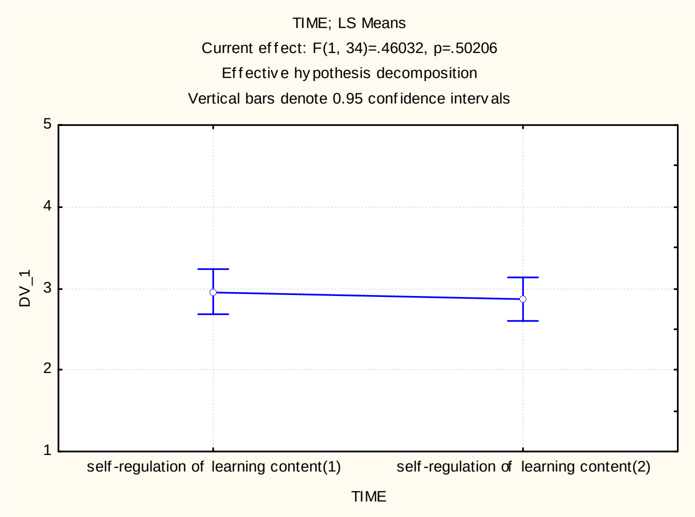


Figure 5.7 Meaning-directed learning pattern (Self-regulation of learning content)

Regarding **meta-cognitive regulation (Learning content)** (F1) quantitative results generated from the completion of the ILS Inventory for pre- and post evaluation purposes indicate no significant change in the students' self regulation of learning content (p=0.50) (see Figure 5.7).

Qualitative results generated from a questionnaire students completed prior to as well as after PBL exposure indicated that none of the students acknowledged consulting literature or other resources outside the syllabus or doing more reading than expected for their individual studies. The explanation for this may be that the students were still mainly attuned to the conventional curriculum, where the final senior examination focused on the content of their text books and no additional reading is required for success.

Learning conception (Construction of knowledge) (F1)

The integration and analysis of the qualitative data for the learning conception component (obtained from eight student groups and staff *during* their exposure to the three PBL problems) will now be discussed.

Problem 1

The integration and analysis of qualitative data during PBL exposure reveal the following beliefs about learning (focusing on construction of knowledge) expressed by one group of students. The group noted the importance of discovering new ways of solving problems: *"Through PBL we discovered new ways of solving problems."*

The following activities (focusing on construction of knowledge) were noted by tutors. Students were constructing their own learning issues by also participating in writing the curriculum and therefore reaching more than the intended outcomes:

"They come up with questions that I haven't thought about and then reach more than my outcomes. They thus also determine the outcomes. They recognized that there are more variables to take into account."

"*I experienced that the students get confused which is fantastic for me, because they are writing the curriculum themselves now."*

The following beliefs regarding control of the learning process were expressed by students: Although one group felt a need for more external regulation from tutors due to the newness of the topics they experienced it to be to their advantage to solve the problems on their own since they did not want to get dependent.

Problem 2

The integration and analysis of qualitative data during PBL exposure indicate the following benefit of PBL noted by tutors: PBL leads to unexpected learning outcomes for all the groups (students are asking good questions):

"With this PBL problem we got to fantastic outcomes." "More things came out than we planned for."

Problem 3

The integration and analysis of qualitative data during PBL exposure reveal the following beliefs and activities about learning (focusing on construction of knowledge) noted by students and tutors. Students were constructing their own learning issues by contributing their own ideas, listening and respecting each others' views and participating:

"The diversity of our knowledge and skills was a great benefit."

"Everyone brought his own personality to the group."

"We were good in different things so everyone at least contributed something to the group."

"Every contribution from each person made it easier and brought more ideas forward." "We always tried by all means to put something on the table."

"Listening to other people's views and how they interpret the problem can make you learn a lot."

"It's amazing how someone can see something that you can't see."

Other observations noted by students as well as tutors were that all eight groups asked their own questions, looked at the problem from different angles, consulted other resources, created their own solutions and came to class prepared.

Tutors noted that PBL was encouraging students to contribute their own ideas:

"I noted how students were empowering each other to work, to keep focus and help each other to contribute their own ideas."

Pre- and post-PBL evaluation results of **conception of learning (Construction of knowledge)** (F1) indicate the following:

Quantitative results generated from the completion of the ILS Inventory for pre- and post-evaluation purposes indicated a significant change (decline) in students' beliefs about constructing their own knowledge (p=0.01) (see Figure 5.8).

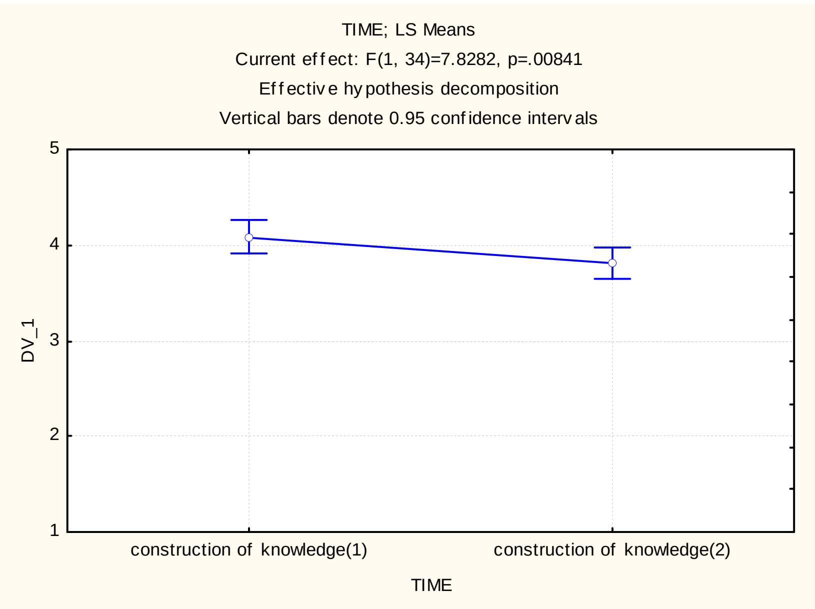


Figure 5.8 Meaning-directed learning pattern (Construction of knowledge)

The qualitative results generated by a questionnaire students completed prior to PBL exposure did not reveal any learning conceptions regarding the construction of knowledge. However, twelve students did indicate the importance of learner independence and responsibility in planning, motivation, and discipline and gaining knowledge.

The qualitative results obtained from a questionnaire students completed after PBL exposure indicated five students acknowledging the importance of learner independence and responsibility when constructing their own knowledge:

"I changed a lot. I'm wiser. I have taken more responsibility for my work. I'm more focused on my goals, something that I never did in the past."

"I mustn't only rely on the lecturers but have to work on my own too. I feel that there is always more than one option to consider."

"I must take responsibility to do my work and give my cooperation in class."

"I learnt that I can solve problems on my own."

"I started taking responsibility for my studies."

It was, however, clear that the majority of students had conflicting feelings about the matter:

"*They* (the lecturers) *must be available to answer our questions; they must present their knowledge to us effectively* (dependence), *and support us in such a way that we can function independently* (independence)."

"They should give clear instructions, be well prepared and open to ideas (dependence). *I must be willing to learn* (independence)."

"The teacher should encourage me, teach me things I don't know or understand, guide me, support me or help me to achieve what I want to achieve (dependence)."

"They must teach me in the specific subject but also ignite my potential. I will especially expect of my lecturer to challenge me (dependence)."

"They must see where they can be of help to me in order to make the work as understandable as possible, to ask me questions to make me think (dependence). *I must ask questions and share my opinions* (independence)."

"They must take note of my questions, be of assistance when I need them, and be enthusiastic when teaching (dependence)."

"To always be willing to answer questions with patience understanding and tolerance (dependence)."

It is important to note that although there was a decline in students' beliefs regarding their responsibility in the learning process (due to their conflicting beliefs), this was not reflected in the learning activities that many students employed in the learning process. Qualitative evaluation results generated from a questionnaire students completed after PBL exposure clearly indicate that more students employed learning strategies so they were taking on more responsibility for their own learning.

As noted above, quantitative results generated from the completion of the ILS inventory for pre-and post-evaluation purposes indicated a significant decline in students' views regarding the importance of constructing their own knowledge and insights, or seeing most learning activities as their responsibility. After studying the qualitative results carefully, the researcher noticed that the data also confirmed these findings. It seemed as if students were experiencing conflicting feelings in this area, in other words experiencing both a need for more support from their lecturers as well as a need for more independence. These results led to many possible interpretations and speculations.

Learning orientation (Personally interested) (F1)

The integration and analysis of the qualitative data (obtained from eight student groups and staff *during* their exposure to the three PBL problems) for the learning orientation component will now be discussed.

Problem 1

The integration and analysis of qualitative data during PBL exposure indicate that two groups experienced the PBL experience as fun (especially group work) and as a way of getting to know each other better:

"Working in a group is quicker, effective and fun." "We enjoyed the group work and the group dynamics was fantastic."

"It was great. We're looking forward to the next task."

Lecturers also experienced the PBL experience as worthwhile:

"For me this was a very worthwhile experience. Not only for PBL, but the students got to know each better."

Problem 2

The integration and analysis of qualitative data during PBL exposure indicate that six groups experienced the PBL experience as fun, informative, exciting, interesting and worthwhile (especially the group work):

"We enjoyed the mysterious nature of the clues and the fact that we had to work together as a team. We especially liked the clues in the math building."

Problem 3

The integration and analysis of qualitative data during PBL exposure indicate that all eight groups experienced the PBL challenge as:

- Fun: "*It's a fun way to acquire knowledge and when you actually get through the challenge you get a great sense of accomplishment." "It was nice to struggle in the beginning to get to the answers."*
- An experience which builds confidence: *"I learnt that I am a very bright person and I should never underestimate my abilities." "The problem made me aware of my lack of confidence. I have learned that I don't trust myself but I have confidence now because I was not shy to say what I was thinking."*
- Challenging: *"It provides a challenge to solve a problem that provides an adrenalin rush." "In the beginning it was very challenging, but near the end everything just fell into place." "In the beginning it's always confusing for me but in the middle it gets interesting when you start changing."*
- Informative, exciting, interesting and worthwhile (especially the group work): *"We truly enjoyed the experience since we had a wonderful group." "It was interesting to bond with other students and we learnt more when in groups."*

Pre- and post-PBL evaluation results of **learning orientation (Personally interested)** (F1) indicate the following:

Quantitative results generated from the completion of the ILS Inventory for pre- and post-evaluation purposes indicate no significant change in students' motivation regarding their personal interest in subject matter ($p=0.55$) (see Figure 5.9).

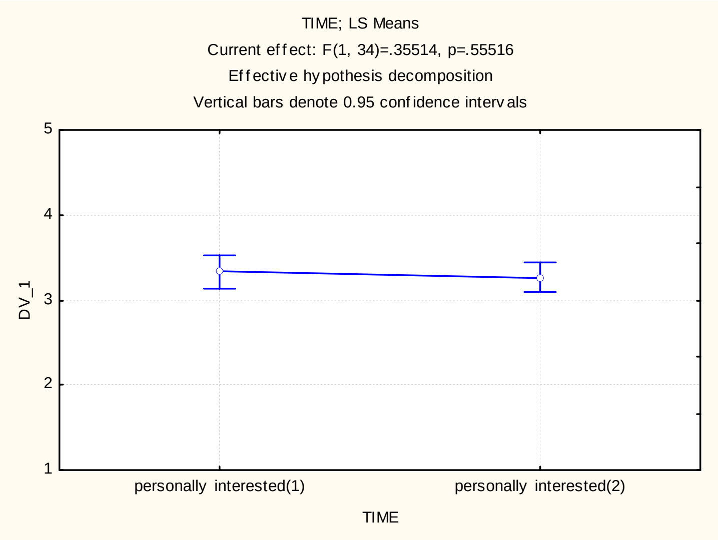


Figure 5.9 Meaning-directed learning pattern (Personally interested)

The qualitative results that were generated by a questionnaire that students completed prior to PBL exposure indicated that seven students noted affective factors for conducting their studies (such as fun, passion and self growth).

The qualitative results generated from a questionnaire students completed after PBL exposure indicated that three students were studying out of interest for their subjects or to develop themselves as people:

“I enjoy science and would like to expand my knowledge.”

“To obtain knowledge, to get my degree so that my future may be clear and brighter and then improve my status.”

“My whole school career math was my passion. I want to know and discover more.”

Thirteen students indicated pursuing their studies for self-development purposes:

“I expected SciMathUS to plant new soil; grow me and leave me to explore my abilities in giving back to the community.”

“I want to develop my inner potential. I have set myself that goal and don’t want to disappoint myself. I want to create a good life for myself and make a big difference in my country.”

“University is the key to an independent and enjoyable life. I want to make a difference in my circumstances.”

“Want to make my dreams come true.”

“I want to contribute in the community as a doctor.”

"My love for math and physical science has improved."
"I expected only to do math and science. I'm a different person now."
"I want to make a difference."

Quantitative results do not indicate any significant change in the students' motivation regarding their personal interest in the subject matter. Qualitative data indicated that a few students are studying out of interest for their subjects or to develop themselves as a person.

See Addendum H for the qualitative display of the learning components of the meaning-directed learning pattern.

5.2.2.1.3 Conclusion

Considering the different learning components the following was noted regarding changes in the meaning-directed learning activities and beliefs of learners after exposure to PBL.

The following changes were noted in the *deep processing and self-regulating learning strategies* of students after PBL exposure. Quantitative results indicated a slight improvement **(p=0.08)** in the employment of deep processing strategies such as **relating and structuring** by individual students. This was also reflected in the qualitative findings regarding the individual learning patterns of learners.

Although qualitative data revealed an improvement in the deep-processing strategies **(critical processing)** employed by student groups during their exposure to PBL qualitative as well as quantitative results did not reflect any changes in the deep processing strategies (critical processing) employed by students prior to and after PBL exposure.

Although exposure to PBL did indicate improvement in the **self regulating strategies** employed by student groups in the learning process no change in the self-regulating strategies employed by individual students regarding learning processes were noted in the quantitative data **(p=0.84)** prior to and after being exposed to PBL. The qualitative results prior to and after PBL exposure, however, did reflect an improvement in the use of self-regulation activities in the learning process of learners. This, however, was not the case for the self-regulation of learning outcomes. The qualitative and quantitative results **(p=0.50)** prior to and after PBL exposure also indicated no change in individual students' **self-regulation** activities regarding **learning content.**

Positive changes are noted in the deep processing and self-regulating learning strategies students employed after PBL exposure since more students indicate that they were relating to and structuring their work and that they were self-regulating their learning processes.

The following changes were noted in the *learning beliefs* of learners regarding the construction of knowledge and a personally interested orientation towards learning after PBL exposure. Quantitative results indicate a significant decline **(p=0.01)** in students views regarding the **construction of knowledge**. This is also evident in the qualitative data where 30 students expressed conflicting feelings about taking responsibility for constructing their own knowledge and thus seeing those learning activities as the responsibility of the teacher. Students acknowledged having both a need for more support from their lecturers as well as a need for more independence.

Quantitative results indicated no change **(p=0.55)** in affective factors contributing to students reasons for conducting their studies. Qualitative results, however, indicated that half of the students were orientated towards studying for self-development purposes after exposure to PBL.

Changes regarding meaning-directed conceptions and learner orientations after PBL exposure were mostly negative due to the conflicting feelings students were experiencing.

5.2.2.2 Reproduction-directed leaning pattern (F2)

5.2.2.2.1 Overall results

The reproduction-directed learning pattern consisted of the following learning components as illustrated in Figure 5.10.

Learning components
Activities (SRL) Cognitive processing: Memorizing & analyzing Meta-cognitive regulation: External regulation of learning processes & outcomes **Beliefs (SDL)** Learning conceptions: Intake of knowledge Learning orientations: Certificate & self-test oriented

Figure 5.10 Learning components of the reproduction-directed learning pattern

Quantitative results generated from the completion of the ILS Inventory for pre- and post-evaluation purposes indicate a slight decline in reproduction-directed learning patterns, bordering on significance (p=0.05) (see Figure 5.11).

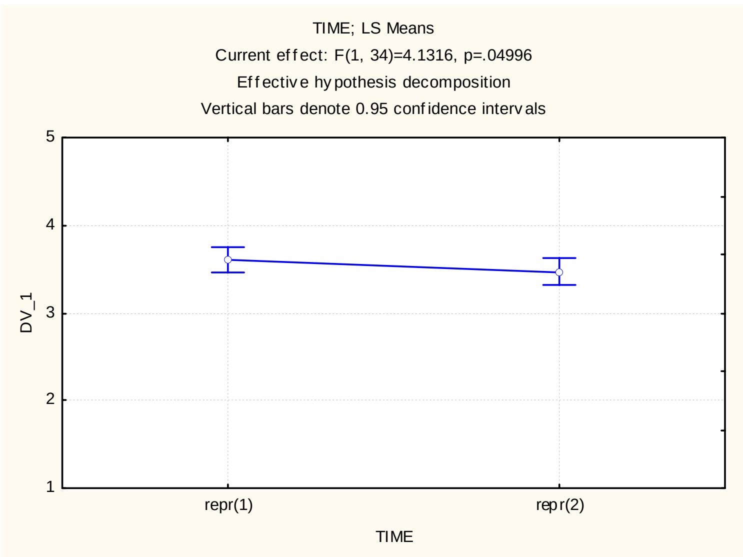


Figure 5.11 Reproduction-directed learning pattern

5.2.2.2.2 Learning component results

Stepwise cognitive processing (F2)

The integration and analysis of the qualitative data for the stepwise cognitive processing learning component (obtained from eight student groups and staff *during* their exposure to the three PBL problems) will now be discussed.

Problem 1

The integration and analysis of qualitative data during PBL exposure indicated that one group applied a stepwise processing strategy by analyzing the problem first before looking for more information: *"We analyzed the problem and went to find more information."*

The tutors acknowledged the students' use of a surface approach for the mathematics problem during the beginning phase of working on the problems by noting that students were looking too wide at the problem and trying to solve it as a social problem. Here it became clear how the realist model conflicted with the mathematical model indicating the importance of more guided facilitation: *"With the math problem one notices that they're not getting to the crux of the matter. Initially they looked very broadly at the problem and tried to address it as a social problem."*

Problem 2

The integration and analysis of qualitative data during PBL exposure indicated one group expressing a systematic approach when dealing with the problem: "*We are a network. When one has a logical answer we systematically identify and share the solution with each other unselfishly."* No other stepwise cognitive processing strategies were noted in the qualitative data.

Problem 3

The integration and analysis of qualitative data during and after completion of problem 3 indicate that six groups made use of a stepwise processing strategy by analyzing the problem first before looking for more information. Three groups indicated that the specific questions provided in the problem statement encouraged them to make use of a stepwise processing strategy:

"We answered it question for question."

"We worked through every question specifically."

"We jotted down important information first and worked at it bit by bit."

Two groups did not make use of a stepwise strategy.

Regarding pre- and post-PBL evaluation results for **stepwise cognitive processing (Memorizing)** (F2) the data analysis indicates the following:

Quantitative results generated by the completion of the ILS Inventory for pre- and post-evaluation purposes indicate that there was no significant change in the use of stepwise cognitive processing learning strategies (Memorizing) (p=0.69) (see Figure 5.12).

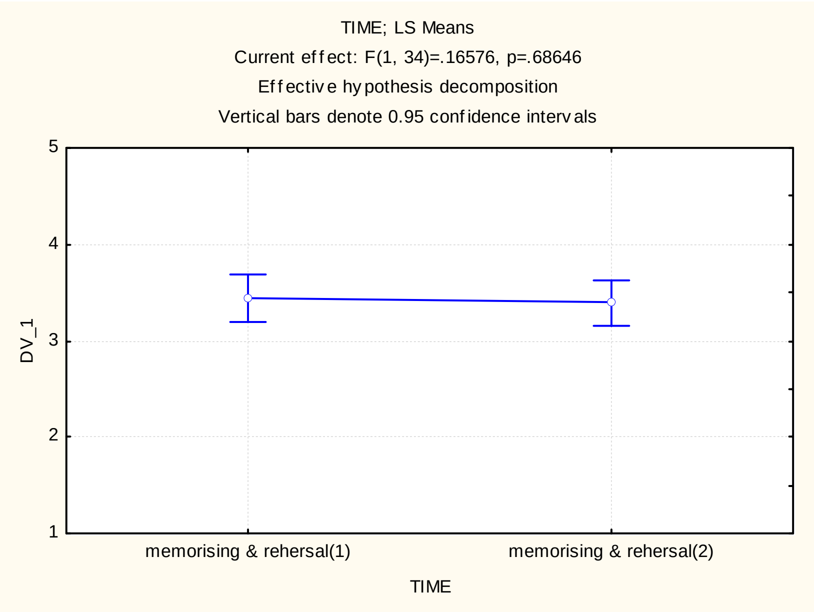


Figure 5.12 Reproduction-directed learning pattern (Memorizing)

Qualitative results generated by the questionnaire students completed prior to PBL exposure, indicate that twenty students acknowledged using a stepwise processing strategy focusing on memorizing, that is learning facts, definitions, and the like by heart by rehearsing them:

"I call my way of studying parroting 'papegaai leer'. I memorize everything precisely like it appears in the text book and write it down so that I can remember it."

One student acknowledged the fact that this strategy was ineffective:

"Most of the time I cram my work on the last minute, thinking I won't forget it but at the end of the day I normally forget everything I've studied."

Qualitative results generated from a questionnaire that the students completed after PBL exposure indicate that five students acknowledged making use of a stepwise processing strategy focusing on memorizing:

"When it's theory I read aloud and rehearse so that I can store the information in long term memory."

"I repeat the content a few times then write it all out. Then I explain the work to myself that I do understand."
"I picture, memorize, read, revise, and write down what can be remembered."
"I do lots of practice with the work. I write the definitions of concepts down on a piece of paper and then learn it until I can rehearse it."
"I first read the section three to four times and take a five minute break, then come back and write or practice it to see if I understand it."

Regarding **stepwise cognitive processing (Analyzing)** (F2) quantitative results generated from the completion of the ILS Inventory for pre- and post-evaluation purposes indicate that there was no significant change in the use of stepwise cognitive processing learning strategies (Analyzing) (p=0.24) (see Figure 5.13).

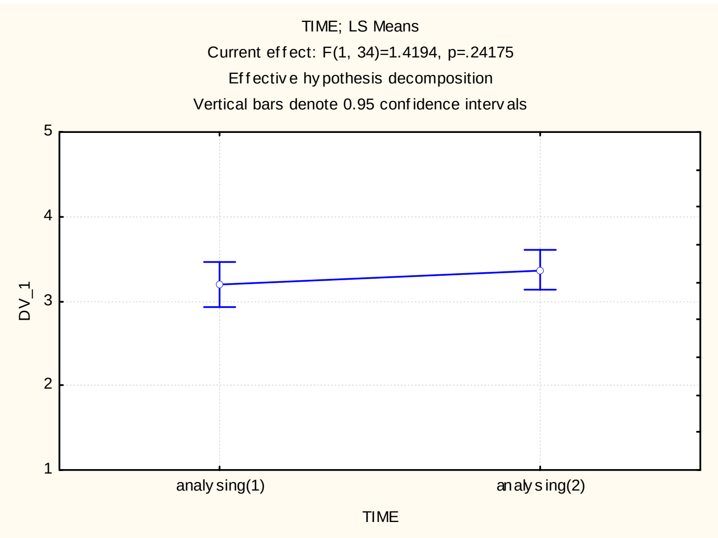


Figure 5.13 Reproduction-directed learning pattern (Analyzing)

Qualitative results generated from a questionnaire students completed prior to PBL exposure indicated that twenty students used a stepwise processing strategy focusing on analyzing, that is going through the subject matter in a stepwise fashion and studying the separate elements thoroughly, in detail and one by one. Many similar responses were found such as: *"I tackle my work chapter by chapter then go through the sub-chapter. I highlight the important facts, and answer the questions based on the chapter."*
Qualitative results generated from a questionnaire students completed after PBL exposure indicated eleven students making use of a stepwise processing strategy focusing on analyzing: *"I study systematically with in-between brakes."*

"I approach my chapters one by one and when I don't understand something I don't go to another one until I understand it."
"I organize everything beforehand, like what chapter I'm going to focus on and how many pages, etc. Then I read through once to get a feeling of the work or an idea. After that I read through step-by step and make rough mind maps that I can incorporate into one mind map and revise soon afterwards."
"I read through each chapter and then work on problem s."

Meta-cognitive regulation (F2)

The integration and analysis of the qualitative data for the meta-cognitive regulation learning component (generated from eight student groups and staff *during* their exposure to the three PBL problems) will now be discussed.

Problem 1

The integration and analysis of qualitative data during PBL exposure indicate that three groups used externally-regulated meta-cognitive strategies when they revealed a 'right answer' mentality and a concomitant need for external control from the tutors:
"Many asked specifically how to do the 'math question'. I got quite a few questions about whether they were allowed to do a specific thing."
"The students didn't use me much. They only used me when they wanted to make sure their 'answers' were right."
It is important here to reflect on the problem statement as well since direct questioning or many questions may encourage the 'correct answer mentality'.

Some lecturers preferred the clear and direct questions in the problem statement. *"I liked the specific questions."* One group felt a need for more external regulation from tutors due to the newness of the topics.

Three groups displayed externally-regulated meta-cognitive control of the learning process by first seeking advice from tutors, group members or text books before attempting the problem on their own. They further indicated that they did not like the unclear questions in the problem statement.

Problem 2

The integration of qualitative data analysis indicates that three groups were more externally regulated. They immediately asked the tutors or their group members for help and advice or consulted their textbooks before attempting the problem on their own. Reasons given were they disliked the unclear questions in the problem statement: *"We would have liked more support from the problem statement itself that would make it more possible for us to solve it effectively."*

Teachers experienced relinquishing control of the learning process as follows: *"We are used to the fact that we know and they don't know. Now it's just the opposite – we and they don't know. It's strange to stand there and not to be in control."*

Problem 3

The integration of qualitative data analysis indicates four groups applying external regulated meta-cognitive strategies. Their 'right answer' mentality led to a need for external control from the tutors or the problem statement:

"*We didn't like it that there wasn't a direct way to get to the right answer."*

"We disliked not knowing better how to go about getting answers so we asked help from the tutors."

Four groups reflected externally-regulated meta-cognitive control of the learning process by first seeking advice from tutors, group members or textbooks before attempting the problem on their own. They further indicated that they did not like the unclear questions in the problem statement.

Four groups monitored their progress and tested their outcomes externally by either approaching the tutors or textbooks first:

"We'd always asked our teachers whether we are still on the right track or not, then we will be able to improve the mistakes."

"We'd first ask our teachers and then explained the work to each other if we still didn't understand it."

"For the group to be content with the work we first had to ask the tutors to come and double check whether it made sense when they read it."

One group approached their textbooks first before approaching the problem: "*We first revised previously covered examples in our notebooks."*

A need for external regulation usually occurred at the start of the process when students were still confused with the problem or when they found some part of the problem too challenging to comprehend:
"It was a bit confusing on when to start but it was quite challenging so we asked our tutors for help."
"We struggled to start solving the problem s so if they could give us some more advice on how to start we could solve the problem faster."
"We needed more support because some of the questions were very unclear so we looked at our textbooks and asked the experts in the field of the study, that is our lecturers."
"We consulted our tutors and asked them to explain when we did not understand anything."

Constructive friction occurred when one group indicated that *"although more support would have made it easier it was quite good for the challenge and stimulating"* not to get the support. Another group indicated that help was only sought when the work was too hard to comprehend: *"The help would only be for clues and comprehension of subject matter which is above our level of thinking."*

Destructive friction occurred in one group when consulting the different tutors led to more confusion: *"We wanted more support, however when we got it we got a wrong idea and were sent in a wrong direction. We had to start all over again when we realized our mistake."*

Destructive friction also occurred when one group admitted to choosing the easy route: "*We decided on the easiest option to ask the lecturers so that they can guide us in the right direction."*

Regarding pre- and post PBL evaluation results for **external regulation of learning processes (F2)** data analysis indicate the following:

Quantitative results generated from the completion of the ILS Inventory for pre- and post-evaluation purposes indicated no significant difference in the external regulation of **learning processes** (p=0.64) (see Figure 5.14).

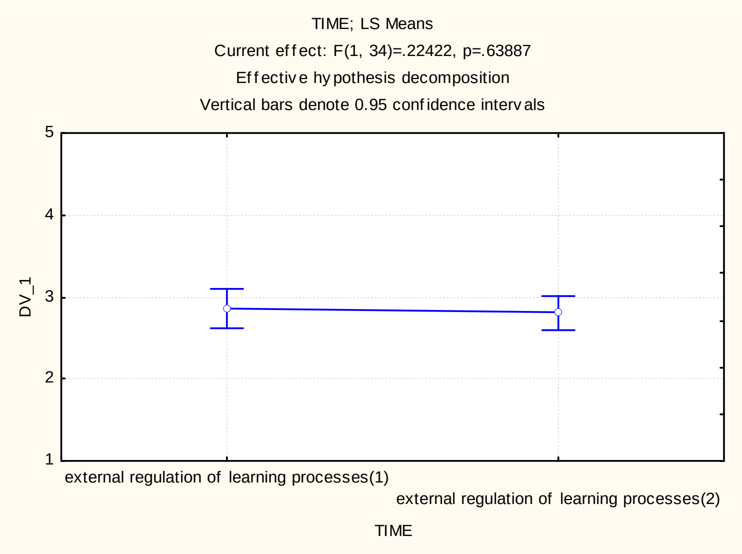


Figure 5.14 Reproduction-directed learning pattern (External regulation of learning processes)

Qualitative results generated from a questionnaire students completed prior to PBL exposure indicated that six students acknowledged applying externally-regulated meta-cognitive strategies: they always approached learning material in the same way; they did just what is expected of them and answered questions from the textbook.

Qualitative results generated from a questionnaire students completed after PBL exposure indicated that four students let their own learning processes be regulated by external sources such as examination questions or questions of teachers or textbook authors:

"The best thing that works for me is to answer last question papers or work questions from the textbook."

"I answer questions based on a chapter."

"I read through my work, do old papers and summarize the work on mind maps."

"I play with the work that I've studied and try and apply it to questions I may get on it."

Three of these students also indicated that it was their tutors' responsibility to provide them with support when needed:

"They have to be passionate about helping me when I encounter difficulty in understanding a certain chapter or work.

"They must make sure that I understand the work thoroughly."

"They must be specific in their explanations. Support you when you experience difficulties with your work and offer their help when they see that their students are struggling."

Regarding pre- and post-PBL evaluation results for **external regulation of learning outcomes (F2)** data analysis indicate the following:

Quantitative results generated from the completion of the ILS Inventory for pre- and post-evaluation purposes indicated no significant change in the external regulation of learning outcomes (p=0.24) (see Figure 5.15).

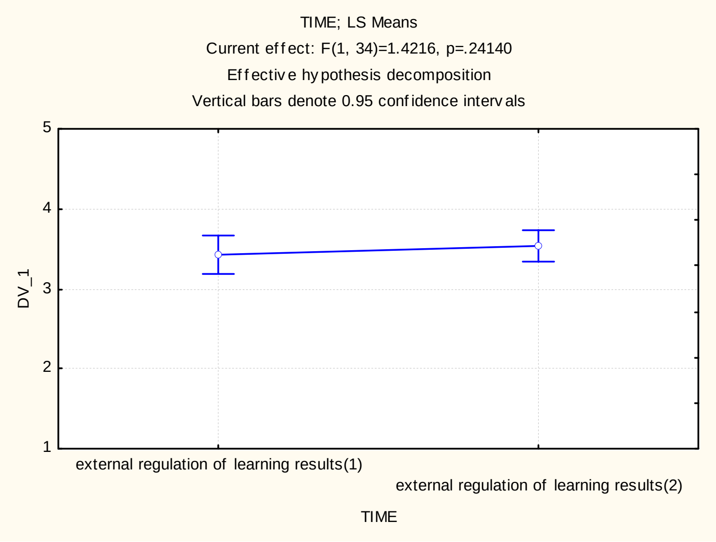


Figure 5.15 Reproduction-directed learning pattern (External regulation of learning outcomes)

The qualitative results generated from the students after completion of a questionnaire prior to PBL exposure did not indicate any external regulation of learning outcomes. Qualitative results generated from a questionnaire students completed after PBL exposure indicated that four students tested their learning outcomes by external means, such as comparing their answers to tests, exercises or notes provided by the lecturer:

"Try to remember what the lecturer mentioned. Check the notes I've made and try to resolve the problem without checking the answer. Remember the basics."

"To facilitate means to give me some courage and tips in studying better as well as exercises to check whether I understood the chapter or not."

"Provide preparation tests before the exams and provide examples on how and when to apply what you have learned."

"I work through at least one examination paper a week."

Conceptions of learning (F2)

The integration and analysis of the qualitative data for the learning conception component (obtained from eight student groups and staff *during* their exposure to the three PBL problems) will now be discussed.

Problem 1

The integration and analysis of qualitative data indicate that two groups confirmed that PBL broadened their knowledge base. One group indicated that they still found the information limited.

Problem 2

According to tutors the students who view learning as the intake of knowledge by reproducing facts experience PBL negative since they feel insecure with the process. *"We did much smaller PBL problem s in the class. Some of the students however did not experience this positively. They feel insecure with the PBL process. They like lectures and facts."*

Problem 3

The integration and analysis of qualitative data indicate four groups expressing a need for more external regulation. They demanded clearer questions and more specific information from the problem statement itself especially at the beginning of the process: *"More information must be provided at the beginning in order to prepare us on what is expected of us."*

"The questions must state clearly what is expected of us."

"The information on the problem can improve. There wasn't enough information provided to determine immediate speed. The problem should consist of more short descriptions."

With regard to pre- and post-evaluation results for **conceptions of learning (Intake of knowledge)** (F2) the data analysis indicates the following:

Quantitative results generated from the completion of the ILS Inventory for pre- and post-evaluation purposes indicated a significant change (decline) in the students beliefs about learning regarding the **intake of knowledge** ($p<0.01$) (see Figure 5.16).

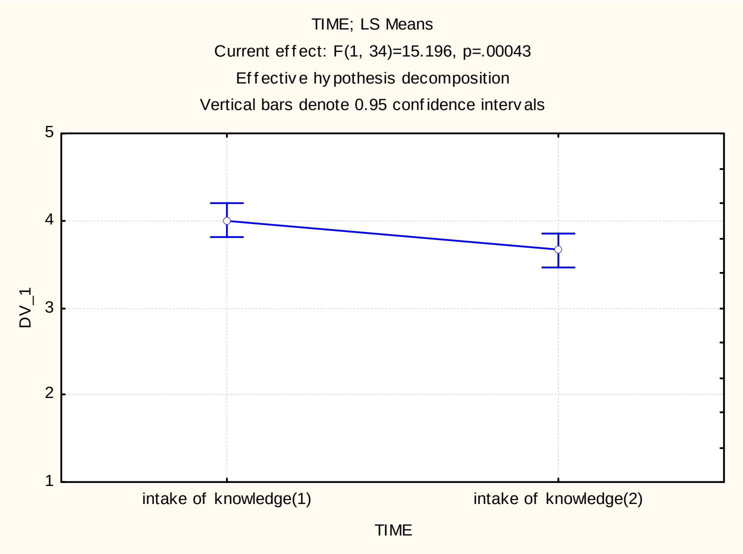


Figure 5.16 Reproduction-directed learning pattern (Intake of knowledge)

Qualitative results generated from a questionnaire students completed prior to PBL exposure indicate that one student viewed learning as the intake of knowledge: *"Learning to me is all about knowing things you didn't know." Another* student viewed learning as the improvement of skill: *"Learning means a notable improvement in skills."*

The following beliefs regarding control of the learning process were expressed by students prior to PBL exposure. All 35 students indicated that the teacher should be in control of the learning process by teaching well, providing a conducive environment (make it fun), encouraging and motivating, inspiring and driving the learning process, providing the learning tasks, challenging students, lecturing in a stepwise fashion, providing clear instructions, answering questions, improving student weaknesses, pressurizing students to perform and monitoring whether they were doing their work.

Although quantitative results do indicate a significant change (decline) in the students' beliefs about learning regarding the intake of knowledge the qualitative data however indicate that after exposure to PBL 23 students still view most learning activities as the task of the teacher: "*The lecturer must support, provide necessary information and motivate."*

"The task of the lecturer is thorough preparation before class, presenting work the easiest way possible, checking progress regularly and thinking about ways to improve it."

"They (the lecturers) must present the work correctly and simply, they must be able to answer all my questions and provide me with a bit of inspiration."

"I must be able to ask then when I don't understand a concept, follow their instructions and listen."

"Helping me out with my difficulties, encourage me and have faith in me."

"To help me understand the work, to help me where I struggle and to push me in the right direction, and give me direction."

"They must tell me where I've made mistakes so that I can try again. They must encourage me sometimes when I get discouraged and negative. They must make sure that the work that I'm doing is correct."

Learning orientation (F2)

No qualitative data for the learning orientation component (F2) (obtained from eight student groups and staff *during* their exposure to the three PBL problems) were noted.

Regarding pre- and post-evaluation results for **learning orientation (Certificate oriented)** (F2) data analysis indicates the following:

Quantitative results generated from the completion of the ILS Inventory for pre- and post-evaluation purposes indicate a significant change (decline) in students' motivation to study for the purpose of mainly obtaining a certificate or a degree (p=0.04) (see Figure 5.17).

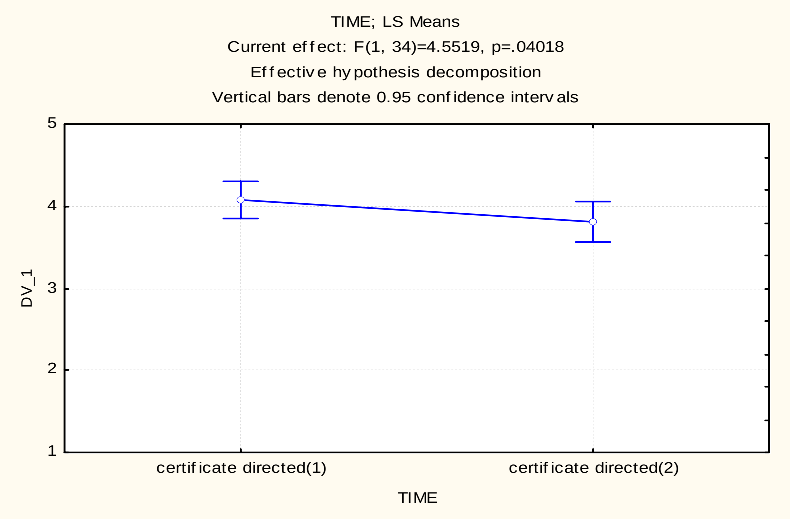


Figure 5.17 Reproduction-directed learning pattern (Certificate-directed)

The qualitative results generated from a questionnaire students completed prior to PBL exposure indicate that fifteen students expressed a certificate-oriented learning orientation in their acknowledgement that they were studying to pass examinations and to obtain a degree.

Although quantitative results do indicate a significant change (decline) in the students' motivation to study for the purpose of mainly obtaining a certificate or a degree the qualitative data after exposure to PBL indicate that some students (11) are still mainly certificate-oriented when conducting their studies by striving for high study achievements and studying to pass examinations and to obtain a degree:

"I want to improve my math marks because I totally struggle with it."

"My greatest desire is to do better in math."

"I want to get better marks."

"That my marks will improve and that I understand the work better." "I want to go to university because I have a dream and in order to obtain that dream I need to go to university to obtain a degree."

"To get a degree and be financially independent."

"I want to achieve my degree. Improve my level of education. I want to have a career."

"Want to complete my degree and have a good career. I want to be able to support myself in the future."

Regarding **learning orientation (Self-test oriented)** (F2) quantitative results obtained from the completion of the ILS Inventory for pre- and post-evaluation purposes indicate a significant change (decline) in students' motivation to study for the purposes to prove themselves ($p<0.01$) (see Figure 5.18).

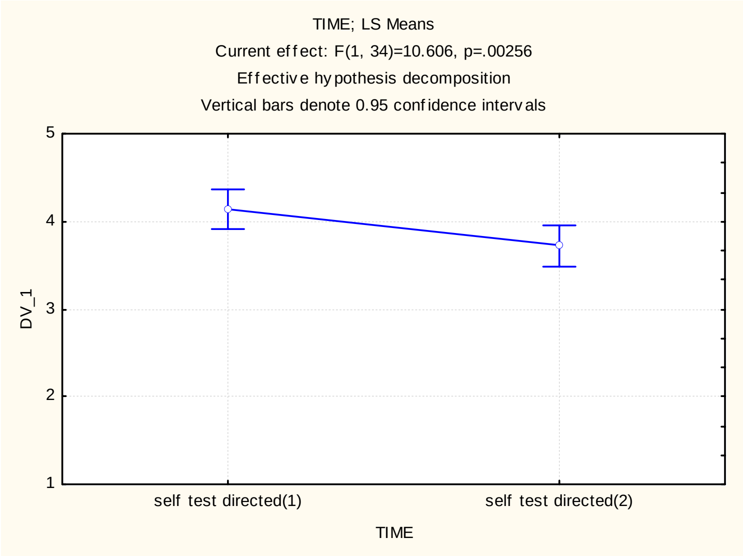


Figure 5.18 Reproduction-directed learning pattern (Self-test oriented)

The qualitative results generated from a questionnaire students completed prior to PBL exposure show that five students expressed a self-test oriented learning pattern. They indicated that they were conducting their studies to prove to themselves and to others that they were able to cope with the demands of higher education and to realize their dreams (in other words becoming role models in their communities). Two students indicated that they were conducting their studies in order to support their families.

The qualitative results generated from a questionnaire students completed after PBL exposure indicated that six students specifically mentioned conducting their studies to prove themselves:

“I want to make my parents, myself and others that have always supported me proud. I will be the first one in my immediate family who has ever been to varsity.

“I want to be successful, become a role model in my community to encourage people to study and give back to my mom who has invested so much into me.”

“I’m going to be the first one in our family and want to be an example for my younger brothers and sister.”

“I want to be a role model for learners in my previous school and others in my community.”

“I want to prove to myself that I have more potential than what I believed.”

See Addendum I for the qualitative display of the learning components of the reproduction-directed learning pattern.

5.2.2.2.3 Conclusion

Considering the different learning components the following was noted regarding changes in the reproduction-directed activities and beliefs of learners after exposure to PBL.

The following changes were noted in the *stepwise processing and external-regulation strategies* of students after PBL exposure. Qualitative data indicated a significant decline in the use of the stepwise learning strategy **memorization** after exposure to PBL (only five students indicated focusing on memorizing) although the quantitative results indicated no significant change **(p=0.69)**.

The qualitative data after exposure to PBL revealed that fewer students were applying the stepwise processing strategy **analyzing.** Prior to PBL exposure twenty students indicated applying the stepwise processing strategy analyzing whereas only eleven students indicated focusing on analyzing after PBL exposure. Quantitative results, however, indicate there was not a significant change **(p=0.24)** in students' regular use of the stepwise cognitive processing learning strategy analyzing.

The fact that students utilized the stepwise processing strategies memorization and analyzing less after PBL exposure as was indicated in the qualitative findings was thus viewed as a positive change towards more meaningful-directed learning patterns.

The quantitative results after PBL exposure show there was no significant difference **(p=0.64)** in the students' occasional application and need for **external regulation of learning processes** or regular **external regulation of learning outcomes (p=0.24)**. This was also reflected in the qualitative findings. Prior to PBL exposure only six students indicated making use of external regulated meta-cognitive strategies. After PBL exposure four students indicated that they let their own learning processes be regulated by external sources when needed. It is also important to note that there was an improvement in the self-regulation activities applied by learners (see meaning-directed patterns). A positive change from external regulation to internal self-regulation was therefore noted. Students however still expressed a need for external regulation of learning content since they needed to be encouraged to make use of resources.

The fact that students utilized the stepwise processing strategies memorization and analyzing less after PBL exposure as well as the fact that improvement was noted in the self-regulation activities applied by learners indicated in the qualitative findings was thus viewed as a positive change towards more meaningful self regulated learning patterns.

The following changes were noted in the *learning beliefs* of learners regarding the intake of knowledge and a certificate and self-test orientation towards learning after PBL exposure. Quantitative results indicated a significant decline in learner views regarding the intake of knowledge **($p<0.01$)** as well as being certificate **($p=0.04$)** and self-test oriented **($p<0.01$).** However, qualitative data indicated that confusion was still apparent in learner conceptions since many students still viewed the intake of knowledge as the task of the teacher.

The fact that qualitative as well as quantitative results indicated a slight decline in students regular use of reproduction-directed learning patterns overall **($p=0.05$)** indicate positive changes regarding the activities and beliefs of students towards more meaning-directed learning patterns. The fact that the decline was not more significant may be attributed to the reality that the students were exposed to traditional education methods for years and that the conventional curriculum is still mainly employed in the programme even though it does provide a few incentives for active participation and self-regulation of learning.

5.2.2.3 Undirected learning pattern (F3)

5.2.2.3.1 Overall results

The undirected learning pattern consisted of the following learning components as illustrated in Figure 5.19.

Learning components
Activities (SRL) Meta-cognitive regulation: Lack of regulation **Beliefs (SDL)** Learning conceptions: Co-operative learning & stimulating education Learning orientations: Ambivalent

Figure 5.19 Learning components of the undirected learning pattern

Quantitative results generated from the completion of the ILS Inventory for pre- and post-evaluation purposes indicate that there is no significant change in undirected learning patterns overall (p=0.41) (see Figure 5.20).

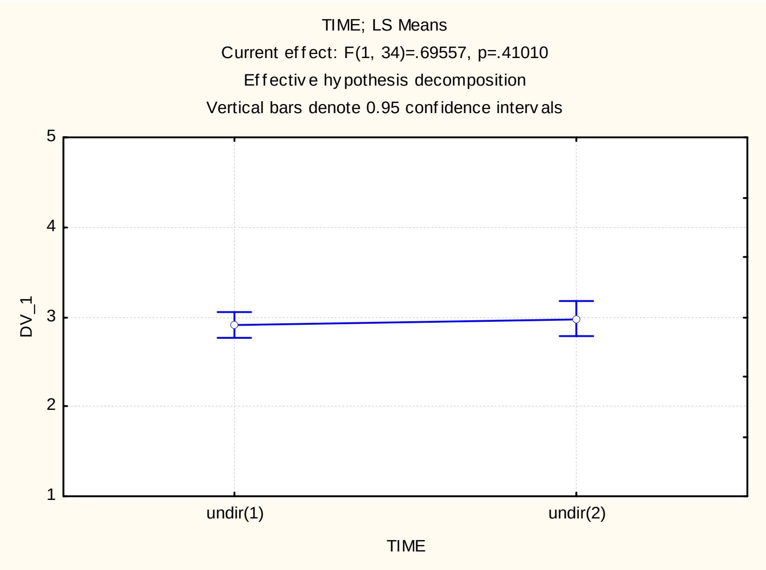


Figure 5.20 Undirected learning pattern

5.2.2.3.2 Learning component results

Meta-cognitive regulation strategy (F3)

The integration and analysis of the qualitative data for the meta-cognitive regulation learning component (obtained from eight student groups and staff *during* their exposure to the three PBL problems) will now be discussed.

Problem 1

The integration and analysis of qualitative data indicate a lack of regulation within four groups. These groups underestimated the problem statement, showed lack of group role performance, expressed bad time management and struggled to process large amounts of information:

"We need to structure our working in our group better."

"We did not use our time effectively."

"We finished too early."

"It is tough to prioritize all the information."

"We underestimated problem 2."

Students indicated a lack of regulation when they indicated unawareness of the credibility of different types of resources. Tutors confirmed this lack of regulation by indicating that students were not using resources unless encouraged to do so, did not do in-depth research, did not read articles with questions in mind and were going off on tangents before thinking problems through:

"*It was clear that the students were not aware of the credibility of the different types of resources."*

"I noticed groups going off on tangents i.e. not focusing on what the crux of the matter was – what was actually being asked and how can this question be answered and the answers justified."

This was a clear indication that more guidance during the facilitation process was needed. According to the tutors *"… this was a natural occurrence since the PBL process and even group work was very unfamiliar to students. Students also did not know each other or the lecturers."*

This, however, did not stop students to work diligently and make plans to improve on their performances.

One group indicated a lack of self-regulating skills when they acknowledged basing their decisions on gut instead of fact: "*"We are basing our decisions on gut instead of facts. We must think this through first."* One group however acknowledged that PBL helped them guard against impulsive thinking: *"We delayed our answers."*

During the facilitation process tutors gave up control of the learning process during problem 1 as follow: lecturers provided guidance and support during the first session (external regulation) and then left students in the second session to work on their own (self-regulation). Lecturers returned in the last session if the students had questions for them as resource people and in order to assist the groups to monitor their progress (external regulation).

Problem 2

The integration and analysis of qualitative data indicate that one group experienced a lack of regulation and since they were externally regulated found the floating facilitator model to be confusing: *"The facilitators all talk differently. The math people made a mistake in their explanations. Now all our calculations are wrong."*

During the facilitation process tutors gave up control of the learning process with regard to problem 2 as follows: The tutors used teaching strategies that would facilitate self regulation. Lecturers left the students to work on their own during the first session (self-regulation) and then provided guidance and support when needed during the second and last session (external regulation): *"We also facilitated stronger in the second session so that the students could first struggle and figure things out for themselves during the first session. They also had an hour before the race to work out a strategy plan for group work and their approach to the race."*

Problem 3

The integration and analysis of qualitative data indicate that three groups expressed a lack of regulation within their groups for underestimating the problem statement, especially when they felt the problem statement was unstructured or the objectives were not spelled out. This was usually experienced by the accounting students in a group or by the students at the beginning of the process:

"It was at times frustrating not to know what you were supposed to do."

"We found it hard and confusing at the beginning, because we struggled to implement the math and science principles in the problem."

"The past problems were fun and I learnt from them but this one left me with a lot of unanswered questions. For example what was the point of it all? I'm not sure what we were supposed to learn from it."

Due to the vague nature of the problem statement one group resorted to guesswork: *"We took a guess because we weren't sure about our conclusions."*

Two accounting students indicated that they felt overwhelmed and struggled to process the large amounts of information:

"We were bombarded with confusing scientific formulas and terms which we were unfamiliar with. There were a lot of papers which made it a little bit confusing.

"There was too much information."

All eight groups indicated that they were confused with the problem in the beginning. The confusion either led to a positive outcome such as implementing a planning strategy:
"First we were confused because we didn't precisely understand the problem. Then we used each other's knowledge to break down the problem."
"We had no idea how to start. Our energy came back over a long time and we started planning, gave each other a topic and worked together."

Or the confusion led to negative outcomes, expressed by three groups such as anger, quarrels and boredom:
"At a certain point each of us was clueless on how to put the words on the page so we quarreled a lot."
"I got angry if I didn't know what to do."
"It was very confusing and boring in the beginning." Tutors confirmed this lack of regulation by indicating that students were going off on tangents before thinking problems through.

One group indicated a lack of group role performance and a need for external regulation: *"Our group wasn't very 'let's get this done.' They waited for others and didn't contribute out of their own in the beginning. Our group did nothing for the first hour."*

Tutors gave up control of the learning process during problem 3, very similar to their approach during problem 2. With problem 3 the tutors used teaching strategies that would facilitate self regulation. The tutors left the students to work on their own during the first session (self-regulation) and then provided guidance and support when needed during the second session (external regulation).

Regarding pre- and post-evaluation results for **lack of regulation** (F3) data analysis indicate the following:

Quantitative results generated from the completion of the ILS Inventory for pre- and post-evaluation purposes indicate a slight increase in lack of regulation although the increase is not significant (p=0.15) (see Figure 5.21).

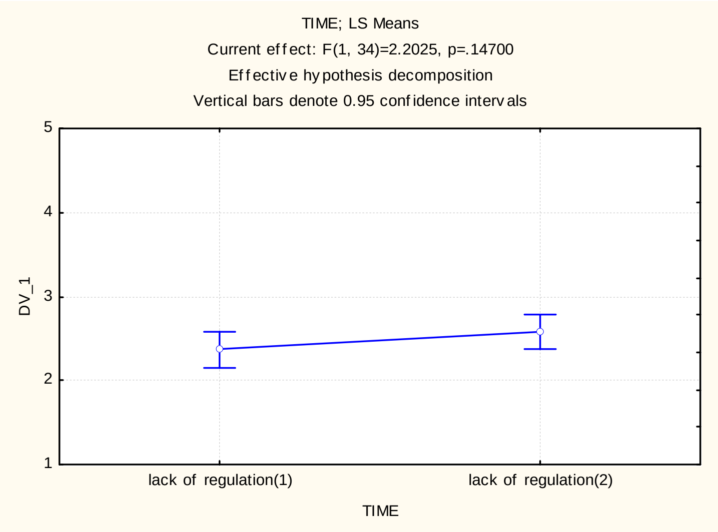


Figure 5.21 Undirected learning pattern (Lack of regulation)

From the qualitative results generated from a questionnaire students completed prior to PBL exposure one student indicated monitoring difficulties with the regulation of their own learning process by experiencing uncertainty when writing: *"I always feel uncertain when I have to write."*

From the qualitative results generated from a questionnaire students completed after PBL exposure one student indicated difficulties with the workload: *"The workload was heavy and exhausting."*

Learning conceptions (F3)

The integration and analysis of the qualitative data for the learning conceptions component (F3) (generated from eight student groups and staff *during* their exposure to the three PBL problems) will now be discussed.

Problem 1

The integration and analysis of qualitative data indicate that all eight groups acknowledged that the following process skills were experienced as positive or leading to improvement via PBL: improved team work, active participation by group members, clear allocation of tasks (roles) which lead to positive group dynamics, the development of interpersonal skills such as respect and tolerance, motivation through encouragement, enhanced communication, improved self-confidence, and the experience of togetherness and leadership:

"We used our abilities more efficiently in solving real world problem s as a unit."

"We all did our research and summarized it."
"Everyone contributed and listened to each other's views."
"Our dynamics improved since Friday. We have formed better relationships."
"We also learned to speak out and be heard."
"Everyone was positive an encouraging. This gave us the will to do more and not to give up."
"We had a good leader."

Three groups acknowledged process skills that were experienced as negative or leading to decline via PBL such as conflict, the uneven distribution of tasks leading to negative group dynamics, bad role performances by the scribe leading to inability to monitor progress towards objectives and a lack of group rules leading to negative group dynamics:
"We argued a lot but that's not necessarily wrong."
"We had jokers."
"We had people that were too serious and we had people that were very lazy."
"Work was not shared equally."
"Some were not punctual."
"Many scribes did not make use of white board paper."

Problem 2

The integration of qualitative data analysis indicate that six groups acknowledged the following process skills as being positive or leading to improvement via PBL: increase in confidence, better teamwork and team spirit leading to positive group dynamics and cooperation, the development of interpersonal skills such as communication, respect, tolerance, and conflict management and an improvement in role performances of group leaders (the chairs). Reasons provided for this occurrence was that students had learnt to know and understand each other better and that they were more familiar with the PBL process. Tutors acknowledged this and added that groups immediately started to focus, listened better and worked better together.

Two groups acknowledged process skills that were experienced as negative or leading to decline via PBL such as a lack of leadership, unequal delegation of duties and increased conflict due to lack of patience in some groups: *"We just have to learn more patience and tolerance."* One group specifically mentioned that their examination results contributed towards their lack of motivation: *"Our working energy as a group was low due to the fact* *that our goals on our performances during the exams were not fully met. Thus we saw no need to put all our efforts during the two days left before closer into the problem."*

Decline in one group's performance was attributed to the fact that the same group formations were used for problem 2 as for problem 1 when the lecturers still did not know the strengths and weaknesses of the students. It was thus decided that each group should have a strong leader.

Problem 3

The integration of qualitative data analysis indicate that all eight groups acknowledged the following process skills as being positive or leading to improvement via PBL: improved team work, active participation by all group members, clear allocation of roles and tasks which lead to positive group dynamics, the development of interpersonal skills such as listening skills, respect for diverse views, tolerance, trust and patience, support and encouragement of each other whilst working under pressure:

"Working together was better than working alone."

"Everyone contributed and struggled together to solve the problem.

Many other benefits were equated with cooperative learning such as attaching a lot of value to learning in cooperation with fellow students and sharing the tasks of learning with them. Other benefits noted were:

"PBL leads to a variety of interpretations and perspectives".

"Groups came up with new problem solving techniques."

"Group members provided assistance and shared their knowledge which enhanced understanding."

"They developed skills such as team work and communication which is important for the real world."

Reasons provided for this positive occurrence was:

- Students know, trust and support each other more: *"When I didn't know something, that does not mean everyone else does not but I can get help from other students. We learnt to work with different people while helping each other." "One doesn't always trust others but I learnt that one can start trusting others and the results was not so bad at all."*

- Students are more familiar with the PBL process and can combine their skills more effectively: *"There were many advantages of working as a group, combining our skills and struggling together."*
- Students respect diversity: *"We learnt to work with people who speak different languages." "Sometimes we didn't agree but worked out our differences."*

No process skills were experienced as negative in the qualitative data. From these results a general improvement in group work since 2005 could be noted when one considers the following comment made by one of the lecturers during 2005: *"We notice that there are students that are working and others that are just coming along for the ride. Group work has not taken place in many of the students yet. In 2006 we will have to plan more thoroughly."*

Regarding pre- and post-evaluation results for **learning conceptions (Cooperative learning)** (F3) data analysis indicates the following:
Quantitative results generated from the completion of the ILS Inventory for pre- and post-evaluation purposes indicate that there was no significant change in students' beliefs regarding cooperative learning (p=0.70) (see Figure 5.22).

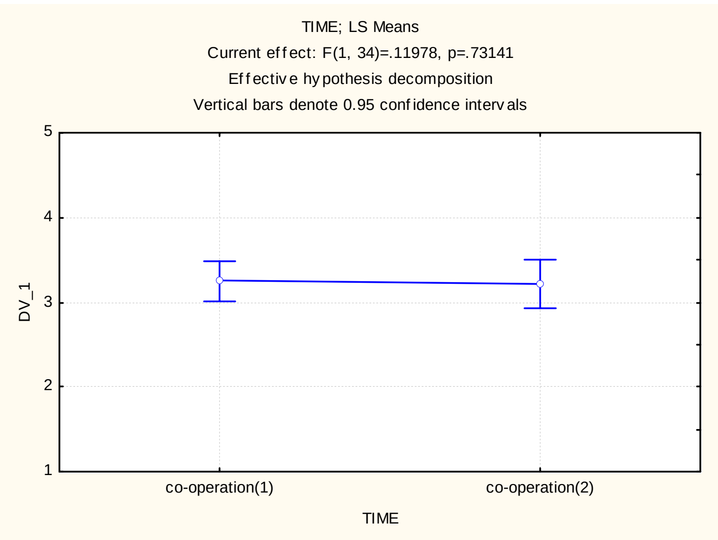


Figure 5.22 Undirected learning pattern (Cooperative learning)

From the qualitative results generated from a questionnaire students completed prior to PBL exposure no data regarding the benefits of co-operative learning were noted.

From the qualitative results generated from a questionnaire students completed after PBL exposure only one student referred to co-operative learning: *"I like to work as a team, but there are certain things that I like to discover for myself."*

Regarding pre- and post-evaluation results for **learning conception (Stimulating education)** (F3) data analysis indicates the following:

Quantitative results generated from the completion of the ILS Inventory for pre- and post-evaluation purposes indicate a significant change (decline) in students' beliefs about the importance of stimulating education (p=0.04) (see Figure 5.23).

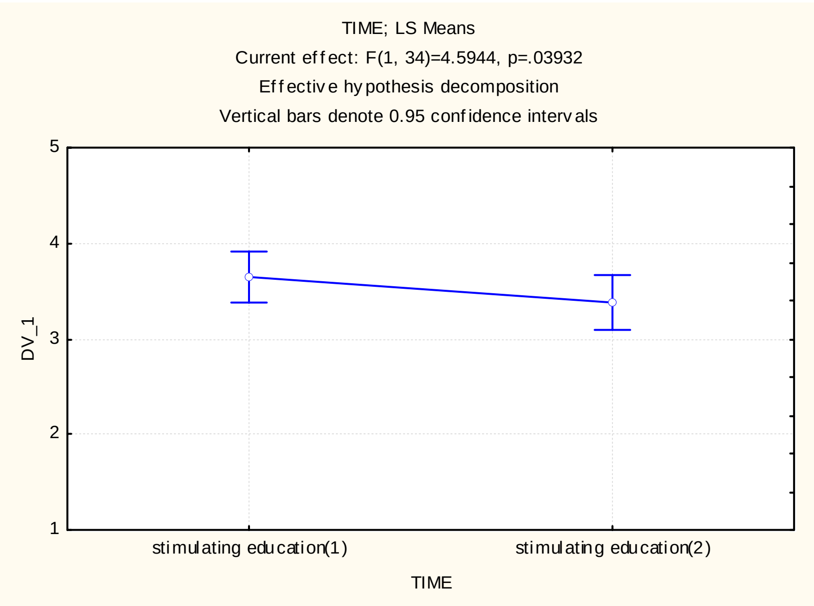


Figure 5.23 Undirected learning pattern (Stimulating education)

The qualitative results generated from a questionnaire completed by the students prior to PBL exposure indicated fifteen responses noting that the lecturer should make learning fun, encourage and motivate, inspire and drive the learning process.

After PBL exposure no qualitative data concerning the importance of stimulating education were noted. That is where learning activities are viewed as tasks of students, but teachers and textbook authors should continuously stimulate students to use these activities.

Learning orientation (Ambivalence) (F3)

The integration and analysis of the qualitative data for the learning orientation component (F3) (obtained from eight student groups and staff *during* their exposure to the three PBL problems) will now be discussed.

Problem 1

No learning orientation data was noted.

Problem 2

The integration of qualitative data analysis indicates that one group disliked the running. Two groups suggested building in more fun clues like dancing and singing: *"Build in more fun clues and exciting activities."*

Three groups disliked the questions after the fun activity:
"We disliked solving the 'hard' questions after completing the task."
"Change the questions… the phrasing of questions."

Peter Bouhuijs confirmed this observation: *"My hesitation is with the two day report writing after the exciting part. I hope with you that the experience sticks, but maybe you could build some excitement in some of your questions at the end."* The staff however disagreed: *"Our learners did not experience the report like that. They were enthusiastic and enjoyed the process.* However, the students' comments did confirm Bouhuijs' concern.

Problem 3

The integration of qualitative data analysis indicate that although four groups experienced the problem as too demanding and tiring in the beginning which led to feelings of stress, panic and discouragement they all agreed that they enjoyed the experience:
"Was very stressful, I struggled a lot but I enjoyed working on the problem."
"It was tiring but still a great experience."
"It was challenging but I learnt more than I could ever have imagined."
"I felt discouraged at first when I couldn't bring the theory to the problem but it got better. I felt small if I couldn't understand parts of the problem."

This experience encouraged some group members to rely on each other for support: *"I panicked at first but my group assured me that it was a group effort."* One group however did not enjoy the experience closer to the end: *"At first we were excited, enthusiastic and felt up to the challenge. Later we became lethargic, overwhelmed, irritable, uncooperative and anxious to finish."* The reason posed by the group was that the problem was too tricky and demanding.

The accounting students especially did not enjoy the experience and felt excluded, isolated, and sidelined. They experienced the problem as extremely challenging:
"I found it extremely challenging as I felt it required the knowledge which I didn't possess as I've never done science before. I learnt some science though."
"The accounting people felt excluded and a bit useless."
"I really did not like being sidelined or not being able to make a contribution to a group task."
"I didn't like the one fact that the problem was too scientific. It made me feel isolated." One member recommended including all subjects in the problem: *"It would be more challenging if all the subjects were included."*

Regarding pre-and post evaluation results for **learning orientation (Ambivalence)** (F3) data analysis indicate the following:

Quantitative results generated from the completion of the ILS Inventory for pre- and post-evaluation purposes indicate a significant change (increase) in students' feelings of ambivalence/doubts towards their studies ($p<0.01$) (see Figure 5.24).

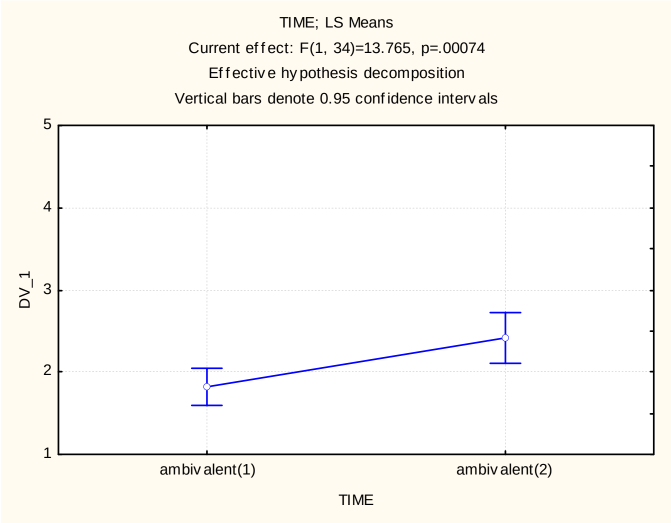


Figure 5.24 Undirected learning pattern (Ambivalence)

Prior to and after PBL exposure no ambivalent responses were noted in the qualitative data obtained from a questionnaire completed by the students. Many reasons can, however, be offered for the increase in students ambivalent responses reflected in the quantitative data. The increase in students' doubtful, uncertain attitude toward their studies, their own capabilities, the chosen subject area, or the type of education they are exposed to may be due to the fact that the students had to adapt to many changes in their environments. Some did not experience much emotional support from family members since many lived far from home. In addition, the students had gone through personality and aptitude tests and career counseling which many expressed as contributing to their confusion regarding their chosen subject area and abilities.

See Addendum J for the qualitative display of the learning components of the undirected learning pattern.

5.2.2.3.3 Conclusion

Considering the different learning components the following was noted regarding changes in the undirected learning activities and beliefs of learners after exposure to PBL.

The following changes were noted in the undirected learning *strategies* (lack of regulation) employed by students after PBL exposure. Quantitative results after PBL exposure indicated a slight, yet not significant increase **(p=0.15)** in students' experiences of lack of regulation. The slight increase in lack of regulation was not noted in the qualitative data after PBL exposure since only one student indicated awareness of any lack of regulation activities prior to and after PBL exposure.

The lack of awareness of any undirected regulation activities in the qualitative data after PBL exposure was viewed as a negative change away from more meaningful-directed learning patterns.

The following changes in the learning *beliefs* of learners regarding cooperative learning, stimulating education and ambivalent feelings towards their studies were noted. Quantitative results indicate a significant change (decline) **(p=0.04)** in students' beliefs about the importance of **stimulating education**. This was also reflected in the qualitative data which could reflect a decline in external regulation processes and a move towards more self-regulated learning.

Quantitative results indicated a significant increase **(p<0.01)** in students' feelings of **ambivalence** and doubts towards their studies. Where students never or only seldom experienced feelings of ambivalence towards their studies they now experienced it more occasionally. The increase in feelings of ambivalence may correlate with the slight increase in lack of regulation. However, prior to and after PBL exposure no ambivalent responses were noted in the qualitative data.

The significant decline in students' beliefs about the importance of stimulating education reflected in the quantitative and qualitative data is viewed as a slight but positive change towards more meaningful self-regulated learning patterns.

5.2.2.4 Application-directed learning pattern (F4)

5.2.2.4.1 Overall results

The application-directed learning pattern consisted of the following learning components as illustrated in Figure 5.25.

Learning components
Activities (SRL) Cognitive processing: Concrete processing **Beliefs (SDL)** Learning conceptions: Use of knowledge Learning orientations: Vocation-directed

Figure 5.25 Learning components of the application-directed learning pattern

Quantitative results generated from the completion of the ILS Inventory for pre- and post-evaluation purposes indicate no significant change (decline) in students' application-directed learning patterns (p=0.01) (see Figure 5.26).

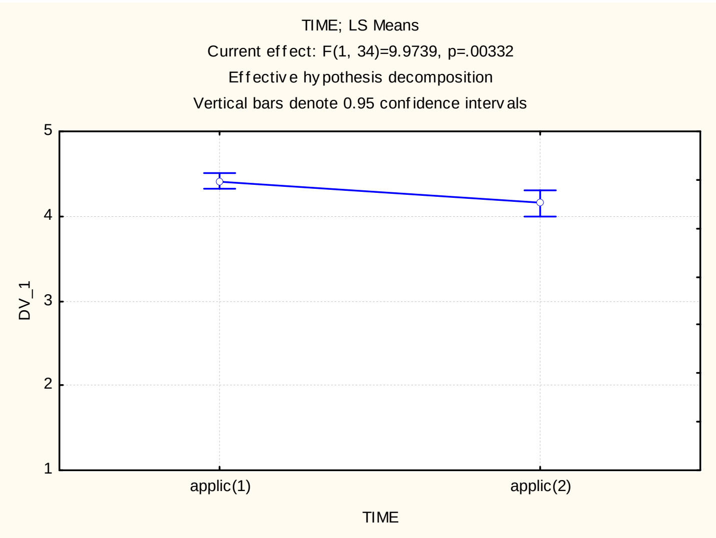


Figure 5.26 Application-directed learning pattern

5.2.2.4.2 Learning component results

Concrete processing (F4)

The integration and analysis of the qualitative data for the cognitive processing learning component (F4) (obtained from eight student groups and staff *during* their exposure to the three PBL problems) will now be discussed.

Problem 1

The integration of qualitative data analysis indicate the following concrete processing strategies noted by students: seven groups found it useful to apply, practice and use the subject matter in real life:

"We realize that math and science can be applied in the real world."

"We loved it. It took us beyond the text book and we find it prepares us for the outside world."

Problem 2

The integration of qualitative data analysis indicates the following concrete processing strategies

noted by the students: five groups experienced PBL as a way of learning how to practice and apply mathematics and science in real life which according to the tutors enhanced their deep processing strategies:

"*It familiarized us with problems that we actually do face and makes us apply our knowledge in everyday life."*

"*As a lecturer I have never done 'displacement' on a map. Now these students can do it physically on a map. When the students were busy with approximations they were busy with a mathematics model while working on PBL."*

Problem 3

The integration of qualitative data analysis indicates the following concrete processing strategy noted by students: eight groups found it useful to apply, practice and use the subject matter in real life which they experienced as fun.

"I have experienced that my studies are real. It helps us to grasp the relevance of math and how science occurs in our daily lives."

"PBL encouraged us to apply our knowledge instead of working out of a text book. It creates a clear picture about textbook theory and real life problems. Math and science happens in everyday life."

"We enjoyed the part where we had to apply calculus to help us find the instantaneous velocity." This assisted in the interpretation of that knowledge. *"It helped us look logically at math when we realized it's applicable in the real world."*

Regarding pre- and post-evaluation results for **concrete processing** (F4) data analysis indicate the following:

Quantitative results generated from the completion of the ILS Inventory for pre- and post-evaluation purposes indicate no significant change in the use of concrete processing learning strategies (p=0.23) (see Figure 5.27).

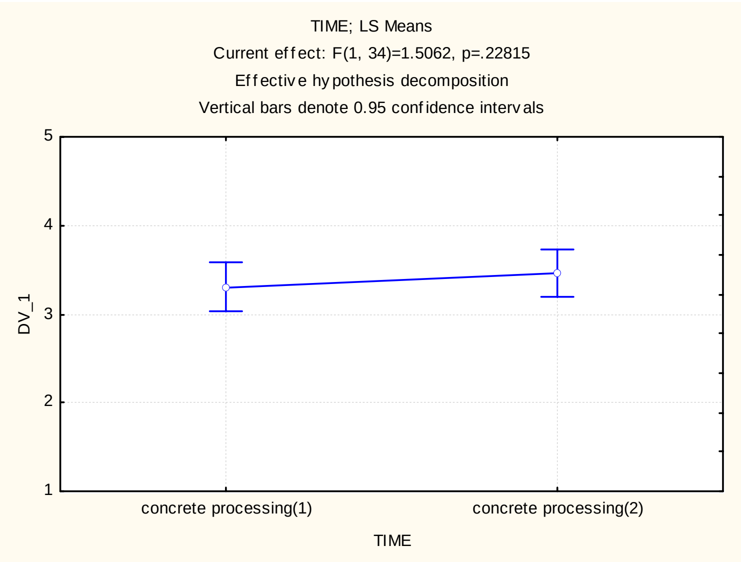


Figure 5.27 Application-directed learning pattern (Concrete processing)

No concrete processing strategies were noted in the qualitative data obtained from the students after completion of a questionnaire prior to PBL exposure.

The qualitative results generated from a questionnaire students completed after PBL exposure indicated that three students acknowledged finding it useful to apply, practice and use the subject matter in real life when they were studying:

"My thinking has drastically improved and I can apply what I've learned."

"It helps understanding and how to apply whenever the knowledge is gained."

"Effective learning to me means now to understand the work and knowing how to apply it."

Although quantitative results do not indicate any significant change in the use of concrete processing learning strategies, qualitative data do, however, indicate that a few students are concretizing and applying the subject matter by connecting it to their own experiences and by using in practice what they're learning in the course.

Learning conceptions (Use of knowledge) (F4)

The integration and analysis of the qualitative data for the learning conception component (F4) (obtained from eight student groups and staff *during* their exposure to the three PBL problems) will now be discussed.

Problem 1

The integration of qualitative data analysis indicates that all eight groups believed that learning through PBL enhanced their application or use of knowledge. That is viewing learning as acquiring knowledge that can be used by means of concretizing and applying. These activities are usually seen as the tasks of both students and teachers.

The following benefit was equated with PBL by staff: PBL leads to increased understanding due to the application in real life: *"This was a very difficult part of math and since their introduction was practical they found it easier to apply."*

Problem 2

No application learning patterns (use of knowledge) were noted in the qualitative data.

Problem 3

The integration of qualitative data analysis indicates that all eight groups believed that PBL enhanced their application and use of acquired knowledge:

"*I know how to apply what I learn in everyday life."*

"PBL helps me to use the mathematics concepts in solving real world problems."

"The lecturers wanted us to see that real life problems have a strong correlation with the math and science we do here in SciMathUS."

"Now I can be able to apply math not only in class, but in everyday life."

"In order to show us that the work we do inside the classroom doesn't end in the class but we can implement the same skills in the outside world."

Regarding pre- and post-evaluation results for **learning conception (Use of knowledge)** (F4) data analysis indicates the following:

Quantitative results generated from the completion of the ILS Inventory for pre- and post-evaluation purposes indicated a slight change (decline) in the students beliefs and views about the use of knowledge, although the change in beliefs is not significant (p=0.15) (see Figure 5.28).

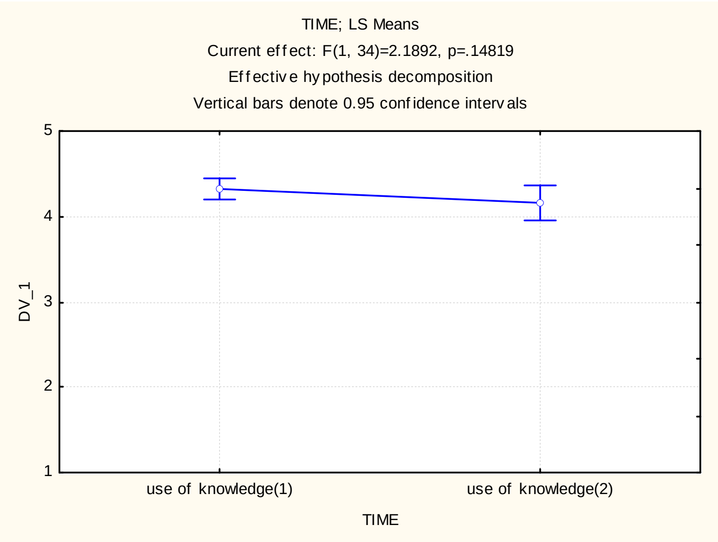


Figure 5.28 Application-directed learning pattern (Use of knowledge)

The qualitative results generated from a questionnaire completed by students prior to PBL exposure indicated that nine students acknowledged the importance of acquiring knowledge that can be used by means of concretizing and applying:

"We have acquired information with the purpose of using it in our future and to implement it in practical situations."

"To use and apply this in our everyday lives."

The qualitative results generated from a questionnaire completed by students after PBL exposure indicated that six students acknowledged the importance of acquiring knowledge that can be used by means of concretizing and applying it whilst one student allocated this responsibility to the teacher:

"Understanding, comprehension and the successful usage of that which I've learnt in my everyday life."

"To help me apply the theory of the subject to practical situations."

"Lecturers should make examples of real life situations and how it links to life."

"To learn something not only to pass but so that I can be able to apply it in real life situation."
"Understanding, comprehension and the successful usage of that which I've learnt in my everyday life."

Learning orientation (F4)

The integration and analysis of the qualitative data for the learning orientation component (F4) (obtained from eight student groups and staff *during* their exposure to the three PBL problems) will now be discussed.

No qualitative learning orientation data (vocation oriented) was noted for **Problem 1 or 2.**

Problem 3

The integration of qualitative data analysis indicate that three groups acknowledged that PBL prepares them for their future careers:
"PBL is helping me in my studies and prepares me for the future."
"PBL helps me feel like a professional."
"The kind of questions you get at varsity gives you an understanding of what is expected in your future career."

Regarding pre- and post-evaluation results for **learning orientation (Vocation-oriented)** (F4) data analysis indicates the following:

Quantitative results generated from the completion of the ILS Inventory for pre- and post-evaluation purposes indicated a significant change (decline) in students' motivation to study for the purposes of finding a job or embarking upon a career ($p<0.01$) (see Figure 5.29).

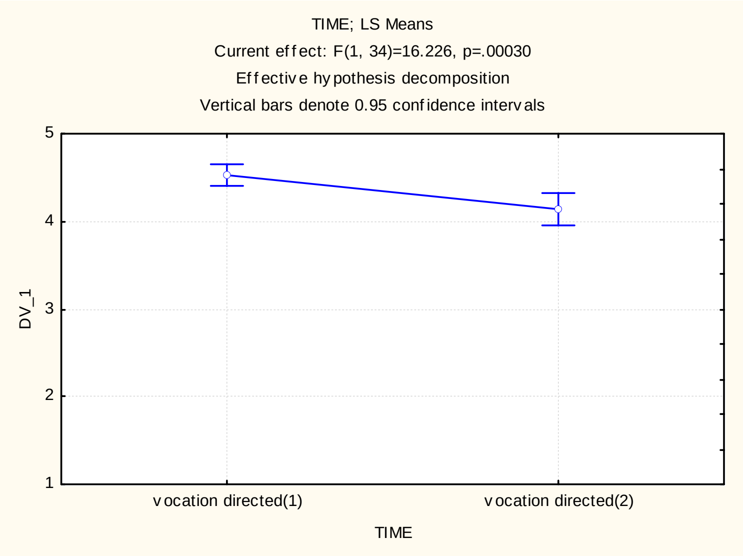


Figure 5.29 Application-directed learning pattern (Vocation-oriented)

The qualitative results generated from a questionnaire completed by the students prior to PBL exposure indicate that 25 students believed that they were conducting their studies for career purposes such as engineering, medicine, and zoology.

The qualitative results generated from a questionnaire completed by the students after PBL exposure indicated that eight students believed there studies were for career preparation:

"To get the best possible education and to get a good job after university."

"For a better life, more opportunities and to be a qualified economist."

"I need the degree to become an engineer."

"To obtain a degree in investment management so as to fulfill my dream of becoming a chartered financial analyst."

"The work that I am interested in doing requires high qualifications of study."

"I want a good career in the future."

"I want to become a chartered accountant."

See Addendum K for the qualitative display of the learning components of the application-directed learning pattern.

5.2.2.4.3 Conclusion

The following changes in the application-directed learning activities and beliefs of learners after exposure to PBL were noted:

No change regarding the application-directed learning *strategy* (concrete processing) was noted in quantitative **(p=0.23)** or qualitative data employed by students after PBL exposure.

A slight decline in students' *beliefs* regarding the **use of knowledge** was noted in the quantitative **(p=0.15)** as well as qualitative data. Positive changes in the learning beliefs of learners were also noted regarding their motives for studying. Fewer students were motivated to study for the purposes of finding a job or embarking upon a career as opposed to pursuing their studies for self-development purposes (see meaning-directed learning patterns).

Although students' views regarding the use of knowledge has declined slightly the fact that no change was noted regarding the regular use of the application-directed learning *strategy* (concrete processing) as well as the positive changes in the learning beliefs of learners regarding their motives for studying was viewed as a slight positive change towards more meaning-directed learning patterns.

5.2.3 Interpretation of the learning patterns

The four learning components generated from all the quantitative and qualitative data from students and staff prior to, during and after PBL exposure was interpreted by referring to the four learning patterns posed by Vermunt (20041; 2004b), namely meaning-directed, reproduction-directed, undirected and application-directed learning patterns from which conclusions were drawn. From the coded data presented in the data displays (see Addendum H, I, J and K) conclusions of a descriptive nature were drawn about possible changes that may have occurred in student learning patterns. The main focus of the interpretation was to assess whether the learning patterns of learners had changed in a more favourable direction after PBL exposure. Within this study favourable learning pattern implies a change in direction mainly toward meaning-directed learning patterns, discouraging reproduction-directed learning patterns with an emphasis on the gradual transfer of control over student learning processes from external regulation to self-regulation of learning (as was discussed in Chapter 2).

Basic tactics for drawing conclusions from the displays were noting differences in pre- and post-evaluation learning patterns and making contrasts and comparisons. The conclusions for each learning pattern were checked against the quantitative and qualitative data whilst additionally clarifying how they tied into the theoretical framework derived from the literature survey (discussed in Chapter 2). Data for the four learning components were divided between *learning activities* referred to as self-regulated learning or (SRL) and *learning beliefs* referred to as self-directed learning or (SDL) for each of the four learning patterns. Whereas SDL refers to the internal change in beliefs and consciousness entailing the movement towards autonomous lifelong learning, these activities (SRL) emphasize what the learner needs to do to move towards the goal of self-directed learning and ultimately lifelong learning. In order to assess the changes in students' learning patterns, it was important to consider both the changes in beliefs and the changes in learning behaviours. According to the literature review, the most complete form of SDL occurs only when the external technical dimension or activities (SRL) is fused with the internal, reflective dimension or beliefs (SDL). This was important to consider when reflecting on the learning patterns of students since all the techniques of SDL may still not lead the learner to exhibit autonomous behaviour (SDL) leading to lifelong learning (see Chapter 2 for a theoretical discussion on SDL and SRL).

The final display (see Addendum L) illustrates the overall change in learning patterns and dissonance or fusion encountered where the researcher illustrated and integrated these multivariate and interrelated dimensions (patterns) generated from the qualitative and quantitative data to prevent jumping to hasty, partial or unfounded conclusions.

It must, however, be noted that the interpretation of the quantitative and qualitative results must be viewed with caution since the researcher is working with probabilities here. Similar to Finucane *et al*. (1998:445-448) the researcher believes that the efficacy of PBL to change learning patterns is difficult to evaluate, as it is generally introduced together with other changes in the curriculum and along with changes in student development, student selection, staff development, and assessment procedures. With so many compounding variables, it is hard to determine the extent to which PBL has contributed to any detectable changes in learning patterns. Many other factors may have contributed to these findings. Furthermore, claims for the effectiveness of the Hybrid PBL approach were based on a small and highly specific case study from a single foundational year programme. It is not possible to generalize from such findings. Conclusions about the effectiveness of the Hybrid PBL approach are thus tentative and case specific.

In order to assess whether the learning patterns of learners have changed in a favourable direction after PBL exposure and whether such changes are sustainable the following questions regarding the four learning patterns were considered: Are there any dissonances/discrepancies between the activities and beliefs of the learners for each of the learning components prior to and after PBL exposure? What could be possible reasons behind these discrepancies? What does this dissonance or lack thereof imply for self-directed learning? And is this learning pattern sustainable?

5.2.3.1 Meaning-directed learning pattern (F1)

The following *discrepancies* between the meaning-directed activities and beliefs of the learners were noted. Although there has been a decline in students' *beliefs* regarding their responsibility in the learning process this was not reflected in the learning *activities* that many students employed. Qualitative data after PBL exposure indicated that more students were employing regulation activities in their individual studies by being more active and taking on more responsibility for their own learning. Although the activities employed by individual learners indicate making use of deep-processing learning strategies such as relating and structuring, they still experience conflicting feelings and beliefs regarding self-regulated learning and specifically their responsibility to construct knowledge in the learning process.

The students' views and beliefs regarding self-regulated learning and specifically their responsibility to construct knowledge (SDL) are not fused with the meaning-directed activities they employ in the learning process (SRL). This means that more needs to be done to change their learning conceptions and orientations toward more meaning-directed learning.
Many possible reasons may be behind these discrepancies between beliefs and activities. When students enter a new type of education such as being introduced to a PBL approach, there may be a temporary misfit, or friction between the students learning strategies and the demands of the new learning environment. This could be an indication of a period of change and acclimatization, comparable to a period of friction, a period in which students find that their ideas of knowledge and how to go about learning are no longer adequate. Other possible interpretations for the discrepancy between students' beliefs concerning taking on more

responsibility in the learning process and the self-regulated activities employed in the learning process may be as follow:

- Many of the students who came from educational backgrounds where teachers directed their learning may still experience PBL as too stressful and demanding. They may not yet be familiar with the process and thus prefer more teacher-directed approaches. Since PBL does not limit what these students may choose to learn, and the process may provide little guidance on the best ways of achieving learning goals, the students may thus be concerned that their learning strategies are misdirected or inefficient and therefore fall back on familiar territory such as becoming externally dependent.
- Since the students are still mainly exposed to a conventional curriculum, the Hybrid PBL approach may not occur with enough regularity for students to change their learning patterns or paradigms regarding their responsibilities in the learning process.
- The conventional curriculum at SciMathUS, which is still very content based, textbook bound and examination oriented (for which students are still coached), can impede more favourable learning pattern changes or paradigm shifts from occurring.
- It also takes time to get used to PBL which may be overwhelming to the student in the face of so much other changes.
- Although learning patterns are susceptible to educational influences especially in a context in which traditional teaching methods are changed into innovative ones some studies show that the stability of learning patterns is rather high (see Chapter 2).

Although quantitative results indicated no change **($p=0.71$)** in the meaning-directed learning patterns of students overall changes were noted towards the application of more meaning-directed learning activities by learners. The sustainability of the meaning-directed learning activities employed by students is, however, questionable. Student beliefs (SDL) do not support the activities (SRL) they employ and learners therefore do not indicate the necessary paradigm shifts needed for continuous lifelong learning. How much time is needed to change learning conceptions remains to be seen, taking into account the natural development of the learner. A further challenge to self-directed learning (SDL) and the employment of self-regulated learning skills (SRL) is part of the context, i.e. students are often re-introduced into a traditional curriculum when they begin tertiary studies. Will application of the acquired self-regulated learning activities be depleted if the learning conceptions of learners do not change or if the educational environment do not support such changes? If so, how long will it take? Is more PBL exposure the answer to changing learner conceptions, or does the fact that students are exposed to a conventional as well as an innovative curriculum add to learners' confusion making the change towards more favourable learning conceptions an even more difficult goal to attain?

5.2.3.2 Reproduction-directed leaning pattern (F2)

No *discrepancies* between the reproduction-directed activities and beliefs were noted although conflicting feelings regarding the external and internal regulation of learning was noted in the qualitative data which may be a normal occurrence for students during a time of transition. The lack of discrepancies between reproduction-directed activities and beliefs indicates a fusion between the SDL and SRL which is considered a good step towards more SDL and conducive towards more sustainable meaningful learning patterns when considering the slight decline in students' regular use of reproduction-directed learning patterns overall.

5.2.3.3 Undirected learning pattern (F3)

Discrepancies between the undirected learning activities and beliefs of learners regarding undirected learning patterns were noted. Students indicated an increase in lack of regulation activities and feelings of ambivalence towards their studies. On the other hand, they showed a significant decline in their beliefs regarding stimulating education. Many reasons can be equated with the increase in students ambivalent responses reflected in the quantitative data. The increase in students' doubtful, uncertain attitude toward their studies, their own capabilities, the chosen subject area, or the type of education they are exposed to may be due to their having too many changes in their environments. Some had not experienced much emotional support from family members since they were far from home. In addition, the students had gone through personality and aptitude tests and career counseling which may have contributed to their confusion regarding their chosen subject area and abilities.

Neither the quantitative nor the qualitative data reflect a significant change in the students' occasional use of undirected-learning patterns overall **(p=0.41).** Since student beliefs have changed positively regarding the need for stimulating education, the researcher is hopeful that in a supportive learning environment where students are given time to adapt to their new circumstances, change towards more meaning-directed learning patterns will be encouraged.

5.2.3.4 Application-directed learning pattern (F4)

No discrepancies between learner activities and beliefs were noted. However, their motivation to study has shifted towards personal interest and self-development purposes, indicating a move towards more meaning-directed learning patterns.

It appears from the findings that introducing a Hybrid PBL approach into the SciMathUS programme achieved the objective of contributing to the promotion of more meaningful learning patterns in students, with a gradual transfer of control over student learning processes from external regulation to self-regulation. It is, however, doubtful that the meaning-directed learning activities employed by students will be sustained. This is because student beliefs (SDL) do not always support the activities (SRL) they employ. Consequently, learners do not always make the necessary paradigm shifts needed for continuous lifelong learning.

5.2.4 Sustainability of the learning patterns

The question of how sustainable these skills are had to be explored next. Bouhuijs (personal communication, March 16, 2006) voiced his concerns regarding the sustainability of the PBL initiative. In broad terms sustainability can be defined as the ability to maintain the positive impact of a programme, once that programme has achieved its objectives (Ismail *et al*., 2002). The challenge to sustainability is that there is no methodology for PBL if it is only introduced in the foundation year, especially if higher education institutions use conventional approaches in their degree programmes. Bouhuijs (2006) stressed the importance of the PBL initiative being successful and being relevant: it is not about the students surviving the foundation year, but about their succeeding in their tertiary studies.

In order to determine the sustainability of the PBL initiative, data were generated from fourteen randomly selected 2006 students via e-mail correspondence and a questionnaire was completed during August 2007. The 2006 SciMathUS students, after a period of eight months, served as the primary judges of whether exposure to the PBL approach had worked for them or not. The basic tenet was whether learners could apply what had been learned during exposure to the PBL approach to the university environment often referred to as the ‘so what’ or ‘now what’ phase. Often some of what has been learned cannot be applied unless changes are also made in current practices or learning institutions. It was important to determine the students' perceptions about the value and practicality of the skills acquired through their PBL experience and the presence or absence of follow-up strategies to apply what had been learned.

It seems that eleven of the fourteen students are able to use the skills they have learnt in PBL in their current studies. The following applications of PBL were noted:

- Five students mentioned that PBL is helpful when completing projects, assignments and practicals where research is required. The PBL experience assists in obtaining correct information at the correct facilities and also helps to save time in the process.
- Three students mentioned that some of the PBL strategies learnt are helpful in getting everyone to participate when working in groups.
- One student mentioned how PBL assists in subjects that require mathematical applications.

Three students mentioned that they could not apply the skills that they had learnt in PBL to their current studies because their work load was too heavy and PBL was too time consuming: One student commented: *"There is not that much time to look at things in depth unless it's on your own time which I don't always have."* This again introduces the depth versus breadth debate in the conventional approaches.

The following self-regulative meta-cognitive activities were noted in seven students indicating that the PBL experience taught them to think before they act, to plan and organize, manage and simplify their work, and to distinguish important from less important work. Three students mentioned that PBL assists them in analyzing and diagnosing problems especially in subjects where the work is difficult to understand.

The following critical cognitive processing strategies were noted by four students. They indicated that PBL helps them structure and formulate their own opinions, encourages critical thinking (they do not just accept everything written down in the text book) and assists them to look at things from different points of views.

Three students indicated that PBL contributes to their independence and enhances their confidence and creativity. One student, however, acknowledged that he finds working on his own to be challenging and thus prefers group work.

Seven students said that a few of the subjects within their university courses use innovative approaches similar to PBL. The subjects mentioned are: financial accounting where they always have to write out their problem:, economics, which they found very similar to their mathematics classes at SciMathUS where they look at different problems and try and find ways to solve them; scientific communication skills classes where they are always acquired to work in groups; the geology class where the questions are often broad and so they can apply PBL strategies to answer them; and English 178 where they experience looking at things from different perspectives. Seven students, however, indicated that they attend classes where a more conventional approach is adhered to. Some comments are:

"My classes are still very much like school where the teacher stands in front and talks and we do the listening."

"I benefit only from a few things that we did in PBL because my course is not like we get many things that we have to think out of the box or use our thinking."

From these findings it is clear that the challenge to sustainability is real especially since these students are still mostly exposed to conventional approaches in higher education. However, when considering the impact PBL had on the learners' belief systems, in other words their internal change of consciousness (self-directedness) producing internal management of instructional events (self-regulation) such as using self-regulative meta-cognitive strategies, expressing critical cognitive processing strategies and taking responsibility for their own learning it is clearly worth the effort.

5.2.5 Conclusion

From the findings it appears as if the Hybrid PBL approach (together with many other contributing factors in the programme) currently does contribute to the promotion of more meaningful learning patterns in students with a gradual transfer of control over student learning processes from external regulation to self-regulation. Regarding deep processing learning strategies the research results show that exposure to the Hybrid PBL approach does promote students' use of deep-processing learning strategies, typified by processing the subject matter critically and self-regulating learning processes and contents whilst making less use of surface approaches to learning such as memorizing and rehearsing. In addition the students appear to make more use of meta-cognitive self-regulation activities such as planning, diagnosing the problem, testing their outcomes and adjusting and reflecting on their solutions. Since students further indicate less need for stimulating education the researcher is hopeful that in a supportive learning environment the change towards more meaning-directed learning patterns will be encouraged. The fact that fewer students are motivated to study for the purposes of finding a job or embarking upon a career and are becoming more motivated to pursue their studies for self-development purposes further supports a move towards more use of meaning-directed learning patterns.

The sustainability of the meaning-directed learning activities employed by students is, however, questionable due to the fact that student beliefs (SDL) do not always support the activities (SRL) they employ. Learners therefore do not always indicate the necessary paradigm shifts needed for continuous lifelong learning. A further challenge to sustainability is the fact that after exposure to PBL these students are again mostly exposed to conventional approaches in higher education. However, when considering the impact PBL had on the 2006 learners' belief systems and their internal management of instructional events by taking responsibility for their own learning exposing them to PBL is clearly worth the effort.

5.3 DISCUSSION

It is evident that the separatist policies of the past and the poor state of some sectors of secondary schooling in South Africa have meant that many students admitted to higher education are ill-prepared for tertiary study (Kgaphola, 1999:38; Quinn, 2003:71). Not only does higher education need to cater for larger and much more heterogeneous student populations than in the past, but it also faces the additional pressure of having to increase the number of graduating students, and prepare them for lifelong learning to compete in the "new global economy" (Dunlap, 1997:1; Masui & De Corte, 2005:351; Quinn, 2003:71; Savin-Baden, 2000:140;). However, the predominant traditional behaviourist school system learners were exposed to enhanced learner dependency, a lack of understanding, reflection and self-direction (Ala & Hyde-Clarke, 2006:121-132; Cross, 2004:337; Engelbrecht, 2001:6; Finucane *et al.*, 1998:445-448; O'Grady, 2004:2). Changing times and a more diverse student population require a broader range of teaching and learning approaches, which take into account a variety of student learning needs and learning patterns. Therefore, many departments and faculties are considering approaches such as PBL (Savin-Baden, 2000:21). Problem-based learning (which is based on a more constructivist teaching philosophy) advocates a sharper focus on learner-centred pedagogy to actively involve learners and make them more accountable for their own learning (Drake, 1993; Finucane *et al*., 1998:445-448; Kgaphola, 1999:41). It supports students as self-directed, independent learners (Adendorff, 2006; De Vita, 2004:70; Johnston & Tinning, 2001:161–169; Kgaphola, 1999:38; Ward & Lee, 2004:73).

Up till now teaching at SciMathUS had mainly focused on the content of the grade 12 curriculum and the quality of the knowledge that the lecturer had and controlled. It encouraged dependency and passivity, where time was wasted on acquiring knowledge that was subsequently forgotten or found to be irrelevant. Application and integration of the acquired knowledge were mostly non existent (Finucane *et al*., 1998:445-448; O'Grady, 2004:2). This kind of approach fosters a closed conception of teaching and a reproductive, superficial conception of learning (Engelbrecht, 2001:6). There was an urgent need to articulate a new teaching and learning approach at SciMathUS. PBL which encourages a focus on the development of self-directed learning skills, where teaching activities aim mainly at facilitating learning rather than at transferring knowledge, seemed worth exploring.

Some variation in the extent to which PBL approaches are used and different species of PBL was found. This is because the implementation of PBL in different institutions and faculties is affected by the theoretical background that supports its implementation as well as by the structural and pedagogical context into which it is placed (Poikela & Poikela, 1997:8; Savin-Baden, 2000:19). The literature review reveals that the way PBL curriculum is designed can be broadly categorized on a continuum ranging from 'hybrid' (or 'adapted') approaches, to the 'full' PBL approaches (Margetson, 1999:359,364; Newman, 2004:13; O' Grady, 2004:3).

Because of the importance of the conventional curriculum in the SciMathUS programme, a decision was made to introduce a *Hybrid PBL approach* (an adapted version of PBL for a specific group of students) into the programme. PBL would be applied to a part of the curriculum, specifically the two main subjects, Mathematics and Physical Science. It was hoped that many of the benefits of PBL would still be generated while ensuring that the conventional curriculum will have its place in the programme. Introducing the Hybrid PBL approach into the programme thus offered a format for a `middle way' for curricular change which fell between true PBL and traditional styles (Miller *et al*., 2000:51).

However, introducing a Hybrid PBL approach within a shorter one-year foundation programme raised specific concerns. Although management and staff felt that the traditional curriculum was improved significantly and some integration did take place, the SciMathUS curriculum is still partly trapped in a discredited conception, which compartmentalises knowledge under discrete subject headings. This meant that PBL was experienced as an add-on at times. This raised the question whether introducing a Hybrid PBL approach into a conventional curriculum could create and support conditions for learners to develop self-directed learning attitudes and skills and whether these attitudes and skills were sustainable.

In order to determine the level of self-directedness the literature review reveals that students possess qualitatively different learning patterns and that some patterns are better than others in view of the knowledge they lead to and the preparation for lifelong learning competence. The four learning patterns identified were meaning-directed, reproduction-directed, undirected and application-directed learning patterns. From the viewpoint of high quality learning the meaning-directed and application-directed learning patterns are viewed as more desirable (Vermunt & Vermetten, 2004:362). Vermunt (in Vermunt & Vermetten, 2004:326) uses the term 'learning pattern' as a super ordinate concept in which four learning components namely cognitive and affective processing of subject matter, the meta-cognitive regulation of learning as well as conceptions of learning, and learning orientations were united. The four learning components are further divided between learning activities referred to as self-regulated learning or SRL and learning beliefs referred to as self-directed learning or SDL for each of the four learning patterns. Whereas SDL refers to the internal change in beliefs and consciousness entailing the movement towards autonomous lifelong learning, the activities (SRL) emphasize what learners have to do to move towards the goal of self-directed learning and ultimately lifelong learning. The literature review also indicates that the most complete form of SDL occurs only when the external technical dimension or activities (SRL) are fused with the internal, reflective dimension or beliefs (SDL). All the techniques of SDL may therefore still not lead the learner to exhibit autonomous behaviour (SDL) which leads to lifelong learning (see Chapter 2 for a theoretical discussion of SDL and SRL).

The traditional behaviourist school system students were exposed to as well as the traditional teaching methods employed at SciMathUS with a high focus on teacher control and transfer of knowledge could be associated with reproductive learning patterns of the students. PBL, on the other hand advocates a more innovative learning environment. Here the emphasis is on active, constructive and self-regulated learning which encourages more meaning-directed learning patterns. The objective of this study was to assess whether exposing students to a Hybrid PBL approach would change their learning patterns in a favourable direction, mainly toward meaning-directed learning.

The findings indicate that it is indeed possible to influence student learning patterns in a favourable direction. It was found that learning patterns which are rather stable within a constant educational context are susceptible to educational influences when introduced to Hybrid PBL approaches (Vermunt and Vermetten, 2004:379). With regard to deep-processing learning strategies, the research results show that exposure to the Hybrid PBL approach did promote the use of deep-processing learning strategies, typified by processing the subject matter critically and self-regulating learning processes and contents whilst making less use of surface approaches to learning such as memorizing and rehearsing. In addition, the students appeared to make more use of meta-cognitive self-regulating activities such as planning, diagnosing the problem, testing their outcomes and adjusting and reflecting on their solutions. Student responses reflected less need for stimulating education. This together with the fact that most students were pursuing their studies for self-development purposes, is congruent with the move towards more meaning-directed learning patterns.

The sustainability of the meaning-directed learning activities employed by students was however questionable. Student beliefs (SDL) regarding their responsibility to construct knowledge and their responsibility in the learning process did not always support the activities (SRL) they employed. Many possible reasons may be behind these discrepancies between beliefs and activities. When students enter a new type of education such as a PBL approach, there may be a temporary misfit, or friction between the students' learning strategies and the demands of the new learning environment. This could be an indication of a period of change and acclimatization, comparable to a period of friction, a period in which students find that their ideas of knowledge and how to go about learning are no longer adequate. Due to the discrepancies between meaning-directed beliefs and activities, it was important to investigate the sustainability of these efforts. In order to determine whether the changes in learning patterns were sustainable it was important to consider both the changes in beliefs and learning behaviours as well as the fact that sustainability would be difficult if PBL is only introduced in the foundation year, especially if higher education institutions use conventional approaches. Data were, therefore, generated from fourteen randomly selected 2006 students after a period of eight months who served as the primary judges of whether they could apply what has been learned after exposure to the PBL approach within the university environment and to determine their perceptions about the value and practicality of the skills acquired through their PBL experience.

From the findings it was clear that the challenge to sustainability is real. These students are still mostly exposed to conventional approaches in higher education characterized by an absence of follow-up strategies to apply what has been learned. However, when considering the impact PBL had on the learners' belief systems, in other words their internal change of consciousness (self-directedness) producing internal management of instructional events (self-regulation) such as using self-regulative meta-cognitive strategies, expressing critical cognitive processing strategies and taking responsibility for their own learning exposing them to PBL was clearly worth the effort.

The impact of introducing PBL into a conventional curriculum was not only assessed by viewing changes in students' learning patterns but also considering the qualitative responses of teachers as well as management. According to management and staff PBL did contribute to the overall improvement of the SciMathUS programme. Some of the reasons provided were: the integration process promotes understanding, staff feel more comfortable with the PBL process and enjoy the new teaching experience, PBL improves staff relationships and leads to improved understanding of each other's subjects as well as addressing misconceptions in own subjects, paradigm shifts in students are taking place and support is experienced from management which enhances motivation overall. Introducing a Hybrid PBL approach into a conventional curriculum was, therefore, clearly worth the effort.

5.4 CONCLUSION

Reflecting on the findings from this study introducing a Hybrid PBL approach into a conventional curriculum therefore appears to be a worthwhile undertaking for a one year foundation programme such as SciMathUS and its members. It not only promotes more meaningful learning patterns in students, but also contributes to a learner-centred learning environment that emphasizes relations in Mathematics and Physical Science and promotes deep approaches to learning. It might, therefore, improve chances for future study success in

Higher Education. These results therefore provided the core team with the necessary findings to support ongoing integration efforts.

It also seems clear that the introduction of an innovative teaching method such as PBL, stressing active, constructive and self-regulated learning was a timely intervention since PBL as a philosophical approach to teaching is more process-oriented in nature and clearly stimulates students to develop more meaning-directed learning patterns that will be needed for long periods of lifelong, self-directed learning (Vermunt & Vermetten, 2004:381). Chapter 6 will focus on the implications of the research findings and recommendations for introducing PBL within existing programmes as a means of programme improvement.

CHAPTER 6: REFLECTIONS AND RECOMMENDATIONS FOR PROGRAMME IMPROVEMENT

6.1 INTRODUCTION

The predominant traditional behaviourist school system learners in South Africa were exposed to have resulted in a high intake of learners who are ill-prepared for higher education. Students have shortcomings such as dependency and lack of self-directedness. In order to address these concerns most higher education institutions are attempting to expand academic development and foundational programmes (such as SciMathUS) in order to provide learning opportunities that support students as self-directed, independent learners.

Research has indicated that the use of self-directed and learner-controlled methods such as PBL is one way to create and support conditions for learners to gain more control of the learning process. However, PBL has predominantly been implemented in long term medical curricula and research and the literature results focus mainly on the design and development of PBL with these longer programmes in mind. The question this study asked was whether introducing a Hybrid PBL approach into a shorter one-year foundation programme could create and support conditions for learners to develop more meaning-directed learning patterns and gain more control and ownership of the learning process.

6.2 RESEARCH SUMMARY

Chapter 1 provided a theoretical orientation to the research, the research problem and research methodology, stating the importance of the research within the South African higher education context from a systemic perspective in order to evaluate the characteristics of PBL as a possible teaching approach at SciMathUS. The reflection in Chapter 1 makes it clear that the new intake of students into higher education is ill-prepared for tertiary study. In theory traditional teacher-centred approaches are giving way to more student-centred, flexible, integrated approaches. However, the majority of institutions and even programmes such as SciMathUS have kept their traditional curriculum formats and use teaching approaches that encourage superficial ways of learning. This results in poorly understood key concepts, as well as weakly developed transferable skills and a lack of reflection and self-direction.

It was against this background and the endeavour to continuously improve their programme that SciMathUS realised the need to re-evaluate their curriculum and teaching approaches by using PBL as a tool to restructure the curriculum. PBL was considered for the following reasons:

- It is a student-centred approach that shifts the classroom focus from teaching to learning.
- It creates and supports conditions for learners to develop more meaning-directed learning patterns and gain more control and ownership of the learning process.
- It creates a student-centred learning environment in which problems drive the learning.
- Teachers are facilitators or guides of the student learning experiences.
- It recognizes that knowledge transcends artificial boundaries by highlighting the interconnections between subjects and disciplines and the integration of concepts which leads to deeper understanding.

The following aims and research questions of this evaluative study were therefore formulated: The primary purpose of the evaluative study was to describe the development and implementation of a Hybrid PBL approach for SciMathUS as a tool for overall programme improvement. The secondary purpose of this study was to evaluate whether exposure to a Hybrid PBL approach in a one-year foundation programme did produce change in the learning patterns of learners and whether the skills acquired were sustainable.

The research questions that derived from the primary aim were formulated as follow:

- What is PBL?
- Is there a need to introduce PBL into the SciMathUS curriculum?
- What PBL model could be appropriately adapted for SciMathUS?
- Was the Hybrid PBL approach well designed?
- Was the Hybrid PBL approach implemented effectively?

The research questions that derived from the secondary aim were formulated as follow:

- Did the Hybrid PBL approach reach the intended outcomes of improving the learning patterns and specifically the self-regulation of learning processes of learners?
- Are these skills sustainable?
- Is this type of innovation a worthwhile undertaking for a one-year foundation programme such as SciMathUS and its members?

Chapter 2 provided the theoretical foundation of the proposed PBL approach followed by a general overview of PBL. Here the discussion moved toward PBL in general and the different PBL approaches or models available from within an international perspective. Within the scope of this study PBL models were divided into three categories, namely models providing a structure for the carrying out of problem units, instructional models and operational models focusing on how PBL operates within different curricula.

It also became apparent that the implementation of PBL in different institutions and faculties is not only affected by the theoretical background that supports its implementation but also by the structural and pedagogical context into which it is placed. When choosing between PBL approaches such as Hybrid or Pure approaches it is thus important to consider all the factors involved when planning, designing and implementing PBL into the curriculum. These would include class size, the intellectual maturity of students, student motivation, the course learning objectives and instructors' preferences.

Chapter 3 paid special attention to all the factors that were involved in planning, designing and implementing a Hybrid PBL approach in the SciMathUS programme. During this process programme needs and objectives were identified, PBL was posed as a possible solution to address those needs, integration options for the curriculum restructuring process were explored for the two main subjects Mathematics and Physical Science, a unique SciMathUS Hybrid PBL approach was developed. PBL learning problems were designed, teachers and learners were prepared for the intended change and the Hybrid PBL approach was applied during 2007.

Chapter 4 described the research design and methodology used to execute the research. This study was located under the broad heading of evaluation research which entailed the use of scientific methods to measure the conceptualization, design, implementation and outcomes of the Hybrid PBL approach within the SciMathUS programme at Stellenbosch University. The theoretical perspective that underpinned the methodology used in this evaluation study was an interpretive-constructivist approach with a pragmatic focus.

In this single case-study, the researcher used purposive sampling. Participants involved in the SciMathUS programme during 2007 consisting of 42 adult students (ranging between the ages of 17 and 22) and three lecturers (two Mathematics lecturers and one Physical Science lecturer) were observed. The study commenced in 2005 which was based on a needs assessment, and was followed by the pilot study phase during 2006. In 2007 the case study was implemented. The pilot phase focused on the conceptualization and development of the Hybrid PBL approach whereas 2007 focused on the implementation of the Hybrid PBL approach and the outcomes achieved.

A mixed-method approach to programme evaluation that involved collecting and analyzing both qualitative and quantitative data was used in this study to converge or confirm outcome findings from different data sources. A *concurrent nested mixed-method strategy* was selected. The quantitative method used in this study was embedded or nested within the predominant qualitative method. This nesting meant that the embedded method sought information from different levels. The data collected from the two methods were mixed during the analysis and interpretation phase of the research.

Multiple data construction strategies were used in this study most of which resulted in qualitative data that were generated from the programme evaluation (during phases 1 to 5) of the study whilst quantitative data were generated during the pre- and post-evaluation stages (phases 1 and 4) of the study. Data were collected at key points over a sustained two-year time period. Different sources of information were used. Primary data were generated through the application of the Inventory of Learning Styles (ILS questionnaire), semi-structured focus group interviews and classroom observations, whilst secondary data were collected through document analysis (including a literature review) and records of meetings.

Analysis of the quantitative data consisted of identifying the variables that the ILS questionnaire measured. Analysis of the qualitative data consisted of observations made by the tutors, the researcher and students themselves on the extent of change in students' learning patterns and self-regulated skill levels, values and beliefs as well as their experiences in the design and implementation of the Hybrid PBL approach. The qualitative data from the various sources were analysed using the thematic and content analysis procedure of open coding.

In **Chapter 5** the research findings regarding the impact of the Hybrid PBL approach on student learning patterns and the sustainability of these patterns were presented. From the findings it seems that the Hybrid PBL approach does contribute to the promotion of more meaningful learning patterns in students with a gradual transfer of control over student learning processes from external regulation to self-regulation although this is still a slow and gradual process. From the findings it is clear that the challenge to sustainability is real especially since these students are still mostly exposed to conventional approaches in higher education. However, when considering the impact PBL had on the learners' belief systems and their ability to apply self-regulative, meta-cognitive strategies it was clearly worth the effort.

The following section in **Chapter 6** focuses on the answers to the research questions and provides suggestions for further improvement of the Hybrid PBL approach within the SciMathUS programme and discusses some of the challenges still experienced. It also formulates recommendations for current and future programmes.

6.3 CONCLUSION AND RECOMMENDATIONS

Several conclusions were drawn from the research findings in an attempt to answer the research questions and aims and recommendations for programme improvement were made. To describe and evaluate the development and implementation process of a Hybrid PBL approach for SciMathUS the following questions are answered:

6.3.1 What is PBL?

PBL is an educational philosophy to learning and an innovative approach to curriculum design and implementation which describes a student-centred learning environment in which problems drive the learning. Learning begins with a problem that needs to be solved and the problem is posed in such a way that students working cooperatively in groups need to gain new knowledge before they can solve it. This prepares students to think critically, to find and use appropriate learning resources at their own accord and challenges them to ‘learn how to learn’.

6.3.2 Was there a need to introduce PBL into the SciMathUS curriculum?

Since teaching at SciMathUS mainly focused on the content of the grade 12 curriculum and the quality of the knowledge that the lecturer had and controlled a likely consequence of this teacher-centred approach is the development of a closed conception of teaching and a reproductive, superficial conception of learning strengthening learner dependency. In this type of fragmented traditional teacher-centred pedagogy, time is wasted on acquiring knowledge that is subsequently forgotten or found to be irrelevant whilst application and integration of the acquired knowledge may be non-existent. It is clear that reform was needed in the SciMathUS programme and one way to address this reform was to evaluate the characteristics of problem-based learning (PBL) as a possible approach to restructure the current curriculum in order to provide the necessary self-directed learning skills for students to cope within a more constructivist learning environment.

6.3.3 What PBL model was adapted for SciMathUS?

Since the SciMathUS programme provides students the opportunity to rewrite the Senior Certificate examinations of the National Education Department, it was important that the curriculum reform should not be too radical. An adapted version of PBL for the specific group of students or a Hybrid PBL approach, also referred to as transitional semi-problem-based curricula, was needed which would gradually infuse PBL within the existing conventional curriculum. Within the hybrid approach PBL is implemented in shorter cycles and there are generally at most two subjects in collaboration.

6.3.4 Was the Hybrid PBL approach well designed and implemented effectively?

In order to answer this question meaningfully, the focus will be on the challenges still being experienced and the recommendations to improve the design and implementation of the Hybrid PBL approach in order to make something that is ‘right’ even ‘better’.

The integration of Mathematics and Physical Science

Challenges

A concern raised by Bouhuijs (personal communication, March 16, 2006) was that PBL would not make an enormous impact if it were not respected by all the teaching staff. This was clearly one of the limitations in the curriculum restructuring process at SciMathUS: not all of the lecturers (especially the part-time lecturers in Statistics and Accounting) were included from the very beginning in the development initiative. Although the part-time lecturers were invited they did not attend the initial training or strategic meetings due to other commitments. One of the biggest shortcomings was the fact that the PBL problems catered only for Mathematics and Physical Science students. This meant that the Accounting and Statistics students not only felt excluded, isolated and sidelined by the process but were also not presented with challenges to their basis of reasoning. This resulted in low contributions of Accounting students since the PBL problems were experienced as extremely challenging given that they did not have much prior knowledge to call on. These students also indicated that they felt overwhelmed and struggled to process the large amounts of information and thus did not enjoy the PBL experience.

However, starting smaller and integrating only the two main subjects, Mathematics and Physical Science gave the core team time to adjust to the new approach, outline the obstacles encountered and become skilled in addressing the challenges experienced with the PBL process in general. This process created an opportunity for the core team to gain more expertise which could later be shared with other lecturers such as the Accounting and Statistics lecturers who may then experience the PBL implementation process as less of a consumer of their time and 'patience'. It was thus decided to first work with the core group of implementers in the two main subjects to confront and overcome initial challenges successfully before embarking on the process of fuller integration during 2008.

Recommendations

The endeavour at SciMathUS towards continuous improvement and acknowledging the concerns thus resulted in the need to develop the Hybrid PBL approach further. The following decisions were therefore made for 2008:

- To involve all the staff in the development process and incorporate more subjects (such as Accounting, Statistics, Language and Thinking skills and Computer Literacy) during 2008 in the curriculum restructuring process at SciMathUS.

- To develop a Mathematics and Accounting and a Mathematics and Physical Science PBL programme where two types of problems will be designed (one focusing on the integration of Mathematics and Accounting and the other making use of the existing problems which focus on the integration of Mathematics and Physical Science).

Scheduling of problems in the Hybrid PBL approach

Challenges

Since PBL exposure must occur with enough regularity for students to gain the necessary skills and to be able to make connections among subject areas, it is important to pay special attention to the scheduling of problems.

- The prior scheduling of the integrated PBL problems in Mathematics and Physical Science places undue pressure on staff members to expose students to work which some staff are not yet ready to cover in the curriculum. According to staff, it is difficult to link specific Mathematics and Physical Science sessions beforehand when there is established practice of working through subject material at your own pace: *"We must plan to work more integrated, we must all work together, but this is not always realistic and possible in practice."*
- The scheduling options for the bigger integrated PBL problems usually at the beginning or end of terms often directly after the exams has a negative effect on some students' motivation and contributes to PBL being experienced as merely an add-on: *"Our working energy as a group was low due to the fact that our goals on our performances during the exams were not fully met. Thus we saw no need to put all our efforts during the two days left before closer into the problem."*
- Due to logistical reasons the Table Mountain problem specifically designed for the first term had to be replaced with the Amazing Race problem placing further demands on staff time to design a new problem.

Recommendations:

- More consideration should be given to the problem-based combination approach. The combination of the three bigger subject integrated problems and smaller subject intra-grated weekly PBL problems could address the conventional curriculum coverage needs of staff. The rationale behind the combination approach or subject inter- and intra-gration approach is that PBL then forms a more integral part of the academic programme and provides opportunities for lecturers to cover curriculum content or analyze misconceptions before starting with new work. It was suggested that more exposure to PBL on a regular basis via smaller subject intra-grated problems need to be considered for 2008.

- More strategic planning opportunities should be provided for all lecturers (including Accounting and Statistics) to plan the curriculum together and search for overlapping themes that lend it for integration.
- The scheduling options for the bigger integrated PBL problems (usually at the beginning or ends of terms) should be reconsidered and offer more flexibility where its implementation will be most effective for all those involved. One option could be building the PBL problem in a parallel mode where students get the problems and work on their own and then the Science and Mathematics lecturers address the problem separately in their classes when it fits into their personal curriculum planning schedule. Another option mentioned was having the Mathematics and Physical Science lecturers facilitating some classes together during normal class periods.
- Careful consideration of the logistics is advised when problems are designed since it may lead to good problems having to be discarded and valuable time lost in the process.

Time constraints and content coverage

One concern raised was that PBL can be a time-consuming process which causes one to proceed slower than usual or cover less content in a curriculum than in a traditional positivist classroom. Although staff found PBL a time-consuming process initially this was not the case for long. This could be because a Hybrid PBL approach was used as opposed to a full, authentic PBL approach so the traditional as well as the innovative curriculum was therefore implemented concurrently in the programme:

"At the beginning I was worried about the time aspect, that we won't have enough time to cover everything. I'm currently two chapters behind but I know I would have been behind with or without PBL."

"If you do the PBL problem so many things come out that you didn't consider covering that which isn't part of your planning and it takes longer. So I thought I went through the work at a slower pace but when I looked back and compared it to the chapters in the math text book I was surprised to notice we covered more work than initially anticipated. We've covered more work than what we did in the past during the same period."

The concern that the Hybrid PBL approach would mean that not enough work was covered was thus unfounded in this context. This further introduced the age-old debate of depth versus breadth of curriculum content coverage. The research findings, however, indicate that the content in the traditional curricula students are exposed to often lack relevance and are quickly forgotten whereas exposure to PBL encourages students to think rather than memorize. This led to increased understanding due to the application in real life.

Problem design

Duch (2001b:47), Schmidt and Moust (1998:73) state that the quality and the type of problem used is a central factor in the successful implementation of PBL since it not only influences the better functioning of the group but also impacts on the amount of time students will spend on self study.

Challenges

The following challenges regarding problem design are still being experienced:

- Some lecturers still do not feel equipped to design integrated problems without some form of external support: "*It is rather difficult to write sensible problems and it's difficult to find good problems even now.*"
- Problem statements need further contextualisation and refinement: scenarios need to be created and there needs to be a greater level of integration between Mathematics and Physical Science.
- Problem 3 is experienced as too demanding and does not focus student learning on the course objectives. This results in important product outcomes not being reached even though important process outcomes are reached.
- The many questions in the problem statements need to be reconsidered since it promotes a 'right answer mentality' and the splitting up of the work, which results in fragmented learning.

Recommendations

- Create opportunities for staff members to do the problems first in the future before presenting them to students in order to address their own misconceptions.

- Adapt the problems (especially problem 1) to have better integration between Mathematics and Physical Science. The staff is eagerly awaiting a book ordered on the topic ‘PBL problems for Science and Mathematics’.
- Contextualize the problems (especially problem 1) by setting a scenario (providing the student with a role or stance to take in order to solve the problem).
- Design and present problems in phases.
- Replace the SC PBL approach (student-centred PBL approach) where students are totally responsible for generating their learning issues by a combination of the SC PBL approach and the PS PBL approach (problem stimulated PBL approach) where lecturers or the problem statement itself provide more learning objectives to students. Kirschner *et al.*, (2006:83) confirm that certain aspects of the Hybrid PBL approach should be tailored to the developmental level of the students. The advantage of guidance begins to recede only when learners have sufficiently high prior knowledge to provide “internal” guidance. The lecturers feel this to be especially important for subjects such as Mathematics and Physical Science and especially for students with low prior education levels. However, an important recommendation by a consultant (specifically for Mathematics) is rather to facilitate the process by making students aware of their meta-cognitive reasoning instead of refining problems. The following is thus proposed: to work from the real life problem to the theoretical model, back to the real life problem and provide adequate mediation to the students during the process rather than refine the problem.

Staff training

Staff training for PBL was experienced as adequate. Whereas staff felt uncomfortable with the facilitation process during 2006, they expressed more confidence in facilitating groups during 2007.

Recommendations

Training recommendations for future programmes are as follow:

- Holding workshops which develop an understanding of PBL and familiarize staff with the principles and processes involved in curriculum restructuring, the writing of problems and assessment.
- Addressing further training needs in the form of articles.
- Providing practice opportunities since facilitation skills are best developed through practice rather than hearing about it.

- Providing continuous informal reflection and follow-up opportunities for staff.

The floating facilitator model

Challenges

The floating facilitator model creates the following problems in combined classes.

- It is difficult to assess students individually without prolonged exposure to the groups.
- It is difficult to follow student comments due to the noise factor.
- Different facilitators repeat the same questions leading to repetition or confusion.

The floating facilitator model, however, works well in smaller classes (where the three classes work separately on smaller PBL problems).

Recommendations:

- A *fixed facilitator* model is proposed for combined classes (where each lecturer is assigned two permanent groups) when working on larger PBL problems.
- *Floating facilitator* models will be kept for separate classes (where lecturers float between the different groups when working on smaller weekly problems).
- The following process operation methods of PBL is recommended when working on smaller PBL problems focusing on working from the real life problem, to the theoretical model, back to the real life problem:

  - Self-study → Group discussion → Discussion with teacher → Re-discussion of groups → Class discussion
  - Self-study → Group discussion → Discussion with teacher → Self-study → Re-discussion of groups → Class discussion
  - Group discussion → Self-study → Group discussion → Discussion with teachers → Class discussion
  - Group discussion → Discussion with teachers → Self study → Re-discussion of groups → Class discussion.

Student orientation

The two-week student orientation programme for the new intake of students may be described as adequate preparation for PBL.

Recommendations

Recommendations for future programmes are as follow:

- Provide students with a thorough introduction to the specific characteristics of PBL.
- Prepare students adequately in order to make PBL teacher proof since in PBL most problems are usually experienced with the teachers.
- Provide students with practice opportunities to work in groups, practice different roles as group members and practice time, organization and conflict management skills.
- Provide practice items on content relevant tasks but with more emphasis placed on process skills and less on content.
- Stress the importance of the development of self-directed learning skills.

Group functioning

Challenges

Decline in group performances (due to lack of leadership in some groups) may be attributed to the fact that the same group formations were used for problem 2 as for problem 1 when the lecturers still did not know the strengths and weaknesses of the students.

Recommendations

Recommendations for future programmes are as follow:

- Limit the group size from six to eight members maximum.
- Determine the strengths and weaknesses of students and establish a strong leader in every group during group formation.
- In order to have groups functioning efficiently, establish a set of ground rules to be agreed upon by the group and enforce them from the first week or two of classes.
- Include a formal statement of roles for groups, which can be used to structure group discussion.
- Emphasize interpersonal trust and acceptance when working with diversity and differences within groups.

Lack of resources

Due to the problem of a lack of resources and the fact that these students do not have printing credits, articles were provided for students to research the problems in their own time. Although articles were available to the groups they still expressed a need to find their own resources. A few groups made use of their cell phones to access the internet. Lack of resources hampered the self-regulation process.

Recommendations

- Provide enough articles for students to research the problems in their own time.
- Provide students with printing credits and internet access.
- Place more articles on reserve in the library.

Feedback

Challenges

With problem 1 the groups were provided with immediate formative feedback about their progress and suggestions for improvement were provided to each group separately. It was also felt that groups that made posters focused on appearance instead of content. The manner of presentations needs to be reconsidered.

With problem 2 all the lecturers together participated in marking the reports and providing their feedback as a team. This contributed to the whole process of integration. However, in the case of problem 2 and problem 3, the feedback to students was only provided after the holidays leading to lack of motivation and boredom.

Recommendations

- Reconsider feedback. Some suggestions are that lecturers could act as a board that interviews the group who has come to make the presentation. In this way the discussion can be more focused.
- Provide a more detailed assessment rubric.
- Present students with specific guidelines on how to design their representations whilst focusing on the content.
- Schedule feedback shortly after the completion of a problem since there is no value in extending feedback time.
- Build the feedback into normal classes when that part of the work is specifically addressed. This can be done at the own accord of the different lecturers depending on their own needs. Thus a more natural approach to feedback is suggested.

Assessment and test achievement

A continuous assessment approach was introduced in 2007. This meant that final marks on report cards at the end of each term consisted of 50% examination results based on summative assessment and 50% class work results (including PBL activities, homework and other assignments) based on formative assessment. Sometimes difficulties were experienced in assessing the personal contribution of each student.

Furthermore, no decline in student test achievement have been experienced whilst improved understanding have been noted by staff. This was confirmed by Alan Cliff from the University of Cape Town who conducted an AARP assessment on the SciMathUS students during October 2006 when he stated that: *"They have grown in their mathematical thinking skills – massively. This may demonstrate the effect of teaching intervention. This is powerful evidence of teaching intervention. Their mathematical comprehension more than doubled which means that they can work at very abstract levels with maths."*

Recommendations

- Build in bonus questions and points in traditional examination papers. Students are thus presented with bonus PBL problems in the traditional examination that capitalize on their use of critical, analytical, and concrete processing strategies which can thus be reflected in examination results.
- Provide students with both written and oral comments regarding their progress.

In order to evaluate whether exposure to a Hybrid PBL approach in a one-year foundation programme did produce change in the learning patterns of learners and whether the skills acquired were sustainable the following questions are answered.

6.3.5 Did the Hybrid PBL approach reach the intended outcomes of improving the learning patterns and specifically the self-regulation of learning processes of learners and are these skills sustainable?

It appears that PBL does promote more meaningful learning patterns in students typified by processing the subject matter critically and self-regulating learning processes and that PBL is contributing to a learner-centred learning environment that emphasizes relationships between Mathematics and Physical Science, promotes deep approaches to learning which may lead to better achievements and study success in Higher Education. However, the challenge to sustainability is real especially since these students are still mostly exposed to conventional approaches in higher education. However, when considering the impact PBL had on the learners' belief systems, in other words their internal change of consciousness (self-directedness) producing external management of instructional events (self-regulation) such as using self-regulative meta-cognitive strategies, expressing critical cognitive processing strategies and taking responsibility for their own learning, it is clearly worth the effort.

Maintenance of the positive impact of the programme, or achieving further improvements is being achieved in a variety of ways, since it was decided:

- To support ongoing integration efforts via PBL in the programme.
- To institutionalize components of the programme in other subjects and assess the programme's ability to respond to future needs.
- To introduce PBL problems in the extended year programme in Economical and Business Sciences (Mathematics) and in the first year BEd Physical Science course.

In order to achieve sustainability a demand for PBL is being created, the right mix of incentives is maintained by leaving the incentives in place and keeping them current. It is further important to assess these incentives periodically to make sure they reflect the set of faculty needs at the time. One big incentive is the upcoming International PBL Conference in Colima, Mexico during January 2008 where staff will be presenting a poster presentation and research report on their PBL experience at SciMathUS. Attendance of the International PBL conference is further part of the process of generating publicity and recognition for PBL at SciMathUS. Other factors that contribute and promote sustainability are the ongoing evaluation and comprehensive evaluation plans that have been incorporated in the curriculum restructuring effort, real commitment from stakeholders, support from management and institutionalization of PBL within the programme through the demonstrated ownership and participation from all staff members, the establishment of an ongoing faculty development programme; creating a demand for the new curriculum or pedagogy and generating publicity and recognition by focusing on developing a critical mass of faculty who use PBL.

In order to maintain the positive impact of the programme for the future the following need to be considered: powerful management is needed to create coherent structures in other faculties; external pressure is needed to legitimize the actions undertaken by the management; and management should try to use external pressure for adopting new ideas and to create a faculty wide approval.

6.3.6 Is this type of innovation a worthwhile undertaking for a one year foundation programme such as SciMathUS and its members?

Regarding the many challenges still experienced the issue is whether introducing a Hybrid PBL approach into a conventional curriculum is a worthwhile undertaking which contributes to the overall improvement of the SciMathUS programme that would support ongoing integration efforts.

According to management and staff, PBL does contribute to the overall improvement of the SciMathUS programme. Some of the reasons provided are: the integration process promotes understanding, staff feel more comfortable with the PBL process and enjoy the new teaching experience, PBL improves staff relationships and leads to improved understanding of each other’s subjects as well as addressing misconceptions in own subjects, paradigm shifts in students are taking place and support is experienced from management which enhances motivation overall.

6.3.8 Conclusion

It is evident that many students admitted to higher education are ill-prepared for tertiary study. The predominant traditional behaviourist school system learners were exposed to enhanced learner dependency, a lack of understanding, reflection and self-direction. Since changing times and a more diverse student population require a broader range of teaching and learning approaches to meet their students’ needs this has led departments and programmes such as SciMathUS to consider approaches such as PBL which supports students as self-directed, independent learners.

Due to the importance of the conventional curriculum in the SciMathUS programme a H*ybrid PBL approach* (an adapted version of PBL for a specific group of students) was introduced into the programme where PBL was applied to a part of the curriculum, specifically the two main subjects, Mathematics and Physical Science. Although evaluation findings revealed that the Hybrid PBL approach was well designed and implemented effectively many challenges are still experienced and the formulated recommendations are therefore to further improve the programme in order to make something that is ‘right’ even ‘better’.

Introducing a Hybrid PBL approach within a shorter one-year foundation programme raised the question whether it would be possible to influence student learning patterns in a more favourable direction and if so, whether these learning patterns would be sustainable. The findings indicated that it is indeed possible to influence student learning patterns in a favourable direction by introducing them to a Hybrid PBL approach. The sustainability of the meaning-directed learning activities employed by students is hindered if student beliefs (SDL) do not support the activities (SRL). From the findings it was clear that the challenge to sustainability is real especially when introducing these students back into more conventional approaches in higher education characterized by an absence of follow-up strategies to apply what has been learned. However, when considering the impact PBL had on the learners’ belief systems and the self-regulation and meta-cognitive activities they learnt to use, exposing the students to a Hybrid PBL approach was clearly worth the effort.

6.4 STRENGTHS AND LIMITATIONS OF THE STUDY

This envisioned programme improvement and evaluation process had many strengths. The dual role the researcher had to perform as researcher and evaluator had several advantages. Assigning the responsibility for the evaluation to the researcher and programme staff made the evaluation part of the programme rather than a separate activity (Bloland, 1992:537). This allowed the researcher to progressively focus on a variety of issues relevant to the development of the Hybrid PBL approach. It also gave the researcher the flexibility to incorporate the issues that emerged from the contact between the evaluator and different programme stakeholders into the evaluation design (Terre Blanche & Durheim, 1999:215). Collaborating in this way strengthened the investigation through the sharing and reflections that came from the investigation and facilitated the writing of the study (Merriam, 2002:423).

The main constraint to the envisioned programme improvement and evaluation process was finding an appropriate balance between scientific and pragmatic considerations in the evaluation design. Rossi *et al*., (2004:25) claim that these type of trade-offs between utility for programme decision makers and scientific rigour are such that it is rarely possible to design an evaluation that serves both interests well. Whereas scientific studies strive principally to meet research standards, evaluations are dedicated to providing maximal useful information. The researcher's task was thus to creatively weave together many competing concerns and objectives into a tapestry in which different viewers could find different messages. Not only did the evaluation need to meet high standards of scientific research, but it also had to be dedicated to serving the information needs of programme decision makers. In practice these two goals were not always very compatible since conducting social research at a high scientific standard generally required time whereas programme decisions often had to be made on short notice. In practice, the researcher had to struggle to find a workable balance between the emphasis placed on procedures that ensured the validity of findings and those that made the findings timely, useful, and meaningful to the stakeholders (*ibid.*:23-26). It was thus important to negotiate a middle way between optimizing the situation for research purposes and minimizing the disruption caused to normal programme operations. What complicated matters were that program circumstances and activities at times changed during the course of the evaluation.

Another concern for the researcher especially at the beginning of the research was the wide diversity of perspectives and approaches in the evaluation field which sometimes provided little firm guidance about how best to proceed with an evaluation. The fact that there is also still little written on the mixed-method approach to guide the researcher through this process was sometimes problematic when interpreting the final results (Creswell, 2003:218-219). Furthermore, the distinction between programme development and evaluation sometimes become increasingly blurred (Mertens, 1998:235, Rossi *et al.,* 2004:21-22/29, Terre Blanche & Durheim, 1999:224).

6.5 FUTURE RESEARCH

In general it seems evident that designing and implementing a Hybrid PBL approach within an existing conventional curriculum is a challenging and pain-staking process but worth the effort. The following is suggested for future research:

- Since this study, along with the majority of developmental programmes focuses on the design, implementation and evaluation phases of such innovations there is an evident need to conduct studies that include the other phases in the innovation process such as the maintenance phase that is how to secure and further develop the innovation process within the wider institutional context.

- More in-depth research focusing on the integration between Mathematics and Physical Science highlighting the interconnections between the disciplines and the integration of concepts is needed.
- Research regarding the writing of effective *integrated* and *intra-grated* PBL problems for subjects such as Mathematics and Physical Science is recommended.
- Research on process-oriented assessment tools must be completed to ensure valid assessment instruments for PBL programmes in order to find more effective ways of evaluating student outcomes.
- More in-depth research regarding the establishment of PBL as a way to foster effective learning among ill prepared learners from diverse backgrounds (with specific focus on foundation programmes) is recommended.
- More evaluation research regarding the effectiveness of Hybrid PBL initiatives in foundational year programmes before comparisons and generalizations can be made regarding its effectiveness is recommended.

6.6 CONCLUDING REMARKS

A concern about implementing a Hybrid PBL approach as opposed to a full-blown authentic PBL approach in a one-year foundation programme was that success could be limited since this could lead to a perception that the programme wanted to train in PBL but not actually change the curriculum, thus becoming a mere teaching approach instead of a changed philosophy informing the whole notion of learning and teaching. The gradual infusion of PBL into the SciMathUS curriculum could therefore pose many future challenges. The curriculum which has some traditional elements together with PBL elements could generate tensions if these elements together do not form part of a well-structured complete curriculum. It was therefore important to evaluate whether the deliberate restructuring of the existing curriculum in which both a more traditional system as well as a new innovative PBL approach is combined was worth all the effort and was beneficial in supporting students to reach their educational goals.

Reflecting on the findings from this study introducing a Hybrid PBL approach into a conventional curriculum appeared to be a worthwhile undertaking for a one-year foundation programme such as SciMathUS and its members. It has contributed to the overall improvement of the SciMathUS programme by not only promoting the use of more meaningful learning patterns by students, but also contributing to a learner-centred learning environment that emphasizes relationships between Mathematics and Physical Science and promotes deep approaches to learning which may improve chances for future study success in Higher Education. These results have, therefore, provided the core team with the necessary findings to support ongoing integration efforts. The researcher believes that the question each of us really needs to ask is, therefore, not whether introducing PBL into a conventional curriculum is worth the effort but rather how much the cost will be if no effort is made to introduce this innovative opportunity into an existing curriculum.

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ADDENDUM A: THE SCIMATHUS PROGRAMME – UNIVERSITY OF STELLENBOSCH

Overview of SciMathUS

SciMathUS is part of the Institute for Mathematics and Science teaching (IMSTUS) of the Department of Curriculum studies in the Education Faculty of Stellenbosch University.

What is SciMathUS?

SciMathUS is post-matriculation programme (or pre-higher education programme) focusing on three main subjects, Mathematics, Physical Sciences and Accounting.

The programme addresses

- Academic preparedness
- The development of general and discipline-specific learning strategies
- Barriers to learning

Why SciMathUS?

- Less than 60% of high school candidates attempt Maths
- Less than 10% of high school candidates attempt Higher Grade (HG) Maths
- Less than 5% of high school candidates pass HG Maths
- Less than 28% of high school candidates pass Maths (HG and SG)
- Less than 22% of high school candidates pass Physical Science

Research shows that:

- 5% of Grade 12 students pass Maths on HG
- Less than 20% pass Grade 12 with endorsement
- Between 50% and 70% of school leavers are underprepared in Maths, as well as writing and/or reading skills

How SciMathUS works

SciMathUS is an opportunity to improve Maths, Science and Accounting for gaining entry into higher education institutions (studies in Economic & Management Sciences, Natural Sciences, Applied Natural Sciences).

<u>Admission requirements for SciMathUS</u>
Students need to obtain a minimum of 50% SG in the subjects Mathematics and/or Physical Science to gain access to the programme.

<u>Admission requirements for access to higher education institutions</u>
Entry requirements range between 50% and 70% HG for Mathematics and/or Physical Science.
Entry requirements for Economic and Management Sciences (especially BComm and Financial Accounting): a minimum of 50% HG in Mathematics.
Entry requirements for Engineering and Medicine: a minimum of 70% HG in both Mathematics and Physical Science.

The programme further:

- Develops multiple facets of each individual to prepare for studies at a higher education institution.
- Contributes to Stellenbosch University's role as a knowledge partner.

Education formats

- Classes start at 08h00 and end at 16h00.
- 65-75 students are selected.
- Accommodation is arranged for students who reside far from the university
- Access is provided to facilities such as lecture halls, laboratories, computer centres, libraries, etc.
- The programme is funded predominantly by the private sector.

The curriculum

- Adopts a holistic approach to education.
- Students develop:
    - General academic skills
    - Language proficiency
    - Effective study skills
    - Life skills
    - Computer literacy
    - Communication skills
- A problem-based learning approach is used
    - Thinking
    - Reasoning
    - Analysis
- The following university subjects are completed in the curriculum
    - Statistics (Introduction to first year statistics)
    - Information systems (Introduction)
    - Financial accounting (Introduction to first year Accounting)
- Upgrading from Maths Literacy to
    - Mathematics
    - Physical Science

Literacy and Numeracy tests

Pre- and post-testing (AARP-tests, 2007) revealed the following

- Maths in thinking and analytic ability increased by a factor of 3
- Language proficiency improved
- Vocabulary improved
- Extrapolation decreased

Success stories (2007)

Eight Ex-SciMathUS students graduated in 2007 in: HonsBSC Human Life Sciences, HonsBSc Physics, BSc Human Life Sciences, B Eng Mechatronics, B Acc, B Comm Fin Acc (2 students) and BA Humanities

ADDENDUM B: PBL PROBLEMS 2007

Problem 1: Problems for Palmiet Power Plant outing

What you can expect this year:

This year you may experience that your classes are quite different than what you were exposed to at school. You will be challenged to work cooperatively in groups while you try to seek solutions to real world problems that we all face on a regular basis in our daily lives.

Upon closer inspection the problems you will be exposed to might be unlike any problems you have experienced at school. Not much information will be provided, and what you are asked to find might not always be crystal clear. You may sometimes even feel frustrated and lost especially when your lecturers do not provide you with ‘correct answers’. Sometimes you may find yourself wondering, “So what do we do? How do we start? How do we know when we are through?” These are all questions to which you and your group must find the answers.

You will have many questions on your way to finding solutions and sometimes you may find that there are no clear or easy solutions or any solutions at all. With some questions your facilitator may be able to guide you, whilst others you must answer for yourself. These problems will help you develop and demonstrate your problem solving and critical thinking skills; skills that are essential in order to cope at university. So good luck, have fun this year! Enjoy the amazing journey of learning and discovery!

“Global warming”

“Hi, did you watch ‘Sewende Laan’ last night? Oom Oubaas is now really fixed on global warming.” says Lebo for Stacey.

“Yes,” answers Stacey “the rules he set up for the people are ridiculous. I think it is nonsense. The whole thing about global warming is totally unnecessary. We still have enough water and power. The weather also has not changed yet!”

“Wow, I don’t know about that. We watched the movie ‘Inconvenient truth’ at school last year and it was scary! I think we should really pay attention to the issue and start doing something about it.” says Tessa.

“What is the movie about?” asks Lebo.

“It is about the causes and implications of global warming. Maybe we can ask the people at Palmiet to explain it to us.”

“Do you know what will be cool? To motivate everybody at Scimathus this year to make a difference regarding global warming.” says Stacey.
“I think I should stop being naive and find out what is going on.”

Now all three girls are phsyced up.

“Where do we start?” asks Lebo

"Let's first collect information – everything we should know; from causes, implications economic implications, precautions. We can even look at the chemistry thereof-how do the gases and pollution influence global warming."

"It sounds like a nice challenge." says Tessa. "Let's make a poster of all our findings and present it to our friends. We can then motivate them to make a difference and become involved!"

Instructions

- Do this task on behalf of Lebo and her friends.
- Group A and B focus on the scientific aspects and group C on the economical implications.
- Make use of the given sources as well as any extra sources.
- Represent your findings on a poster.
- Make use of the given rubric as indication of the criteria for the posters.
- Assessment of poster presentations: 8 February

Criteria	0/1/2/3
Headings	
Logical and self explanatory lay out	
Neatness	
Readable, language and spelling	
Summarizing character of poster	
Reactions on questions (Insight, etc.)	
Total: 18	

Problem 2: The Amazing Race

Outcomes

Given a map and clues to find specific destinations, students should be able to:

- Work together as a group.
- Interpret the clues and follow the instructions.
- Read the map to find the specified destinations.
- Note the route as well as the time they have taken to find each destination.
- Use the scale to calculate the distance covered.
- Use the map to determine the displacement from one point to another.
- Be able to reconstruct their route using sketches and words.
- Calculate the average speed and velocity for the route.

- Decide on appropriate units to use.
- Calculate area.

AMAZING RACE
FIRST CHALLENGE

Congratulations!
You are one of the chosen groups for “Amazing Race SciMathUS”. You have already done the introduction and now it is time for serious stuff. For your first challenge you have to wear comfortable shoes and a hat and remember to take a bottle of drinking water. Follow the clues given below. Each group should also take along:

- The map and clues provided
- R2
- Pen
- Note book
- A small container with a lid

The rules of the game:

- The group has to stay together in all circumstances.
- The group must have at least one cell phone, in working order, with air time. Punch Rudi’s number in (0824485984).
- You have to take note of the route you follow as well as the time taken between the destinations.
- You have to complete the race as fast as you can without skipping any of the clues and without taking any detours.
- You have to complete the calculations in the conference hall.
- Rudi will decide who the winner is and his decision is final.

Clue 1
Hamba uye ePosin uyothenga istampu sencwadi.
Uzakufumana i Post Office ekoneni yase x Avenue kunye nasesitalatweni sakwa y.
$x+y=4$
$x<y$

Clue 2
Slaap
Wat is die slaap ‘n wondersoete ding!
Sag op haar blou oë daal die vaak
Soos maneskyn diep waterkuile raak
Om daar te droom in silwer skemering
DF Malherbe
Hierdie Afrikaanse digter was baie lief vir die see en het gereeld op die bankie voor sy huisie by die see gesit en mediteer. Hy het behalwe gedigte ook verskeie boeke geskryf waar onder andere die boek Hans-die-Skipper in 1929. Soek sy huis en vind die plaat agter die lae muur voor sy huis. Skryf die woorde op die plaat neer.

Clue 3
Cross the foot bridge to the beach.

- Collect sand in your small bottle

- Each of you must collect, from the beach, one other object with special meaning to you personally.

Clue 4
Return to the Conference centre. Check in with Rudi. You will now receive the final challenge.

AMAZING RACE
FINAL CHALLENGE

Congratulations, you have completed the first challenge of the race!!! You have now collected all the information that you need to answer the following questions.

1. Describe the route that you have taken using words and a sketch.
2. How long did you take to complete the race?
3. What is the distances you traveled between the clue points?
4. What is the total distance from the starting point to the end point?
5. Find the average speed that you traveled at.
6. Use your map to measure the displacement between the different clue points.
7. What is the total displacement of the race?
8. Are the answers to 4 and 7 the same? Explain.
9. Determine the average velocity with which you completed the race.
10. Calculate the total area bounded by the straight lines joining all the consecutive 'clue-points', that is the starting and end points included.
11. Write a letter to Mss Lourens, Marnewick and Malan of at least 50 words but not more than 70 words to describe your experiences of the race. All of the group must sign this letter. Address it to Ms Poole; IWWOUS; Private Bag X1; Matieland; 7602

So far so good. You are almost there.

Post your letter. Remember to stay together as a group.
At least one person must know the poem by heart.

You are one step from completing the race.

One person must recite the poem for Rudi.
Show Rudi your treasures from the beach and hand in your answers.

WOW!

NB!!!! Bring your answers as well as all your trigonometric instruments to class on Monday!!!!

Problem 3: The Two Oceans Marathon Problem

TWO OCEANS

You are a member of the Sports Analysis Department of SAS and received the following e-mail.

Dear Sir/Madam

Re: Analysis of Results of 2007 Two Oceans Marathon

As agreed at our last meeting, the Sports Analysis Department of SAS will analyze the data collected during the 2007 Two Oceans Marathon and will possibly make recommendations regarding the data to be collected in the 2008 Two Oceans Marathon.

In particular the strategies employed by the women in the Veteran Category (40-49 years) are to be analysed by comparing the times recorded for per split of the first women, a representative/average women and the last women in this category. (See attachment).

In 2007 the only data that was collected was the time taken by each athlete to cover certain distances. This time was measured as the athletes crossed a mat at the 4 splits (28 km and 42,2 km at 5km 24km 35km 42km) and the finish line (see http://www.seiko.co.jp/en/experience/sports_timing/roadevent.html).

The organizing committee would also like to determine the *speed* of each athlete at each of the split points and at the finish line but is not sure whether sufficient data has been collected. The committee therefore requests that your department either calculates the speeds at each split points of each of the women whose times are to be analysed **or** that you make a recommendation regarding how to obtain these measurements in 2008.

The analyses and recommendations are to be presented in the form of a report (not more than 5 pages) including the following:

- A clear summary of the relevant data in an excel table
- Graphical representation of the relevant data using an excel graph
- Analysis of the relevant data
- Speed of each woman at each split **or** recommendation regarding the measuring of the athletes' speeds at each split
- Explanation of how speeds were calculated **or** explanation of why the recommended means of measuring speed will be effective

The report is to be emailed to Ms Pool (apool@sun.ac.za) by the 25 July 2007 17:00.

Yours sincerely
The Organising Committee of the Two Oceans
Ms M Marnewick, Ms E Lourens, Ms S Malan, Ms I Mostert, Ms E Beyers

Do we want them to say that this person started off running too fast compared to the rest of the race or that this person started off too fast compared to the other people in their league?

ADDENDUM C: CONCEPTUAL MAP: PBL AND THE INTEGRATION OF THE CURRICULA FOR MATHEMATICS AND SCIENCE

Physical science	**2006**	**Mathematics**
• Displacement • Forces • Velocity, displacement, acceleration • Graphs of motion • Newton's laws • Gravity	1. Short integrated PBL problem 2. Short integrated PBL problem	• Solving equations • Functions • Euclidian Geometry • Basic graphs from data • Interpreting graphs • Solving triangler • Trigonometry • Graphs
• Momentum • Gasses • Solids and liquids • Solutions • Redox reactions and reaction rates • Equilibrium • Acids and bases • Volumetric Analysis • Organic chemistry	3. **Pedestrian fatalities** (also integrated statistics)	• Inequalities • Exponents and logs • Transformations of functions and graphs • Double & compound angles • Absolute value • Concurrency • Euclideon Geometry
• Inorganic chemistry • Electrical energy and power • Electrostatistics • Electric fields & potential difference • Electrical currents • Electromagnetism	4. Electricity **PBL Crossed circuit** (Energy used in a household) PBL: Spring break	• Linear programming • Trig equations • Analytical geometry • Sequences and series • Calculus • Similar triangles

Physical science	2007	Mathematics
• Condensed phases • Solutions • Gasses • Reaction rate • Equilibrium • Acids and bases • Volumetric analysis	**1. Palmiet power plant** (For science it provided a broad overview and created a need for electricity and energy transfer) PBL: Cooking pasta PBL: Riverside PBL: Small problems in maths classes	• Functions • Graphs • Inverses • Transformation • Interpretation • Linear programming
• Organic chemistry • Redox reactions • Inorganic chemistry • Displacement • Vectors • Speed, displacement, acceleration • Newton's laws • Power • Energy	**2. Amazing Race** PBL: An organic disaster PBL: An electric idea Students presented work	• Trigonometry • Solving trigonometry equations • Similar triangles
• Equations of motion • Graphs of motion • Electrical energy & power • Electrostatistics • Electrical fields & potential difference • Electrical current & magnetism • Resistance	**3. Two Oceans Marathon** PBL crossed circuits PBl Springbreak PBL small problems in class	• Differential Calculus • Analytical Geometry • Sequences and series • Euclidean Geometry

ADDENDUM D: THE PILOT PHASE OF THE STUDY

The following was tested during the pilot phase of the study

January 2006:
Staff training

- Staff training
    - Orientation towards PBL
    - Writing of PBL problems
    - PBL block construction
    - Facilitation skills
- Staff PBL planning session

February 2006:

- Student PBL orientation commences (6 weeks)
- Students complete SDL Learning Style Inventory

March 2006:

- Student interviews regarding training (Orientation weeks)
- Staff working together in the curriculum restructuring of discipline content and design of PBL problems for Mathematics and Science for the 2nd semester (Management was not included during the design phase)

April 2006:

- Implementation of PBL Project (6 week project block)
- Student interviews
    - General PBL experience
    - Experience with working on the problems
    - Experience with working in groups
    - Experience with the PBL 7-jump approach
- Teacher feedback of student assessment results
- Teacher interviews and focus groups
    - Teacher experience of PBL
    - Reflections on problems
    - Suggestions for improvement

June 2006:
Due to assessment results the lecturers of Mathematics, Science and Academic Literacy worked together in the design of shorter PBL problems (using Clearinghouse as a resource)
Change to Hybrid PBL approach

July 2006:

- Implementation of shorter PBL problems in Mathematics and Science classes (forming part of the curriculum)
- Class observations

August/September 2006:

- Class observations
- Interviews with students and lecturers
    - Experiences of Integrated PBL approach vs. Project PBL approach

    - Experiences with bigger, once-off problems vs. smaller, regular problems
- Attendance of Henk Schmidt's presentation at UCT:
    - Outcomes of PBL: curricular comparison (including the alumni study)
    - What happens to the learner in the PBL process
    - The cognitive Psychology of PBL
    - Active learning
- Attendance of Montana University's Online conference: Retaining under-prepared students

October 2006:

- Strategic planning session commences on 16 October (Includes management and lecturers)
    - Planning of implementation of PBL-innovation in 2007
    - Finalizing PBL model
    - Review of problems and design of more PBL problems (management included in the design phase).
    - Review of curriculum restructuring
    - Finalizing evaluation

ADDENDUM E: FOLLOW UP QUESTIONNAIRE FOR 2006 STUDENTS

Dear ….

Ms Malan here. Hope you're still coping well with your studies.

I need a very important favour from you. I urgently need your comments to the following questions. The questions focus on the PBL (problem based learning) experiences you had last year and whether you are benefitting at all this year from what you've learned being exposed to PBL. We need your inputs for a very important conference next year in Mexico. Would you be so kind as to answer the following questions for me.

1. To what extent are you capable of using and applying the skills that you've learnt in PBL to your current studies?

2. What in your environment at the university makes it easy/difficult for you to develop the skills that you've learnt in PBL?

3. What skills that you've learnt in PBL are you still developing in your first year. Explain.

4. Do you currently attend classes that have a similar approach to what you've experienced in PBL? Explain. If not, explain how the classes are conducted.

5. Do you still benefit from the skills that you've learnt in PBL? In what way or if not, why not?

6 How beneficial were the skills that you've acquired through PBL in preparing you for your university studies? Explain

7. Did PBL equip you to work more independently? Explain

Thank you so much for your inputs. Promise me to never give up on yourself! You have everything it takes to make a success of your life!

ADDENDUM F: EXAMPLE OF DATA DISPLAYS

	Prior to PBL	After P1	After P2	After P3
Cognitive processing strategies	1 F1: **Deep processing**: 8 responses indicated the importance of understanding. “*I go through the notes,* understand the *contents then try to answer the questions related to the chapter concerned”*. 2 F1: **Critical process**: 1 response indicated the importance of making deductions. *“Die beste manier om jou werk te kan leer is om dit te verstaan en afleidings te maak”*	21 F1: **Deep processing** Views on the PBL problem & thinking, understanding and skills. Students: *“… we enjoy the problems, it gives us insight.”* Lecturer: *“… they realize how important it is to reason logically.”* The PBL problem also assisted lecturers in assessing misconceptions and lack of understanding in students. *“Die studente weet nie x en y is getalle nie. Hulle dink dis deel van die alfabet.”* PBL leads lecturers to deep processing of their subjects. *“Dit laat jou werklik diep na jou vak kyk.”* 21a T **Encourage:** Ask why to improve understanding 22 Deep processing (relating/structuring) **F2: Reproductive directed** (Lack F1: Deep processing) *“Met die wiskunde probleem kom mens agter dat hulle nie by die diepte vd probleem uitkom nie.”* *“Aanvanklik het hul baie wyd na die problem gekyk en wil*	1 F1: **Deep processing** Views on the PBL problem & how it expands and challenges their thinking. Students: 4/8 groups responded with: *“You think beyond your set boundaries.””It broadened our minds to think outside of the box.” ”It develops your thinking.” “Dis uitdagend en jy leer baie.”* The PBL problem assisted lecturers in discovering misconceptions & assessing thinking flaws/fallacies made by students: *“Baie het gesukkel met die skaal, bv om hul antwoorde in mm te gee...en meer goed het toe uitgekom as wat beplan is.” “Studente kom uit met goeie vrae. Dis exciting met wat die studente uitkom. Dis interessant hoe hul nog steeds aannames maak.” “On day 2 it was clear that many still made the mistake of working on assumptions”.* The PBL problem assisted lecturers in (continue)	1 F1: **Deep processing**: 3 students indicated that they are more inclined to think critically, make their own deductions and question things more when studying: “*I question things more and don’t just accept things.” “Yes, there is a change. I realized not everything can be taken for granted like we did at school but that I have to work very hard and think well.” “I’ve learnt to think more critically; not just to accept things that are given to me but also to question it.”* A minority (3) of students are employing critical processing learning strategies in their studies (such as forming their own views, drawing their own conclusions and being critical of conclusions drawn by textbook authors and teachers. CONTINUE

ADDENDUM G: CRONBACH'S ALPHA INTERNAL RELIABILITY FOR THE DIFFERENT CONSTRUCTS ON THE ILS AND MEAN SCORES FOR THE PRE- AND POST EVALUATION RESULTS

Constructs	**α (Pre-test)**	**α (Post-test)**	**Mean scores for pre-test results**	**Mean scores for post-test results**
F1: Meaning directed learning patterns	.89	.87	3.35	3.32
Relating and structuring	.66	.68	3.10	3.20
Critical processing	.70	.54	2.91	2.95
Self-regulation of learning process/outcomes	.67	.75	3.27	3.24
Self-regulation of learning content	.61	.70	2.96	2.90
Construction of knowledge	.72	.62	4.09	3.82
Personally interested	.42	.10	3.33	3.26
F2: Reproduction directed learning patterns	.83	.86	3.61	3.47
Memorizing	.59	.55	3.45	3.40
Analyzing	.71	.70	3.20	3.37
External regulation of learning process	.62	.55	2.87	2.81
External regulation of learning outcomes	.61	.33	3.42	3.53
Intake of knowledge	.71	.67	4.00	3.66
Certificate directed	.58	.62	4.09	3.81
Self-test directed	.62	.53	4.14	3.72
F3: Undirected learning patterns	.77	.87	2.91	2.98
Lack of regulation	.50	.54	2.37	2.58
Stimulating education	.80	.85	3.65	3.39
Co-operation	.73	.80	3.25	3.21
Ambivalent	.46	.73	1.81	2.42
F4: Application directed learning patterns	.41	.70	4.41	4.15
Concrete processing	.74	.68	3.30	3.46
Use of knowledge	.44	.75	4.32	4.16
Vocation directed	.02	.32	4.53	4.14

ADDENDUM H: MEANING-DIRECTED LEARNING PATTERN (F1) – no change (p=.706)

Learning components	**Prior to PBL** Qualitative data N=35	**During PBL (P1, P2, P3)** Qualitative data N= 8 groups	**After PBL** Quantitative & Qualitative data N=35
Activities (SRL) (Deep processing) **COGNITIVE PROCESSING** Relating & structuring Critical processing **META-COGNITIVE REGULATION** Self-regulation of learning process Self-regulation of learning content	**Relating & Structuring** 0/35: indicate importance of relating & structuring 8/35: indicate importance of understanding, deductions **Critical processing** 0/35: indicate critical processing **Self-regulation (learning process)** 1/35 indicate importance of SR (by setting up own questions, testing yourself, using own words, prioritizing, creating own examples) **Self-Regulation: (learning content)** 0/35 consult other resources	**Relating & structuring** P1: 8/8 insight & understanding reasoning logically P2: 1/8 built on prior knowledge & noticed connections P3: 7/8 noticed connections (improved conceptual understanding) P3: 2/8 built on prior knowledge **Critical processing** P1: 1/8 evaluate answers P1: tutors encourage deep processing: ask why P1: assess misconceptions, fallacies, lack of understanding, encourage thinking & deep processing in T & L P2: 4/8 challenged thinking P3: 6/8 express own opinions, form own conclusions, assess level of understanding (build confidence & creativity). More ways to solve a problem **Self-regulation (learning process)** P1: 8/8 Self-regulation (brainstorming, planning, rereading questions, diagnosing problem, identify key issues, speculating, asking own questions, monitoring progress then textbook and tutors P2: 5/8: Self-regulation (brainstorming, establishing goals, rereading questions, assessing understanding, prioritizing, monitoring progress, coming up with & testing own solutions) then textbook & Tutors P3: 8/8 Self-regulation (brainstorming, strategizing, delegating, diagnosing problem, ask own questions, monitor progress via group feedback, reflecting, adjusting, testing & evaluating own solutions then textbook and tutors **Self-regulation (learning content)** P3: Extra research (consult sources outside syllabus & approaching outside experts) **Teaching activities or functions**: <u>Tutors encourage SRL:</u> P1: via questions (Think of the viability of solutions, pro's & cons, reflect & adjust & monitor approaches) P2: put questions into own words P3: answer questions with more questions **Control:** P1: 8/8 no need for more ext control P2: 3/8 Need more internal control P2: 1/8 tutor the tutor P3: 3/8 Need more internal control Destructive friction P2: Ignored tutor recommendations Destructive friction P2: Tutors offer support when not needed Constructive friction P3: Tutors offer support when needed	**Relating & structuring:** <u>Quantitative</u>: Slight increase (p = .78) <u>Qualitative</u>: 18/35: indicate importance of clear thinking, relating, structuring (enhance understanding) Activities: important points on mind maps, examples, relate chapters, make summaries, etc. **Critical processing:** <u>Quantitative</u>: no change (p =.80) <u>Qualitative:</u> 3/35: indicate critical thinking, make own deductions, question things **Self-Regulation: (learning process)** <u>Quantitative:</u> no change (p=.84) <u>Qualitative:</u> 19/35 indicate importance of SR (by being more active & taking on more responsibility, planning, using own words, asking own questions, taking initiative, being self-disciplined reflecting) – improve **Self-Regulation: (learning content)** Quantitative: no change (p=.50) <u>Qualitative:</u> 0/35 consult other resources

Learning components	Prior to PBL Qualitative data N=35	During PBL (P1, P2, P3) Qualitative data N= 8 groups	After PBL Quantitative & Qualitative data N=35
Change in consciousness (beliefs) (SDL) **LEARNING CONCEPTIONS** Construction of knowledge **LEARNING ORIENTATIONS** Personally interested	**Construction of knowledge** 0/35 no learning conceptions regarding construction of knowledge noted 12/35 indicate importance of learner independence and responsibility in gaining knowledge	**Construction of knowledge** P1: 1/8: note importance of discovering new ways of solving problems P1: 8/8 (noted by tutors) Groups constructing own learning issues, writing the curriculum, (reaching more than intended outcomes) P2: 8/8 (noted by tutors) leads to unexpected outcomes (students ask good questions) P3: 8/8 (noted by students and tutors) contributing own ideas, listening to & respecting others' views, asking own questions, look at problem form different angles, create own solutions **Beliefs about control:** 1/8 need more ext reg when topics are new	**Construction of knowledge** Quantitative: Significant decline (p=.008) Qualitative 5/35 indicate importance of learner independence and responsibility when constructing own knowledge 30/35 conflicting feelings about learner responsibility in constructing knowledge
	Personally interested 7/35 indicated affective factors for conducting their studies (fun, passion, self-growth)	**Personally interested** P1: 2/8: PBL is fun (group work and getting to know each other P1: (tutors) Worthwhile experience P2: 6/8: PBL is fun, informative, exciting, interesting, and worthwhile P3: 8/8: Fun, builds confidence, challenging, informative, exciting, interesting and worthwile	**Personally interested** Quantitative: No change (p=.55) Qualitative: 3/35 studying out of interest for their subjects or to develop themselves as a person 13/35 pursue studies for self-development purposes

ADDENDUM I: REPRODUCTION-DIRECTED LEARNING PATTERN (F2) – slight decline (p=.049)

Learning components	**Prior to PBL** Qualitative data n=35	**During PBL(P1, P2 & P3)** Qualitative data n=8 groups	**After PBL** Quantitative & Qualitative data n=35
Activities (SRL) (Stepwise processing) **COGNITIVE PROCESSING** Memorizing Analysing **META-COGNITIVE REGULATION** External regulation of learning process External regulation of learning outcome	**Memorizing** 20/35 indicate stepwise processing focusing on memorizing (learning facts, definitions, etc. by heart by rehearing them) **Analyzing** 20/35 indicate stepwise processing focusing on analyzing (going through subject matter in stepwise fashion, studying separate elements thoroughly, in detail and one by one) **External regulation (learning process)** 6/35 indicated external regulated strategies (study different learning material the same, do just what is expected, and answer questions from text books) **External regulation (learning outcomes)** No external regulation of learning outcomes noted in data	**Memorizing** No memorizing data noted **Analyzing** P1: 1/8 analyze problem first before looking for more information P1: (Tutors) at beginning students look to wide at math problem – try to solve it as a social problem P2: 1/8 use a systematic approach P3: 6/8 analyze the problem first P3: 3/6 indicate stepwise approach due to questioning in problem statement **External Regulation (learning process)** P1: 3/8 indicate Ext Reg by expressing a 'right answer' mentality P1: right answer mentality leads to need for Ext control from tutors P1 & P2: 3/8 Ext Reg (seek advice from tutors, group members, text books then attempt it self - due to unclear questions in problem statement and newness of topics) P3: 4/8 Ext Reg (seek advice from tutors, group members, text books then attempt it self - due to unclear questions in problem statement) P3: 4/8 Right answer mentality leads to need for Ext control from tutors or problem statement **Teaching** P2: Tutors experience relinquishing control as strange **Control:** P3: 4/8 Need Ext control at the beginning (when confused about problem or when problem is too challenging or questions too vague) Constructive friction: 1/8: stimulating not to get support Destructive friction: 1/8: Consulting tutors led to more confusion or choosing the easy route **External regulation (learning outcome)** P3: 4/8 monitored their progress & tested outcomes Ext (by approaching tutors or text books)	**Memorizing** <u>Quantitative:</u> No change (p=.69) <u>Qualitative:</u> 5/35 indicate stepwise processing focusing on memorizing **Analyzing** <u>Quantitative:</u> No change (p=.24) <u>Qualitative:</u> 11/35 indicate stepwise processing focusing on analyzing **External regulation (learning process)** <u>Quantitative:</u> No change (p=.64) <u>Qualitative:</u> 4/35 indicated external regulated strategies (guided by examination questions or questions of teachers) **External regulation (learning outcomes)** <u>Quantitative:</u> No change (p=.24) 4/35 indicate testing learning outcomes externally (comparing their answers to tests, exercises or notes provide by teachers)

Learning components	Prior to PBL Qualitative data N=35	During PBL (P1, P2, P3) Qualitative data N= 8 groups	After PBL Quantitative & Qualitative data N=35
Change in consciousness (beliefs) (SDL) **LEARNING CONCEPTIONS** Intake of knowledge **LEARNING ORIENTATIONS** Certificate directed Self-test oriented	**Intake of knowledge** 1/35 views learning as the intake of existing knowledge 1/35 views learning as the improvement of skill 35/35 indicate that the teacher should teach well, drive the learning process, provide the learning tasks, challenge students, lecture in a stepwise fashion, provide clear instructions and pressure students to perform. **Certificate oriented** 15/35 are mainly motivated to study for the purpose of passing exams & obtaining a degree **Self-test oriented** 5/35 indicate a self-test orientation to prove to themselves & others that they can cope in higher education and to realize their dreams (i.e. role models in community) 2/35 indicated they were conducting their studies in order to support their families	P1: 2/8 PBL broadened their knowledge base P2: (Tutors note): Students who view learning as intake of knowledge by reproducing facts experience PBL negatively (feel insecure with process) P3: 4/8 demand clearer questions and more specific information from problem statement No learning orientation data (certificate & self-test oriented) was noted during P1, P2, and P3	**Intake of knowledge** Quantitative: Significant decline (p=.0004) Qualitative: 23/35 still view most learning activities regarding the intake of knowledge as the task of the teacher. **Certificate oriented** Quantitative: Significant decline (p=.04) Qualitative: 11/35 are still mainly certificate oriented although this is not their primary purpose for conducting their studies **Self-test oriented** Quantitative: significant decline (p=.003) Qualitative: 6/35 indicate conducting their studies to prove themselves

ADDENDUM J: UNDIRECTED LEARNING PATTERN (F3) – no change (p=.41)

Learning components	Prior to PBL Qualitative data N=35	During PBL (P1, P2, P3) Qualitative data N= 8 groups	After PBL Quantitative & Qualitative data N=35
Activities (SRL) **META-COGNITIVE REGULATION** Lack of regulation	**Lack of regulation** 1/35 indicated monitoring difficulties with the regulation of own learning processes (experiencing uncertainty when writing)	P1: 4/8 express lack of regulation (underestimate problem statement, lack group role performance, bad time management, struggling with information processing, unaware of credibility of different types of resources) P1: Tutors note: Students not using resources unless encouraged, no in-depth research, do not read articles with questions I mind, going off on tangents before thinking problems through P1: 1/8 based decisions on gut instead of facts. P1: 1/8 acknowledged that PBL helped them guard against impulsive thinking P3: 3/8 express lack of regulation (underestimate problem statement – especially accounting students P3: 8/8 express lack of regulation in the beginning of the PBL process (leading to planning strategies) 1/8 resorted to guesswork P3: 3/8 expressed anger, quarrels, & boredom P3: Tutors note: going off on tangents before thinking problems through **Control:** P1: Ext reg in 1st session, self reg in 2nd session & Ext reg last session (to answer questions and monitor student progress) P1: (tutors note) Students need more guidance P2: Self reg in 1st session, ext reg in 2nd and last session (when needed). P3: Self reg in 1st session, ext reg in 2nd and last session (when needed). 1/8 indicate lack of group role performance & a need for external regulation **Teaching** P2: 1/8 found floating facilitator model confusing	**Lack of regulation** Slight increase (p=.15) 1/35 indicate difficulties with the workload

Learning components	Prior to PBL Qualitative data N=35	During PBL (P1, P2, P3) Qualitative data N= 8 groups	After PBL Quantitative & Qualitative data N=35
Change in consciousness (beliefs) (SDL) **LEARNING CONCEPTIONS** Co-operative learning Stimulating education **LEARNING ORIENTATIONS** Ambivalence	**Co-operative learning** 0/35 indicate benefits to co-operative learning **Stimulating education** 15/35 indicate teacher should make learning fun, encourage, motivate, inspire and drive the learning process **Ambivalence** No learning orientation data noted	**Co-operative learning** P1: 8/8 indicate process skills experienced as positive (improved team work, active participation, clear allocation of roles, positive group dynamics, development of interpersonal skills such as respect & tolerance, motivation through encouragement, improved self-confidence, togetherness& leadership) P1: 3/8 indicate process skills experienced as negative (conflict, uneven distribution of tasks, negative group dynamics, bad role performances by scribe, lack of group rules) P2: 6/8 indicate process skills experienced as positive (increase in confidence, better teamwork and team spirit, co-operation, development of interpersonal skills, improvement in role performance of leaders) Reasons provided: Know & understand each other better More familiar with PBL process P2: 2/8 indicate process skills experienced as negative (lack of leadership, unequal delegation, increased conflict) Reasons: Same group formations used as in P2 P3: 8/8 indicate process skills experienced as positive (improved team work, active participation, clear allocation of roles, positive group dynamics, development of interpersonal skills such as listening, respect for diverse views, tolerance, trust, patience, encouragement) Reasons: Know, trust & support each other More familiar with PBL & combine skills effectively Respect diversity P3: 0/8 experience process skills negatively **Stimulating education** P1: no learning orientation data was noted P2: 1/8 disliked the running; 2/8 wanted more fun clues; 3/8 disliked the questions after the	**Co-operative learning** <u>Quantitative:</u> No change (p=.078) <u>Qualitative:</u> 1/35 mentioned co-operative learning **Stimulating education** <u>Quantitative:</u> significant decline (p=0.04) <u>Qualitative:</u> No data regarding stimulating education were noted **Ambivalence** <u>Quantitative:</u> Significant increase (p= <0.01) <u>Qualitative:</u> No ambivalent responses noted

		fun activity P3: 4/8 experienced problems as too demanding, tricky & tiring (led to stress, panic, discouragement) Led to relying on other members for support Accounting students felt excluded, isolated, sidelined **Ambivalence** No ambivalence data noted	

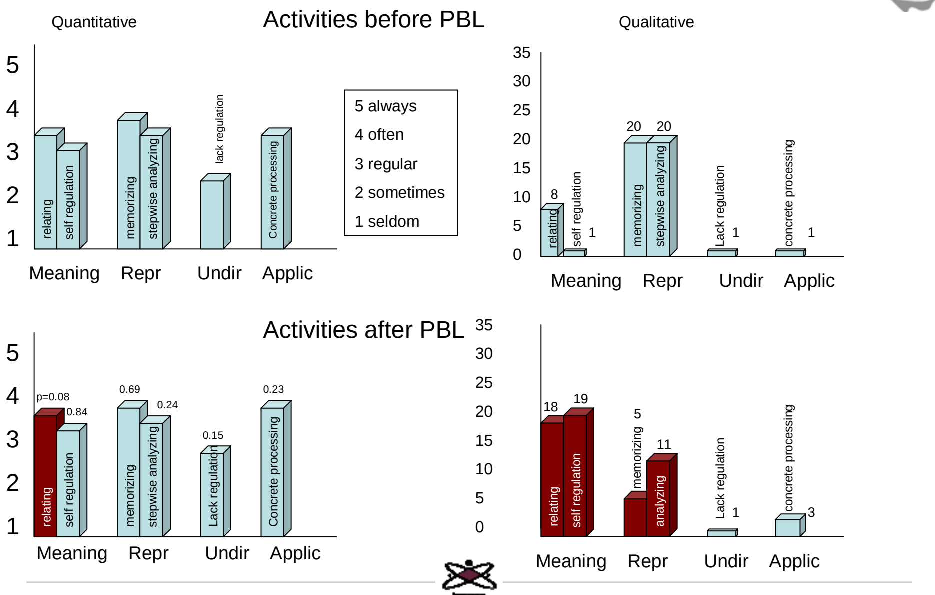
ADDENDUM K: APPLICATION-DIRECTED LEARNING PATTERN –no change (p=.003)

Learning components	**Prior to PBL** **Qualitative data** **N=35**	**During PBL (P1, P2, P3)** **Qualitative data** **N= 8 groups**	**After PBL** **Quantitative & Qualitative data** **N=35**
Activities (SRL) **COGNITIVE PROCESSING** Concrete processing	**Concrete processing** No concrete processing strategies noted	**Concrete processing** P1: 7/8 apply, practice & use subject matter in real life P2: 5/8 apply, practice & use subject matter in real life P2: Tutors note – it enhances deep processing strategies P3: 8/8 apply, practice & use subject matter in real life and experienced it as fun	**Concrete processing** Quantitative: No change (p=.228) Qualitative: 3/35 apply, practice & use subject matter in real life
Change in consciousness (beliefs) **LEARNING CONCEPTIONS** Use of knowledge **LEARNING ORIENTATIONS** Vocation directed	**Use of knowledge** 9/35 indicate importance of acquiring knowledge by means of concretizing & applying **Vocation oriented** 25/35 indicated the were motivated to study for the purposes of finding a job or embarking upon a career	**Use of knowledge** P1: 8/8 PBL enhanced application & use of knowledge P1: Tutors note – leads to increased understanding P2: no data on use of knowledge noted P3: 8/8 PBL enhanced application & use of knowledge **Vocation oriented** No vocation oriented data was found	**Use of knowledge** Quantitative: Slight decline (p=.15) 6/35 indicate importance of acquiring knowledge by means of concretizing & applying 1/35 allocated this responsibility to the teacher **Vocation oriented** Quantitative: Significant decline (p=.0003) Qualitative: 8/35 indicated the were motivated to study for the purposes of embarking upon a career

ADDENDUM L: OVERALL CHANGE IN LEARNING PATTERNS

SRL (ACTIVITIES)	SDL (BELIEFS)
MEANING-DIRECTED PATTERN Positive change (increase) in deep processing relating & structuring No change in critical processing Positive change (increase) in self-regulating (learning process) No change in self-regulating (leaning content) POSITIVE CHANGE	**MEANING-DIRECTED PATTERN** Negative change (decline) in learning conception (construction of knowledge) Conflicting feelings regarding self- and external regulation of learning processes Positive change (increase) in learning orientation regarding personally interested SLIGHT NEGATIVE CHANGE
REPRODUCTION DIRECTED PATTERN Positive change (decline) in surface processing: memorizing & analyzing No change in external regulation (learning process & outcomes) SLIGHT POSITIVE CHANGE	**REPRODUCTION DIRECTED PATTERN** Positive change (decline) in learning conception intake of knowledge Positive change (decline) in learning orientation certificate and self-test oriented POSITIVE CHANGE
UNDIRECTED PATTERN Negative change (increase) in lack of regulation NEGATIVE CHANGE	**UNDIRECTED PATTERN** Positive change (decline) in learning conception stimulating education Negative change (increase) in learning orientation ambivalence SLIGHT POSITIVE CHANGE
APPLICATION DIRECTED PATTERN No change in concrete processing NO CHANGE	**APPLICATION DIRECTED PATTERN** Negative change (decline) in learning conception use of knowledge Positive change (decline) in learning orientation vocation oriented SLIGHT POSITIVE CHANGE

Findings



Findings