CHAPTER 3

Investigating problem-based learning as a strategy to operationalise outcomes-based education in the training of pre-service technology teachers: Designing an OBE-PBL model

3.1 Introduction

In Chapter 2 the outcomes-based paradigm which lies at the heart of educational transformation in South Africa, was described. Where the previous chapter focused on the philosophical and systems dimensions of the paradigm, Chapter 3 will focus on a third dimension. This dimension comprises the challenge of translating OBE into practice. OBE in practice has major implications for training teachers, because it implies that teachers need to rethink the way they do their day-to-day planning, teaching and assessment. Teacher trainers therefore, need to rethink their training practices to align them with the prevailing OBE paradigm.

In this regard, problem-based learning (PBL), will become a major focus area for this chapter for two reasons:

- PBL has the potential as a teaching or training strategy to operationalise OBE in practice.
- PBL and the nature of technology education are inextricably linked and similar. Therefore, the potential of PBL for the training of technology teachers will be explored.

Each of the two aforementioned reasons, acting as driving forces for implementing PBL, will be discussed in more detail in this chapter. The final outcome of this literature-based chapter will be the construction of a meta-curriculum model which can be implemented when planning PBL training programmes for prospective pre-service technology teachers.

3.2 Outcomes-based education: From theory to practice

To be able to explore implementation of the OBE philosophy in practice, it is necessary to briefly be reminded of the purpose and premises of OBE on a praxis level.

3.2.1 Purposes and premises of OBE to be operationalised in practice.

The fundamental belief of OBE is that all learners can be successful in their learning so that they can eventually become successful in performing complex real life roles. For South Africa, these complex real life roles are contained in the seven plus five SAQA critical outcomes. When these outcomes are successfully internalised and demonstrated learners are believed to have the basic competencies which enable them to become lifelong learners and productive members of society. Therefore, the educational system, from the macro managerial level to the micro level in classrooms, should be structured in such a way that learners can indeed be successful (Spady, 1994b:9). This belief is based on the optimistic view of learner potential explicated in the following premises (Spady, 1994b:9-10):

- **All learners can learn, but not at the same pace and in the same way:** This premise acknowledges the different rates of learning and learning styles. It is important to note that barriers such as different learning rates and styles are not viewed as obstacles to learning, but as realities which have to be designed for in practice.
- **Successful learning promotes even more successful learning**: This premise suggests that learning success may be enhanced when learners have strong foundations of cognitive and psychological prior learning success.
- **Institutions such as schools and universities control the conditions that directly affect successful learning**: Institutions can restructure themselves, their courses, time schedules, methodologies and strategies for teaching, learning and assessment differently from in the past, to encourage and support all learners to be successful in attaining the immediate and real life performance competencies.

To put the OBE purpose and premises in action, teaching and training practice have to reflect very specific characteristics which differ from the traditional paradigm. Some of the characteristics of an OBE practice can be outlined as follows:

- ***Learning opportunities are learner-centred and not content or teacher-centred***

It is often believed that there are two broad approaches to teaching, namely teacher and learner-centred approaches. Killen (1998b:v) contends that, in some way, it is an unfortunate set of labels, because learning, and therefore learners, should be at the centre of learning. Never the less, *"these labels certainly convey the idea that in some approaches to teaching the teacher plays a more direct role than in other approaches"* (Killen, 1998b:v). Learner-centredness on the other hand, places the focus on the learner. This characteristic must be interpreted in its broadest sense. Firstly, it means that learners are not merely receivers of the curriculum, but participants in it. In learner-centred settings, learners are actively constructing meaning while accessing and utilising information in a variety of ways (Windschitl, 1999:752). They are not merely passively absorbing information by means of listening to what teachers have to say. This is in agreement with constructivistic theory where a learner constructs new knowledge based on prior learning (Hewson & Hewson, 1983:732; Novak & Gowin, 1984:xiii and Redish, 1994:1-21).

In traditional curricula, which are content-centred, the covering the content of the core curriculum was the purpose for all learning as explained in the discussion of the educational philosophies and their effect on curriculum development, teaching and learning in Chapter 2 Section 2.3. Whatever content was transmitted by the teacher mainly had to be memorised by learners and reproduced in assessment, which tended to encourage rote learning. Rote learning of content is also promoted when learning takes place outside a particular context that is meaningful for a learner. Often in the traditional paradigm where learners were expected to do something, the teachers believed that they had to demonstrate first, which implied that the learners had to imitate the teachers (Slabbert, 1996:30 and Boshuizen, 1994:5-6). Consequently, learners remained dependent on a teacher and did not necessarily become empowered as lifelong learners.

Learner-centredness entails more than using strategies which involve learners actively in their learning processes. It may also mean that the development of the whole learner and the society in which the learner has to function, is implied. While learner-centredness in OBE implies the holistic development of a learner, it also implies that every learner achieves the set of outcomes. Malcolm (1999:120) says that Curriculum 2005 commends processes as well as specific outcomes in its definition of quality education and by doing so "*it acknowledges covert learning about individuals, societies, human interactions and moral principals as outcomes of schooling*". In terms of science education for example, it means that instead of asking "what science should learners know", we should also ask "how will the science contribute to a learner's and a nation's life?". The point made here is that learner-centred curricula also acknowledges the learning and generic needs of learners. It seems an appropriate thing to do since a large-scale survey of schools learners in the United Kingdom for example reported that 20-30% were bored and disappointed with their school experiences, 10-15% were openly hostile and 5-10% were frequent truants (Malcolm, 1999:118). These figures show that about half of the learners disconnected themselves from their classrooms. This reality seems to imply that learner-centredness should attempt to align learner and teacher agendas. Advocates for learner-centredness also promote the idea that learners should have a say in the setting and interpretation of outcomes which they have to demonstrate, or else they may not value the official prescribed outcomes which might result in a percentage of the learner generation getting lost. This particular notion of learner-centredness is compatible with the mission of the humanistic curriculum which was discussed in Section 2.3.3.

The above mentioned interpretations of learner-centredness have one principle in common if learning is to be efficient and effective. This principle is responsibility on the side of learners and teachers. This important OBE principle will be elaborated in the next paragraph.

- ***Learners take responsibility for their own learning***

In OBE, learners are expected to take more responsibility for their learning than might be the case in traditional teacher-centred approaches. Learning opportunities should be designed so that the teacher allows learners to be accountable for their own learning by being actively involved in the learning process. By doing this, learners are empowered to become lifelong learners. However, this characteristic if often misinterpreted by teachers in that they perceive their role to be a laissez-faire one with reduced responsibility. This cannot be further removed from the truth. It is the teacher's responsibility to promote responsibility in learners. A teacher is ultimately accountable for his/her learners' quality of learning – that is their core business. Killen (1998b:v) explains that, when learner-centred approaches such as co-operative learning are used, the teacher still sets the agenda, but he/she has much less direct control over what and how learners learn. This is in line with the third OBE premise posed by Spady (1994b) which states that teachers and institutions are responsible for creating the conditions for learners to be successful.

- ***OBE is characterised by the principle of expanded opportunity***

This principle is inextricably linked with the belief of OBE which states that all learners can be successful. In order to provide learners with expanded opportunities which can help them to become successful, teachers must take a broad view of intelligence and capacity to learn. Basically the principle of expanded opportunity requires educators to give learners more than one chance for learning and demonstration of that learning, since not all learners learn in the same way at the same pace (Spady, 1994b:12). This means that, for example, time must be used as a flexible resource and that learners who did not understand a concept fully when the bell rang at the end of a period, should be provided with additional learning opportunities. This, however, does not mean that learners can take as long as they want to learn something or to complete their work. Learners must be responsible and accountable to meet the conditions which will "earn" them the expanded opportunities (Spady, 1994b:12).

Expanded opportunities can also be designed for in teaching and learning strategies and methods. In Chapter 2 Section 2.3.5 it was seen that post-modern classrooms are typified by pluralism and diversity in terms of cultures, world views, learning and teaching styles, learner capabilities, intelligence and interests. Much research has already been done on how to accommodate the variety of learning and teaching styles in classrooms (Dunn, 1984; Hyman & Rosoff, 1984 and Smith & Renzulli, 1986).

Gardner (1993:6) voiced his dissatisfaction with the unitary concept of intelligence with his vision of intelligence which is

> *... a radically different view of the mind, and one that yields a very different view of school. It is a pluralistic view of mind, recognizing many different and discrete facets of cognition.*

His vision and definition is in accordance with post-modern curriculum philosophy. He defines intelligence as follows (Gardner, 1993:7):

> *Intelligence is the ability to solve problems or to fashion products that are valued in one or more cultural or community settings.*

Gardner's (1993) framework for multiple intelligences distinguishes seven categories of which some are associated with the left and some with the right hemisphere of the brain (Jensen, 1994). The intelligences mainly associated with the logical-analytical left hemisphere of the brain are the following (Jensen, 1994:126-138 and Slabbert, 1996:162-163):

- **Mathematical-logical:** The ability to solve problems, do mathematics, troubleshoot, understand order and program.
- **Verbal-linguistic intelligence**: It constitutes the ability to perceive, interpret and produce language, speak, argue and debate. It is essentially verbal in nature.

The following intelligences are mainly associated with the right sphere of the brain:

- **Spatial:** This intelligence deals with one's relationships to objects and others. A mental model is constructed of a spatial world which is used to manoeuvre and operate in spatial reality, such as sport, dance, parallel parking, driving a truck and ice-skating.
- **Musical-rhythmic intelligence**: It deals with the ability to perceive, appreciate, make and compose music.
- **Bodily-kinesthetic intelligence:** It is the ability of control over bodily movement to solve problems. Bodily movement is localised in the motor cortex of the brain, where each hemisphere controls the movements on the contra-lateral side. It involves sport, exercise, mime, drama and acting.
- **Interpersonal intelligence:** It is the ability to relate with others and co-operate with

other people. It involves social skills, empathy, friendships and cultural bonding.

- **Intrapersonal intelligence:** It involves a relationship with the inner self. Meta-learning and its associated strategies such as planning, monitoring, evaluation, is thus the central determinant of intelligence (Sternberg, 1981). Intrapersonal intelligence reflects the characteristics of meta-learning which is reflection, introspection, self-assessment, vision and knowing weaknesses and strengths.

Another type of intelligence which is not cognitively based but which focuses on emotions, is called emotional intelligence (Goleman, 1995). The five domains of intelligence are knowing one's emotions, managing emotions, motivating oneself, recognising emotions in others and handling relationships. This type of intelligence becomes important for some of the critical outcomes which deal with collaboration in a team, handling conflict, group work, co-operative learning and managing oneself. Alongside Gardner (1993) and Goleman (1995), De Beauport (1996:xxvii) also redefined and reorganised categories of intelligence. She distinguishes between mental, emotional and behaviourial intelligence, with the following sub-categories of intelligences classified under each of the three main types:

The mental intelligences

- *Rational intelligence*: the process by which we perceive information through sequential connections, involving primarily the use of reason, logic, cause and effect.
- *Associative intelligence*: the process that allows us to perceive information through multiple connections, involving primarily the use of juxtaposition, association, and relationship.
- *Spatial intelligence*: the process of perceiving information at a deeper level, synthesized sometimes into images, sometimes into sounds, or other combinations received from the senses and deeper brain systems.
- *Intuitive intelligence*: direct knowledge without the use of reason; knowing from within.

The emotional intelligences

- *Affectional intelligence*: the process of being affected by something or someone; developing the ability of closeness with a person, place, object, idea, or situation.

- *Mood intelligence*: the ability to enter into, hold with and shift from any mood, whether the experience feels painful or pleasurable.

- *Motivational intelligence*: being aware of our desires and knowing what excites us and moves us the most; the ability to guide our life in relation to what we love.

The behaviourial intelligences

- *Basic intelligence*: the ability to move ourselves toward or away from; being able to imitate or inhibit anything or anyone on behalf of our own life or the lives of others

- *Pattern intelligence*: the ability to know the patterns governing our behaviour and being able to alter them when necessary.

- *Parameter intelligence*: the ability to recognize, extend, or transform the rhythms, routines, and rituals of our life.

These alternative conceptualisations of intelligence types provide teachers with more insight into learner interests and capabilities which need to be planned for in instructional design in terms of expanded opportunities which can enhance learner success and excellence.

- ***The role of the teacher has changed from that of teacher to that of facilitator of learning***

A teacher is no longer perceived as a transmitter of knowledge (Slabbert, 1996:30) and can therefore no longer only use teaching strategies such as direct instruction, deductive or expository teaching which are typified by a lecture format used for whole class teaching (Killen, 1998a:15 and Ornstein & Hunkins, 1993:44). Piaget (Armstrong, 1991:44) gave his impression of a teacher being more than an instructor when he said that a teacher's *"role should rather be that of a mentor stimulating initiative and research"*. Heidegger (Armstrong, 1991:48) explicitly describes facilitating learning when he says:

The real teacher, in fact, lets nothing else be learnt than – learning. His conduct, *therefore, often produces the impression that we properly learn nothing from him.*

Teachers are now designers, implementers and managers of learner-centred learning opportunities, earning them the name of facilitators of learning. It is important to note that teachers are not merely facilitators. Since their core business is to optimise learning for each learner, they are facilitators of learning. Whenever the term 'facilitator' is used in this work, it is meant to refer to facilitator of learning. This does not mean, however, that facilitators will never use the strategy of direct instruction again. A professional facilitator will be able to decide on the best teaching strategies, depending on the nature and purpose of a particular learning opportunity. If a section of a learning opportunity will be best served through direct whole class instruction, the professional facilitator will make the best decision and teach the class accordingly. As a facilitator of learning, a teacher will also give intellectual and emotional support to learners in their active search for and construction of knowledge. In a less structured learning environment, such as problem-based learning for example, the facilitator of learning might need to support learners more regularly on an emotional level. Learning in problem-based environments might not always be of the calm, rational kind but emotionally charged when learners experience failure and frustration (Claxton, 1999:26).

A teacher is also no longer the only authoritarian source of knowledge, but one of the many information resources available to learners (Department of Education, 2000a:15-16). They are more than instructors only. They are collaborators, mentors and coaches who should sustain an environment that promotes meaningful, successful learning (Seifert & Simmons, 1997:90). Pike (1989:67) elaborates on the actions to be demonstrated and roles to be played by facilitators of learning when he addressed a group of trainers in the following manner:

> *Our purpose as trainers is not primarily to counsel, interpret, instruct, or in any way lead people to believe that we are to supply the answers to their questions. Instead we should let the seminar, the instruments, the projects, the case studies, and the other materials serve as the resources that the participants can draw on to solve their problems and develop appropriate plans of action.*

> *The approach I recommend limits lectures and maximizes discovery and participation. Sometimes it may not seem that you are needed, but you are – often in ways that participants don't perceive. Ideally, you're the best kind of teacher - a facilitator of insight, change and growth who teaches that answers come from within.*

Killen (1998b:75-76) also describes various roles which a facilitator of learning will need to adopt, especially when learners are engaged in co-operative learning. When a group is not making adequate progress the role of *tutor* may be most appropriate. A tutor may provide additional information, explain things or simply answer questions. The role of *consultant* may be adopted especially when a group is unsure if their conclusions are valid due to a possible lack of knowledge of a subject. In the role of *discussion leader*, a facilitator might need to intervene to temporarily take on the leadership of a particular group by asking questions or making suggestions. This might happen when a group leader is temporarily unable to keep the group focused and productive. The role of *counsellor* is appropriate when group dynamics or conflict is interfering with the group's progress. The counsellor must help learners to focus on the task again and to understand group dynamics.

More roles of teachers as facilitators in the OBE paradigm, as presented in the Norms and Standards for Teacher Education (Department of Education, 2000a), will be attended to after this sub-section.

- ***OBE practice is characterised by collaborative and co-operative learning***

Midkiff (1990:13) identifies three situations in which learners may find themselves working in a classroom setup. They can *compete* with one another to see who is the best and according to Taylor (1991:245) traditional classrooms are characterised by competition. They can work *individually*, not needing one another or sharing ideas. They can *work together* in a way where each learner has interest in their own work, but also in that of their fellow learners. Sometimes, depending on the outcome to be demonstrated by the learner, it will be necessary to work with a combination of these situations.

In real life contexts, problems are seldom solved in isolation, because of the holistic and inter-related nature of real problems (Gorman, Plucker & Callahan, 1998:531 and Seifert & Simmons, 1997:91). It must be noted that although the OBE South African documentation suggests the use of team, group and co-operative learning (Department of Education, 1997b:38 and Department of Education, 1995a:32), is does not mean that learners should be forced to do all learning in this way. Killen (1998a:16) puts the focus on co-operative and group strategies in perspective when he explicates that "*co-operative learning should be used as part of any OBE system, but it is by no means the only teaching/learning strategy that should be employed*".

One of the aims of the General and Further Education and Training Bands supports this interpretation of implementing co-operative strategies in the following manner:

> *Develop in all learners the ability to work independently as well as co-operatively (as member of a team/group/organisation/community) when and where acquired.*

It must be stated at this point of the discussion that collaboration can be enhanced by using either learners working as *pairs, groups or co-operative learning* groups. These methods are not the same and a facilitator will have to know the differences when planning a learning opportunity with a certain outcome in mind. Davidson (Davidson & O'Leary, 1990:1) comments as follows on group work and co-operative learning groups:

> *Co-operative learning involves more than just putting students together in small groups and giving them a task. It also involves careful attention and thought to various aspects of the group process.*

It seems then that very specific *criteria* have to be met before the purpose of co-operative learning will be realised. The criteria for co-operative learning to qualify as co-operative learning, will briefly be presented (Johnson & Johnson, 1990:12 and Johnson, Johnson & Holubec, 1988:8-9):

- **Positive interdependence:** This means that a problem must be designed in such a way that each individual's contribution in the group is of the utmost importance to meet the final demands of the task. Successful completion of individual tasks which are part of the overarching group task, is a premise for success. It implies that individual learners depend on one another to achieve success.

- **Individual accountability:** In the overarching problem or learning task design, a task for which the individual learner is responsible, should be built in. To be successful as a co-operative group however, each individual learner in the group should have complete knowledge in terms of the what and how of *other individuals'* tasks in the group (Slabbert, 1996:237). The implication of this is that learners are compelled to question and teach one another on the what and how of their individual tasks (Johnson & Johnson, 1990:103-106 and Sharan & Sharan, 1987:22).

To enforce this accountability, any learner in the group can be nominated to score the work of the whole group. This criterion avoids learners becoming non-participative in the learning process. It was often the concern of teachers that learners who were not verbally participative in a group, did not learn in the process. However, Webb (1991;1992) reported in review of research on co-operative learning that the less verbally participative students in a group can and *do learn as well* as the more prominent group members.

- ***Person-to-person interaction***

In this interaction, not only a relationship with what is to be learnt is established, but also an interdependent one. This social relationship can be achieved when learners engage in assisting, helping, encouraging and supporting one another while solving a problem (Johnson & Johnson, 1990:103-106 and Sharan & Sharan, 1987:22).

- ***Social co-operative skills***

Social co-operative skills are important in any small group discussion as learners engage in the exchange of ideas, the construction of meaning and the interplay of personalities (Wilkerson, 1996: 29). Some of the social skills involved in co-operation include listening, soliciting opinions, encouraging explicitness, highlighting differences of opinions, synthesizing viewpoints and co-operating in the execution of a task (Wilkerson, 1996: 29). Johnson & Johnson (1987:109-123) give a broad summary of social co-operative skills which are related to those described by Wilkerson (1996):

- Communication skills.
- The skills to establish and maintain a climate of trust in one another.
- The skills to handle conflict in a constructive way.

Skills which also contribute towards effective group functioning are *equal opportunity* amongst group members and *rotation of roles* (Basson, Oosthuizen, Duvenhage & Slabbert, 1983:59). The different roles which learners can take on, depend on both the skills involved for executing the *learning task* as well as the *social skills*. These roles must change and rotate frequently to give learners the opportunity to practice each of the roles.

- ***Group size and group composition***

Groups may vary in size from two to six learners, but Kagan (1992:62) suggests that four is an ideal number. According to him this is the smallest group size which allows maximum interactive communication. Wilkerson (1996:24) however, takes a realistic view of group size when she says that group size is determined by the number of learners, how many facilitators or tutors can be recruited and how many rooms are available. Hare (1962) who reviewed studies on group size found that most PBL programmes prefer groups of eight or fewer, but concluded that five members were the most productive group size. Slabbert (1996:234) suggests that groups should be as heterogeneous as possible in terms of sex, ability, skills, races and culture. By doing this groups are provided with the biggest variety of resources available. Learners also learn how to deal with diversity and multiculturalism, which is a reality in post-modern classrooms.

3.2.2 Norms and Standards for South African Educators who need to facilitate OBE

The training practice of teachers should empower pre-service teachers to become competent in the designing and facilitation of OBE learning opportunities reflecting OBE charateristics. The aforementioned section gives a generic overview of what needs to be addressed in future OBE teacher training programmes. Since this is generic and very broad, the Norms and Standards for Educators (Department of Education, 2000a) can give more precise indication as to the "what" and "how" that need to be accommodated in OBE teacher training programmes for the South African context.

The exit level outcomes to be demonstrated by future teachers are described as roles in the policy document called the Norms and Standards for Educators (2000a). Exit level outcomes are the learning demonstrations that define a system's ultimate expectations for learners, occurring at or after the end of the learners' study for a qualification (Spady, 1994b:190). Learners cannot graduate until they have achieved all the exit level outcomes of a programme (Killen & Spady, 1999: 201). It is worthwhile, at this stage, to briefly investigate what is expected of future teacher training in South Africa, before exploring a particular teaching strategy -PBL - and its possibilities to operationalise OBE.

The "Norms and Standards" document defines seven roles for educators and describes a set of associated competences for each role. (Department of Education, 2000a:15-22). These seven roles embody the exit level outcomes of the teaching profession for schooling. The competences have further been divided into practical, foundational, and reflexive competences which provide the assessment criteria (Department of Education, 2000a). Practical competence is described as

> *the demonstrated ability, in an authentic context, to consider a range of possibilities for action, make considered decisions about which possibility to follow, and to perform the chosen action (2000a:10).*

Foundational competence entails

> *the demonstration of the understanding of the knowledge and thinking which underpins the actions taken (2000a:10).*

Reflexive competences have been mastered when a learner

> *demonstrates (the) ability to integrate or connect performances and decision making with understanding and with the ability to adapt to change and unforeseen circumstances and explain the reasons behind these actions*

(2000a:10).

The seven roles which prospective teachers will need to play are the following (Department of Education, 2000a:13-22):

- **Mediator of learning**: Teachers will mediate learning in a manner which is sensitive to the diverse needs of learners; construct learning environments that are appropriately contextualised and inspirational; communicate effectively showing respect for the differences of others. In addition teachers will demonstrate a sound knowledge of subject content and various principles, strategies and resources appropriate to teaching in a South African context.

- **Interpreter and designer of learning programmes and materials:** A teacher will understand and interpret provided learning programmes, design original ones, identify the requirements for a specific context of learning, select and prepare suitable textual and visual resources of learning. The teacher will also select, sequence and pace the learning in a manner sensitive to the differing needs of learners.

- **Leader, administrator and manager:** The teacher will make decisions appropriate to the level, manage learning in the classroom, carry out classroom administrative duties efficiently and participate in school decision-making structures. These competences will be performed in ways which are democratic, which support learners and colleagues, and which demonstrate responsiveness to changing circumstances and needs.

- **Scholar, researcher and lifelong learner:** The teacher will achieve ongoing personal, academic, occupational and professional growth through pursuing reflective study and research in the Learning Area, in broader professional and educational matters, and in other related fields.

- **Community, citizenship and pastoral role:** The teacher will practise and promote a critical, committed and ethical attitude towards developing a sense of respect and responsibility towards others, one that upholds the constitution, and promotes democratic values and practices in schools and society. Within the school, the teacher will demonstrate an ability to develop a supportive and empowering environment for the learner and respond to the educational and other needs of learners and fellow educators. In addition the teacher will develop supportive relations with parents and other key persons and organisations based on a critical understanding of community development issues.

- **Assessor:** The teacher will understand that assessment is an essential feature of the teaching and learning process and know how to integrate this process. The teacher will have an understanding of the purposes, methods and effects of assessment and be able to provide helpful feedback to learners. The teacher will design and manage both formative and summative assessment in ways that are appropriate to the level and purpose of the learning and meet the requirements of accrediting bodies. Detailed and diagnostic records must be kept. The teacher will also know how to interpret and use assessment results to feed into the processes for the improvement of learning programmes.

- **Learning area/subject/discipline/phase specialist**: The teacher will be well grounded in the knowledge, skills, values, principles, methods, and procedures relevant to the discipline, subject, Learning Area and/or phase of study. The teacher will know about different approaches to teaching and learning and how these may be used in ways which are appropriate to the learner and the context. The teacher will have a well developed understanding of the content knowledge appropriate to the specialisation, which is technology education, for the purpose of this research.

A pre-service teacher who can demonstrate these competences is considered competent to perform the roles and have achieved the exit level outcomes of the qualification (Department of Education, 2000a:15-17). Some of the competencies most relevant for this research are included in the following excerpts from the Norms and Standards Document presented in detail in Table 3.1:

Table 3.1: Selected roles to be performed by prospective teachers

ROLE: LEARNING MEDIATOR
Practical competencies
Using key strategies such as higher level questioning, problem-based tasks and projects; and appropriate use of group work, whole class teaching and individual self-study.
Adjusting teaching strategies to: Match the developmental stages of learners, meet the knowledge requirements of the particular Learning Area; cater for cultural, gender, ethnic, language and other differences among learners.
Using media and everyday resources appropriately in teaching including judicious use of: common teaching resources such as text-books, chalkboards and charts; other useful media like over head projectors, computers, video, audio, popular media and resources, like newspapers, magazines and other artefacts form everyday life.
Foundational competencies
Understanding the pedagogic content knowledge – the concepts, methods and disciplinary rules- of the particular Learning Area being taught.
Understanding the learning assumptions that underpin key teaching strategies and that inform the of media to support teaching
Reflexive competencies
Defending the choice of learning mediation action undertaken and arguing why other learning mediation possibilities were rejected.
Reflecting on how teaching in different contexts in South Africa effects teaching strategies and proposing adaptations.

ROLE: INTERPRETER AND DESIGNER OF LEARNING PROGRAMMES AND MATERIALS
Practical competencies
Adapting and/or selecting learning resources that are appropriate for age, language competencies, culture and gender of learner groups.
Designing original learning resources including charts, models, worksheets and more sustained learning texts.

Foundational competencies
Understanding the principles and practices of OBE, and the controversies surrounding it, including debates around competence and performance.
Understanding the Learning Area to be taught, including appropriate content knowledge, pedagogic content knowledge, and how to integrate this knowledge with other subjects.

(Department of Education, 2000a:15-17)

One specific strategy and its multiple different dimensions will be the centre of attention in the next sub-section, namely, problem-based learning.

3.3 Problem-based learning: A teaching strategy with the potential to operationalise OBE in practice

One of the major professional responsibilities of teachers is to design and implement meaningful learner-centred learning experiences, which will lead to mastery of the outcomes (Cockburn, 1997:7). Consequently, teachers need to have a sound base of academic and practical competence regarding the variety of teaching strategies and methods, as was indicated by the Norms and Standards for Educators (2000a).

3.3.1 Defining teaching strategies and methods

Before one particular learner-centred strategy will be discussed, it is necessary to state what teaching strategies and methods are. Often in the literature these terms are used interchangeably when in fact describing the same teacher-learner interventions. In this research, a teaching strategy is defined as a "*broad plan of action for teaching activities with a view to achieving an aim*" (Loubser, 1993:143).

While strategies emphasise the broad actions for teaching and learning, refinement of these actions takes place on a micro level when programming for a particular unit of learning is done. Part of the refinement may involve the selection and sequencing of teaching and learning methods to be used when deploying the broad teaching strategy.

A method can be defined according to Fraser (1993:153) as a *"planned procedure intended* *to achieve a specific aim.* The procedure referred to in this general definition can be interpreted in an educational context as *"the various classroom activities planned by the teacher"* (Fraser, 1993:143).

Problem-based learning will be interpreted as a teaching strategy within the context and purpose of this research. PBL does not only refer to the "how" mechanism of teaching, but also to the entire approach which was used to organise the curriculum of the pre-service teachers.

3.3.2 Defining problem-based learning

A brief overview of the history of problem-based learning (PBL) provides evidence that the medical field has pioneered a major effort in using PBL as a way of curricular renewal. Albanese & Mitchell (1993) who have studied the literature on PBL from 1972 to 1992, chronicle that it has existed in medical schools since 1960. McMasters University Faculty of Health Sciences in Ottawa Canada, introduced PBL as a tutorial process to promote learner-centred education for lifelong learning (McCombs, 2000). Harvards' Medical School utilized a hybrid problem-based model of lectures, tutorials, conferences and clinical problems. Michigan State University College of Human Medicine, also implemented a problem-solving curriculum.

Up to the mid 1980's, PBL evolved as a more descriptive process than analytical. Research mostly related to learners' perceptions and performance with very few impact studies on graduates, faculty, the institution or the profession. Most evidence came from a handful of medical schools with a few examples of coherent PBL curricula for other professions, leaving curriculum designers with not much evidence if they wanted to restructure curricla around problems. In the USA various other university medical schools who are also currently using PBL are Bowman, Gray, Boston University, Georgetown Illinois, Southern Illinois University, Tufts, Mercer, Indiana, Northwestern, Hawaii, Missouri-Columbia, Texas-Houstan and Pittsburgh. Other universities outside of the USA who are also using PBL include Maastricht (Netherlands), Newcastle (Australia), Canada, Denmark, South Africa, Finland, and Sweden. The recent advantages of information networks such as the internet, e-mail, PBL-dedicated journals, conferences and books have facilitated a wide spread usage of PBL (Everwijn, Bomers & Knubben, 1993:426, Kaufman & Mann, 1996:1096 and McCombs, 2000).

Different reasons exist for implementing PBL as curriculum transformation. Albanese & Mitchell (1993) report that physicians believed that a better way exists for training medical students, avoiding hours of lectures and then testing their ability to recall bits of trivia. Barrows & Tamblyn (1980:7) distinguish between the roles of *content knowledge* and *professional skill* in medicine and explicate that traditional curricula put too little emphasis on the latter. Everwijn, Bomers & Knubben (1993: 426) discussing educational management, stretch the belief of the physicians when they state the following:

> *For a long time it has been assumed that a curriculum designed around disciplines and functional areas would adequately prepare students for future management positions. ... Real life business problems supersede the boundaries of individual disciplines and functional specialisms. They require an interdisciplinary perspective and interdisciplinary know-how and expertise.*

It can be concluded that a major reason for using PBL in professional training, is to bridge the gap between *knowledge acquisition and ability to apply* it in practice (Barrows & Tamlyn, 1980, Everwijn, Bomers & Knubben, 1993 and Gallagher & Stepien, 1996).

In the aforementioned training of physicians and educational managers, PBL has been used as a teaching strategy in one of three ways. In both the aforementioned training, PBL was used as a basis for an entire curriculum, course or learning programme **through** which teaching in an integrated manner could take place. This strategy advocates starting with the problem, rather than with the problem-solving tools. PBL and consequently problem-solving strategies can also be studied as a theme, for example by pre-service education students. In this regard they learn **about** problem-solving and the processes involved in solving problems. A third way of using PBL is where teachers teach **for** problem-solving where learners have to acquire the knowledge, understandings and skills which are useful for solving problems.

In this research PBL was used as a teaching strategy **through** which the pre-service technology teachers were trained. Being pre-service teachers, they also had to learn **about** problem-solving, since they had to design and facilitate PBL experiences in practice after their training period themselves. Since they had to be prepared for technology education, they also had to learn how to solve problems, especially of the kind associated with technology. This approach of **'teaching teachers the way they are expected to teach'** is believed to enhance transfer of their competencies to real classrooms, thus improving the quality of their future teaching practice.

With this background knowledge of PBL a definition for PBL as a teaching strategy can be presented (Barrows & Tamlyn, 1980:18):

> *(Problem-based learning is) the learning that results from the process of working toward understanding or resolution of a problem. The problem is encountered first in the learning process and serves as a focus or stimulus for the application of problem-solving or reasoning skills, as well as for the search for or study of information or knowledge needed to understand the mechanisms responsible for the problem and how it might be resolved. The problem is not offered as an example of the relevance of prior learning or as an exercise for applying information already learnt in a subject-based approach. A problem in this context refers to an unsettled, puzzling, unsolved issue that needs to be resolved. It is a situation that is unacceptable and needs to be corrected.*

Nickerson, Perkins & Smith (1985:222) elaborate on this definition when saying that by simply giving an answer to a question or applying a known principle to explain an observation is not PBL and that the learning required of a learner in PBL is active, not passive. Barrows & Tamlyn (1980:83) explains what activity means when they say that

> *the student does not listen, observe, write, and memorise; instead, he is asked to perform, think, get involved, commit himself, and learn by trial and error. He is asked to learn both cognitive reasoning skills and psychomotor skills ... and to identify learning needs made apparent by his work with a problem.*

For any definition to be realised in practice, it must be translated into some form of a curriculum framework or model.

3.3.3 *A problem-based curriculum framework and problem-based learning models*

Several researchers have worked on the design and development of problem-based curricula (Barrows, 1986; Ross, 1991; Schmidt, 1983-1993 and Walton & Matthews, 1989). The overview of a curriculum framework for PBL presented, is based on the work of Ross (1991:36-37). This is shown in five steps below:

1 The first component of the framework deals with who selects these problems. Problems can be selected by the following role players:

- A curriculum design team. If applicable problems do not exist they can design or simulate them or get them from problems listed by the learners.
- By the learners as a group or as individuals.

2 This component provides a framework for the purpose of a problem which is selected. It defines the area of knowledge to be covered at least. The problem can be selected with the following purposes in mind:

- To ensure that learners cover a pre-defined area of knowledge.
- To help learners generate relevant ideas and learn important concepts, skills and techniques.
- A problem can be selected for its suitability for leading the learners to the "field" or parts of it.
- A problem can be selected for its intrinsic interest, potential to motivate or overall importance.
- A problem can be selected because it represents a typical problem to be faced by the profession.

3 This component deals with the form in which the problems are presented to the learners. For example, the design team presents the learners with a problem as a "trigger" and the learners define the problem from the "trigger" as a set of questions. The form that a problem can take could be the following:

- An authentic event or simulation of an event – a "trigger".
- A descriptive statement.
- A set of questions.

4 This dimension deals with the defining of resources needed to solve the problems. The resources to be used by learners can be selected as follows:

- The design team can select all the resources needed to be studied by the learners.
- The learners themselves can select from a resource "package" which has been compiled by the design team.
- The learners themselves can select from any resources available to them.

5 Learners can work in the following manner:

- In groups with a facilitator.
- In groups without a facilitator.
- As individuals who are free to contact the facilitator when needed.

In most circumstances, learners will be expected to work in all of these ways depending on the type of problem and the stage of the problem-solving process. The aforementioned framework must be interpreted as descriptive and flexible, rather than prescriptive. All the steps mentioned are not mutually exclusive and variations can be made as resources allow. This framework may be adapted to be in coherence with different PBL models.

A very basic and general PBL model is presented by Barrows (1986) for medical learners:

- The problem is *encountered* by the learners.
- *Problem-solving* takes place by using clinical reasoning skills and identifying learning needs in an interactive group process that involves self-study and applying new gained knowledge to the problem.
- The PBL process ends with learners *evaluating* the information and resources they have

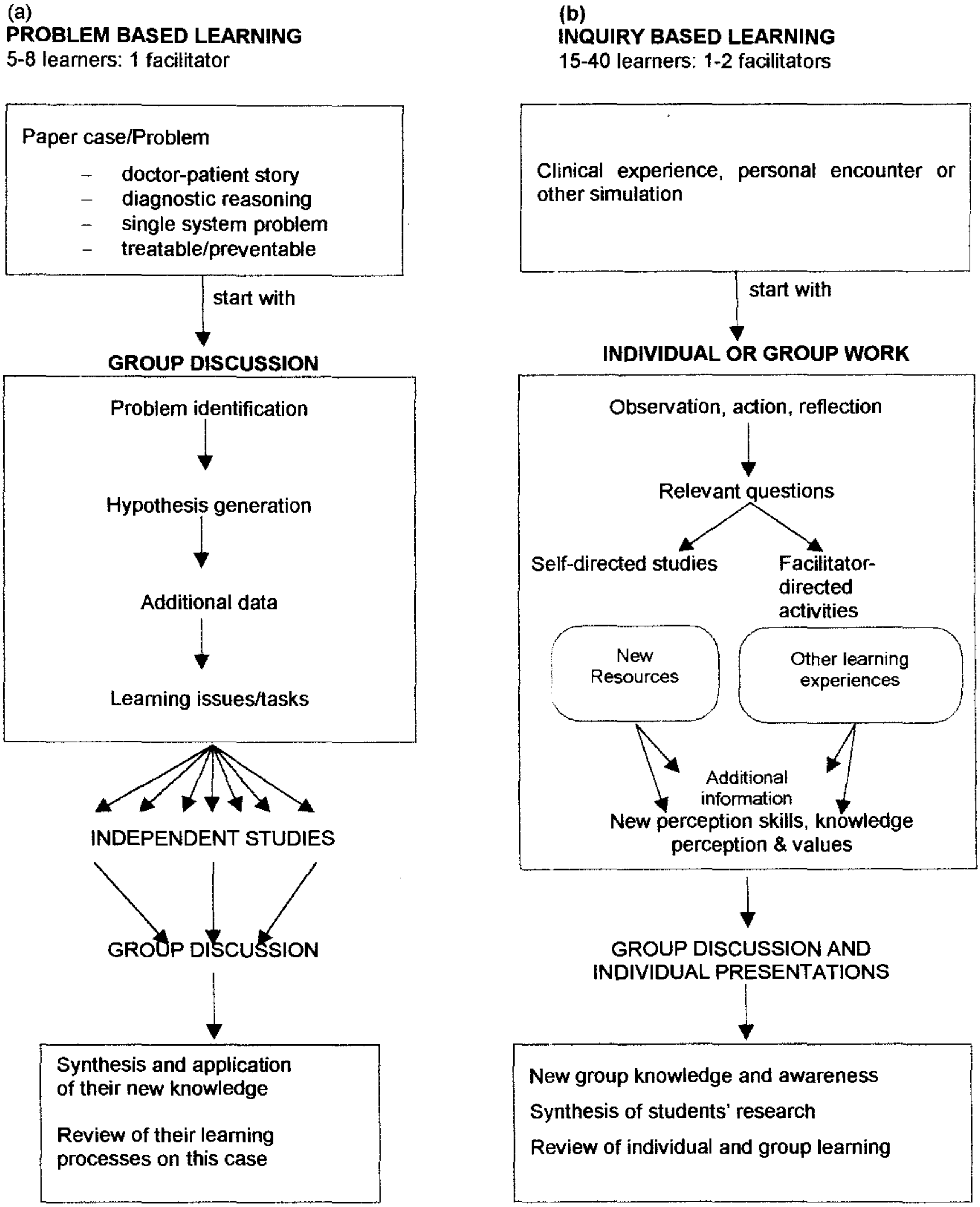
used in the solution by focusing on how they could have managed the problem better.

Savoie & Hughes (1994) also present a PBL model in terms of what a facilitator has to do:

- Identify problems useful to learners.
- Place the problem in context for the learner to make it authentic.
- Structure the subject content around the problem and not the discipline.
- Make learners responsible for their learning and problem solutions.
- Advance collaboration by forming learning groups. If learners have no practice in group work, they need to be coached in the process of group work and social interaction skills.
- Demand all learners demonstrate their learning by presenting a product or constructing and making a public presentation.

Two other models, also developed for the field of medical training, but which may be adapted for any PBL learning environment, are presented below (Williams & Williams, 1997:94) These models are basically similar and have been adapted to include terminology used in this research. The one model is representative of *inquiry-based learning*. Since the problem in PBL is something that gives rise to doubt, uncertainty, a question or an inquiry that starts from given conditions, PBL can be viewed as a form of inquiry based learning (Van der Horst & McDonald, 1997). Dewey (1929:189) who advocates "*reflective inquiry*" explicates the role of problems in reflective inquiry when he states that "*all reflective inquiry starts from a problematic situation*". For Dewey (1929) the value of this form of learning is not only the fact that problems trigger reflective inquiry, but that it engages learners in looking for problems. Learners are problematising their experiences with problems to understand them more fully (Hiebert, Carpenter, Fennema, Fuson, Human, Murray, Olivier & Wearne, 1996:12-21).

Figure 3.1: Models for problem- and inquiry-based learning used in medical training



The similarities between the basic components of these models for PBL and the models used in the technological design process, are remarkable. These similarities will be highlighted in Section 3.4 where technology education is discussed.

Cognisance should be taken of the fact that *group work* or *collaboration* between learners features at some stage during the PBL process, as indicated by the models on PBL. It seems then that collaboration in terms of group work or co-operative learning is one of the characteristic features of PBL. This characteristic, as well as others will briefly be discussed now.

3.3.4 Characteristic features of problem-based learning

A number of characteristic features exist for PBL, regardless of the context in which it is applied. Some of the characteristics are discussed below.

3.3.4.1 Learner collaboration and co-operative work

In the discussion on OBE in Section 3.2.1, learner collaboration in terms of group or co-operative learning was addressed. Different reasons for incorporating collaboration amongst learners somewhere in the process of PBL exist. Williams & Williams (1997:93) recommend collaboration in order to foster a supportive learning environment. The rationale for a supportive learning environment is stretched by Bridges & Hallinger (1992) when they state that it allows for an emotional tone that resembles real life situations. Also when projects go awry, the PBL group learner gains insights into how they deal with frustration, disappointment and socio-emotional conflict.

However, Brown & Palincsar (1989) emphasise that conceptual change in collaborative PBL is more the result of processes of co-elaboration and co-construction due to a shared cognitive conflict rather than to a social one. The cognitive conflict experienced amongst learners, also induces meta-learning. When collaborating, learners often find themselves at loggerheads with a fellow learner which, in fact, "forces" the learners to reflect on their own ideas, premises and motives.

3.3.5 Conceptual dimensions of PBL

PBL is hypothesised to have a number of advantages over traditional strategies for teaching and learning, associated with cognitive processes it is believed to stimulate (De Grave, Boshuizen & Schmidt, 1996:321). Schmidt (1983, 1993) emphasises the cognitive effects of PBL in terms of *knowledge activation* and *elaboration* and presented empirical evidence for this claim (Norman & Schmidt, 1992).

3.3.5.1 Information processing and constructivist theory

The major theory which Albanese & Mitchell (1993) and Barrows (1986) base their support for PBL on, is *information-processing*. The essence of this theory holds that what learners will learn is influenced by their prior knowledge and past learning (Ausubel in Novak & Gowin, 1984:7). This support for PBL is in line with the constructivist theory of learning. This theory states that knowledge is constructed through a process of reflective abstraction, that prior cognitive constructs effect the construction of new meaning and that cognitive structures are in constant state of evolution (Seifert & Simmons, 1997:90 and Novak & Gowin, 1984:4-5). Therefore, for effective meaning construction to take place, the teaching strategy must activate a learner's prior knowledge. Norman (1988) indicated that PBL is highly compatible with the notion of stimulating prior knowledge. In a study where PBL was used in an undergraduate Construction Management course at the Western Australian Institute of Technology, PBL learners reported "*less book type research and more use of previous learning*" (Davis, 2000:7).

It is especially in the first stages of PBL, namely during *problem-analysis,* where learners need to reflect on prior knowledge to become aware of the mismatch or a gap in their prior knowledge and the knowledge and competencies needed to resolve the problem (De Grave, Boshuizen & Schmidt, 1996:323-324). This conflict which results from a disagreement between prior knowledge and the problem, will lead learners to conceptual change. In fact, inducing cognitive conflict within learners to establish conceptual change is an axiom of PBL (De Grave, Boshuizen & Schmidt, 1996:323).

3.3.5.2 Recall and transferability of knowledge

A major advantage of PBL is that a problem provides a *context* for learning. Knowledge is much better understood and recalled in the context in which it was originally learnt (Norman, 1988). In the process of solving-problems, much searching takes place and according to Kingsley (1946) we learn when we recognise the objects of our search. Bridges, Hallinger & Hallinger (1992) explain that information is better understood, and thus remembered when learners get the opportunity to *elaborate* on it by means of searching. Confrontation with the problem, as well as with other learners' knowledge of the problem, helps learners to elaborate on their knowledge (De Grave, Boshuizen & Schmidt, 1996).

Another advantage is that new information and skills acquired by a learner within a context simulating reality through problems, will be more easily transferred to a related "real" context or problem situation. The same PBL undergraduate learners who did the Construction Management course noted that the PBL learning was "more practical and realistic" (Davis, 2000:7). It seems that the power of transferability is vested in the authenticity of problems used in the classroom.

3.3.5.3 Meta-cognitive processes associated with PBL

Effective problem-solving demands conscious and/or unconscious utilisation of meta-cognitive processes. The purpose and role of meta-cognitive processes in PBL will be clearly comprehended when metacognition is clarified. Flavell (1976:232) defines meta-cognition in the following manner:

> *One's knowledge concerning one's own cognitive processes and products...(and) the active monitoring and consequential regulation of those processes in relation to the cognitive objects or data on which they bear.*

Nisbet & Shucksmith (1986:8) add to their definition the concepts of *awareness* and *reflection*, which are necessary for effective decision-making in problem-solving. They also refer to metacognition as a "seventh sense":

> *(The) seventh sense is meta-cognition, the awareness of one's own mental processes, the capacity to reflect on how one learns, how to strengthen memory, how to tackle problems systematically – reflection, awareness, understanding, and perhaps ultimately control, the seventh sense is a relatively undeveloped sense among people generally.*

In the context of problem-solving, or any learning for that matter, reflection is a key concept. Slabbert (1996:142) explains that reflection implies that there must be something to reflect upon such as prior constructed knowledge or new knowledge being constructed. By reflecting and thus being aware of the progress or problems encountered in the process of finding solutions and constructing meaning, learners will be able to *control* their own learning processes. In other words the locus of control can shift from an external one such as a teacher to an internal locus of control in the learner himself. Consequently the learner is empowered to become an autonomous, independent and lifelong learner (Slabbert, 1996:142). This in fact, coincides with the purpose of PBL.

A link exists between metacognition and learning and because of this close association of metacognition with effective learning the term 'meta-learning' came into existence (Baird, 1986:263, Biggs, 1985:185 and Ford, 1981:250). Slabbert (1996:144) defines meta-learning as follows:

> *Metalearning comprises the higher order learning activities or the control activities of learning (superstructure) such as planning, execution, monitoring and evaluation. These higher order learning activities exert control over the lower order learning activities or executive activities of learning. Metalearning guides and directs (controls) the learning process.*

The nature of PBL both demands the utilisation of meta-learning and it operationalises meta-learning. In the experimental group intervention in this research, a meta-learning checklist by the name of "research checklist" was included in the resource kit for each school learner who was part of the PBL intervention. It was argued that this meta-learning checklist could initially serve to make learners aware of the meta-learning process while actually dealing with the problem to be solved. The idea of meta-learning strategies is to finally be internalised and automatised by learners, but they first need to become aware of meta-learning strategies and its value within a context and not in a vacuum.

3.3.6 PBL and its effects on learner attitudes and motivation

Numerous studies have examined PBL processes and outcomes in terms of cognitive and meta-cognitive outcomes, especially in the training of health care professionals (Albanese & Mitchell, 1993; Barrows, 1986; Barrows & Tamblyn, 1980; Bridges & Hallinger, 1992 and De Grave, Boshuizen, & Schmidt, 1996). This section will briefly look into current research findings regarding learners' *attitudes* towards this strategy. One of the aims of this research is also to get some feedback regarding attitudes of *learners* who were exposed to PBL, by *pre-service teachers* who were trained through PBL as a strategy.

In a study by Norman & Schmidt (1992) it was found that PBL enhances *intrinsic interest* in content. This finding is in line with the aims of inquiry learning as described by Dewey (1929) which implies that once content is treated as a problem to be solved, only then learners examine it more carefully, begin to understand it, gain control over it and use it more effectively to their advantage. This sense of cognitive achievement promotes intrinsic interest which in turn results in positive attitudes towards the curriculum. The fact that learners are challenged through problems, can assure that they derive great satisfaction from discovering new knowledge for themselves which may enhance a personal pride and positive self-concept (Cobb, Yackel, Wood, Wheatley & Merkel, 1998).

Kaufman & Mann (1996: 1096) found that the attitudes of second year medical students from the Dalhousie University Faculty of Medicine, were significantly more positive than the conventional curriculum students. The PBL learners had more positive attitudes towards their learning environment regarding the sub-scales of academic and faculty enthusiasm, democratic decision-making and vigorous class discussions. They did find however, that traditional learners were more positive than the PBL learners about learner interactions in their classes. The PBL learners appeared to form several factions or cliques within their class. They contributed this happening to the fact of the intensity of the small group process and that learners became acquainted at a deeper level more quickly than in the lecture-based curriculum. A lesson to be learnt form this, is to rotate members in a group to allow learners to work with as many learners as possible on different problem tasks if the forming of cliques within one class is to be inhibited.

However, it was found by Albanese & Mitchell (1993:68) that learners experience a PBL environment more nuturing and enjoyable than conventional classrooms. Compared with traditional curriculum learners the PBL learners were more highly rated with regard to faculty attitudes, learner moods, class attendance and measures of humanism (Vernon & Blake, 1993:68).

In an Educational Leadership Programme which was conducted using PBL, significantly higher evaluations on "value of the course" and "performance of the professor" were received, as compared to learners in the traditional methods course (Tanner, Galis & Pajak 1997). Tanner, Galis & Pajak (1997:10) reported that *"students liked the approach and thought the professor did a superior job of teaching".* Their colleague who facilitated PBL learning for the first time did not receive the same positive evaluations initially and this is contributed to the fact that he had to work through the experimental phase where PBL materials had to be developed for the first time. In later PBL programmes, however, his evaluations actually surpassed his former evaluations in the traditional classes (Tanner, Galis & Pajak , 1997:10). Finally, for maximum benefit to the student, they concluded that **special training** by a formal institute such as the PBL Institute at Stanford University or mentoring, is needed by the facilitator before taking on the job of employing PBL activities successfully in the classroom (Tanner, Galis & Pajak , 1997:10).

In a critique on PBL in health care profession training, Bruhn (1997:69) reports the following findings in general and on motivation. He states that Berkson (1993) found that health care graduates going through PBL are not necessarily better prepared for practice with respect to clinical knowledge and its application. PBL graduates do however have a broader range of interpersonal skills, a greater appreciation of the complexity of problems and the resources available for a solution, and a *heightened motivation* for continued self-learning (Norman & Schmidt, 1992 and Williams, Saarinen-Rahikka & Norman, 1993).

High school research on an economics PBL project, undertaken by Seifert & Simmons (1997) also reported qualitative results reflecting the general attitude towards this strategy. Learners indicated the following:

> *They learned more in this project than they had in any course in high school. They particularly liked the opportunity to research a topic and suggest a solution without trying to arrive at some pre-conceived answer. Some of the students felt they needed and wanted more direction early in the process, but by the end of the project they felt fulfilled and indicated this process would be most helpful in the future (Seifert & Simmons, 1997: 97).*

In this project it was found that the parents were very supportive and helpful in using this approach. Several of the parents indicated that they got the impression that it was the first time that their children were truly challenged to think on their own since the beginning of their elementary or secondary school years. Parents especially liked the concept of making their child responsible for some of his or her own learning.

From the reported findings in the aforementioned section it seems that learners who have experienced PBL in different ways over varying time spans, have varying attitudes towards this strategy, depending on the degree of experience or expertise of the facilitator implementing PBL. It does, however seem that PBL induces intrinsic motivation, which results in learners who are motivated for self-directed learning – a premise for lifelong learning.

3.3.7 PBL and knowledge acquisition: Depth vs breath

Part of the rational for implementing PBL in teaching and training is the overcoming of the gap between *knowledge acquisition* and the *ability to use this knowledge* (Everwijn, Bomers & Knubben, 1993:425). This has the implication that some of the content topics in a regular syllabus have to be reconsidered to make space for the higher cognitive processes involved in solving a problem, which usually uses more time than only covering topics. In a study by Gallagher & Stepien (1996:257) they report that a continuous barrier to the implementation of PBL curricula is the perception that it "*inevitably results in lower levels of content acquisition*". They challenged this assumption in a study which compared high school learners' history scores on a multiple-choice standardised test (National Assessment of Educational Progress History Test) after traditional and problem-based teaching strategies were used. In their study, 50% of the school year was devoted to PBL, where there was no direct instruction of content to be 'covered' either before, during or after the problem-based intervention. To minimize the potential for traditional learning they also did not prescribe any textbook readings.

The statistical evidence provided shows that in their case, learners in the PBL course, retained as much factual information as learners in the other classes and that this strategy "*did no harm*" in terms of knowledge acquisition (Gallagher & Stepien, 1996:270). They claim that this particular study adds to the growing body of evidence that teaching for depth of understanding also facilitates retention of content facts.

In another of the existing studies, the Harvard Social Studies Project obtained results supporting the notion that higher order thinking induced by PBL is an avenue to factual, content learning - equivalent levels of content acquisition were found among learners in problem-based and traditionally structured classes (Olivier & Shaver, 1963).

Reporting on research findings in PBL without looking at the medical field where extensive work has been done in this regard, will not be complete. One study by Baca, Mennin, Kaufman & Moore-West (1990) found that medical learners in a traditional and PBL curriculum received equivalent scores in their clinical blocks during the last two years of medical school. In a similar study comparing McMaster University, which has a PBL curriculum, and the traditional McGill University medical learners, the PBL learners were found to hypothesise more, but they arrived at the correct diagnosis less often then the non-

PBL learners (Patel, Groen & Norman, 1991). PBL learners at Rush Medical College performed better on patient interviews, ability to obtain and summarise histories and problem-solving than their counterparts who did not experience PBL (Goodman, Brueschke, Bone, Rose, William & Harold, 1991). Shin and his colleagues also compared PBL and non-PBL learners and found that their clinical knowledge of hypertension management was more current than that of their counterparts (Shin, Haynes & Johnston, 1993). In a study of medical interns who were assessed by their supervisors, it was determined that the majority of the graduates were graded 'above average' in four clinical subjects but below average in knowledge of anatomy.

In defense of the PBL strategy Barrows & Tamlyn (1980) (Nickerson, Perkins & Smith, 1985:222) give a perspective on this debate which will serve as a conclusion for a matter which will continue as long as different strategies for teaching and learning exist. They say that medical learners often complete training by passing all the knowledge exams, but still do not know how to *practice* medicine effectively. In support of their view that knowledge that is not used is not well retained anyhow, they cite Miller's (1962) finding that before students graduate, they typically forget most of what they learned in their first year anatomy and biochemistry courses. A major mathematics student summed up the many mixed opinions with this short critique: *"You never get a chance to ask when am I gonna use this, because you always just did"* (Ulmer, 2000:5). This comment captures the essence of the value of PBL, which is to make learning meaningful, relevant and hands-on in authentic learning environments.

These sections briefly reviewed some of the various findings regarding the depth and breadth of knowledge in either PBL or traditional curricula. It seems that is should be accepted that PBL does not conform to or necessarily yield the results normally emanating from traditional curricula and vice versa. This particular research will also attempt to give some answers on the depth versus breadth debate regarding knowledge acquisition and application.

3.3.8 Designing a problem-based learning task

In PBL a problem serves as the initial stimulus and framework for initiating and maintaining learning. In programming or planning for OBE it should be kept in mind that the outcome should not be designed around the problem, but vice verse. Once a facilitator is very clear about the outcome(s) to be demonstrated by learners after a learning task, only then should problems be identified, selected or designed. Since problems are the 'triggers' of meaningful learning, it is *crucial* to understand the nature and criteria for identifying, selecting or designing them.

3.3.8.1 The nature and criteria for problems in problem-based learning

Since problems are the triggers for initiating and maintaining learning in a PBL environment, the problem designers (facilitators of learning) need to be knowledgeable about the nature and criteria to which problems have to adhere. Killen (1998b:118) contends that the real challenge is not to find problems, but to find suitable problems which will lead learners in the attainment of new knowledge, skills and attitudes. Killen (1998b:118) continues to say that this is most likely to occur when a problem requires learners to relate new knowledge with prior knowledge, make explicit what they understand and do not understand, and learn concepts well enough to explain them to others as part of the understanding process.

Duch (1996) reports that many faculty who have implemented PBL in their courses and learners who have taken those courses agree on several factors that are essential for good problems. He presents these common factors as a set of generic characteristics which are present in effective problems. These characteristics are the following:

- An effective problem must first engage learners' interest and motivate them to probe for deeper understanding of the concepts being introduced. It should relate the subject to the real world, so that learners have a stake in solving the problem.

- Good problems require learners to make decisions or judgements based on facts, information, logic and rationalisation. Learners should be required to justify all decisions and reasoning based on the principles being learned. Problems should require learners to define what assumptions are needed and why, what information is relevant, and what steps or procedures are required in order to solve them.

- Co-operation from all members of the learner group should be necessary in order to effectively work through a good problem. The length and complexity of the problem or case must be controlled so that learners realise that a "divide and conquer" effort will not be an effective problem-solving strategy. For example, a problem that consists of a series of straight-forward "end of chapter" questions will be divided by the group and assigned to individuals and then reassembled for the assignment submission. In this case, learners end up learning less and not more.

- The initial questions in the problem should have one or more of the following characteristics so that all students in the groups are initially drawn into a discussion of the topic (a) open-ended, not limited to one correct answer (b) connected to previously learned knowledge and (c) controversial issues that will elicit diverse opinions. This strategy keeps the learners functioning as a group, drawing on each other's knowledge and ideas, rather than encouraging them to work individually at the outset of the problem.

- The content outcomes of the course should be incorporated into the problems, connecting previous knowledge to new concepts, and connecting new knowledge to concepts in other courses and disciplines.

In the field of medical education it is suggested that problems should be chosen

- that have the greatest frequency in the usual practical setting
- that represent life-threatening or urgent situations
- that have a potentially serious outcome in terms of morbidity or mortality, in which

intervention – preventive or therapeutic – can make a significant difference in prognosis

- that are most often poorly handled by doctors in the community.

(i) Authentic, real-life problems

The type of problems can range from a series of short-, intermediate or a single long term problem, either real or simulated (Hoffman & Ritchie, 1997:98 and Wilkerson, 1996:27). Killen (1998b:118) divides problems into three categories namely, routine, non-routine and open-ended. Routine problems are solved by using a known algorithm and can be related to practice and drill exercises. In non-routine problems the method of solution has to be discovered and is part of the problem-solving process. Open-ended problems are often real-life orientated and may be solved through different methods. In the literature a central, overarching criterion constantly comes to the fore which deals with the **authentic, real life** essence of which ever type of problem is designed. Seifert & Simmons (1997:92) suggest that problems should be useful to learners. To make it useful, the problem should be embedded in a richly contextualised situation. A problem should be set in terms of" *a real problem that students may have to deal with"* (Bridges & Hallinger, 1992:5-6). Real life problems are mostly ill-defined and less structured. It should not be a problem for the facilitator, but one where the learner is placed in a situation where the problem is *actually* experienced (Slabbert, 1996:116). The nature of problems to be designed for PBL environments are not the analytical type suitable for typical test or multiple choice tests which tend to

- have been formulated by other people
- be clearly defined
- come with all the information needed to solve them

- have only a single right answer which can be reached by only a single method
- be disembedded from ordinary experience
- have little or no intrinsic interest

The type of problem suitable for a PBL environment tends to

- require problem recognition and formulation
- be poorly defined
- require information seeking
- have various acceptable solutions
- be embedded in and require prior everyday experience
- require motivation and personal involvement (Claxton, 1999:32).

Eason & Green (1987:243) also provide guidelines for selecting problems which are suitable for PBL. They suggest that problems

- need to be based on the concerns of learners
- have immediate, practical effects on a learner's life
- are "actionable" in the sense that learners are able to do something to change or improve matters

- have no right answers and fixed boundaries

- require learners to use their own ideas and efforts to solve a problem

- are complex enough to require considerable effort and activity.

An authentic problem should be designed in such a way that a mismatch is created between the learners' knowledge and the problem, which will result in cognitive conflict (De Grave, Boshuizen & Schmidt, 1996:323-324). It is the cognitive conflict which challenges, elicits and evokes spontaneous self-directed learning, where the facilitator actually becomes redundant due to a learner's preoccupation with the " *challenge and enjoyment"* of the problem-solving process (Slabbert, 1996:114).

(ii) Presentation of problems

Just as important as the design of a challenging problem is the presentation of that problem. One weakness with the presentation of problems, identified by Hoffman & Ritchie (1997:100), is that many PBL courses rely primarily or exclusively on written or oral problem statements. This may adversely effect transfer between the problem situations in a course and similar ones in real life. Bridges (1992:97) offers the following advice to PBL designers:

> *To become an expert, a great deal of perceptual learning must occur, and this cannot happen unless the student learns to recognise the salient visual, auditory, and non-verbal cues. When designing a PBL curriculum, program designers should strive for a variety of modalities in presenting problems ... If students encounter only verbal descriptions of problems, they may be unprepared to deal with real problems.*

Hoffman & Ritchie (1997:103) suggest that multimedia provides multiple modalities through the creative use of text, video and audio for presenting real world problems. They contend that multimedia has the ability to increase the richness of problem presentation, which in turn increases the user's ability to interpret and understand the problem through repeated exposures (Hoffman & Ritchie, 1997:104). Repeated exposure to the problem and related materials*" at different times, in rearranged contexts, for different purposes and from different conceptual perspectives"* provides new insights and strengthens cognitive associations (Spiro, Feltovitch, Jacobson & Coulson, 1992:65).

In schools and classrooms where highly sophisticated technology is not available, which is the reality in many rural South African schools, facilitators need to tap their own creativity to **present real life problems in real life formats**, true to the nature of a field or Learning Area. In technology education, which has a need-driven nature, the need which should be addressed by the technological process, actually needs to be experienced by the technology learners themselves as far as possible. They need to 'go to the problem' instead of the problem always coming to them in a written format in the classroom. The nature and structure of some Learning Areas lend themselves more easily to real life presentations and simulations than others. In summary, creative, challenging problems need to be presented in a credible convincing way to yield the intended learning effects.

(iii) Preparing learning resource materials

In problem-based learning, learners, apart form their own resources and that of their peers and the facilitator, depend on resource materials to use during the research stage in problem-solving. In high-tech learning environments, such as universities and some schools, where written and electronic information are available in abundance, learners can be left on their own or directed to access and select the information which they need, once they are competent in using these information resources. The World Wide Web, for example is a very valuable tool and resource to because of its ability to involve learners actively in information seeking and problem-solving (Killen, 1998:139). According to Dyrli & Kinnaman (1996:56) involving learners is not enough. Teachers should have the skills to co-ordinate a range of experiences designed for a specific purpose. They should equip learners with electronic information processing skills, teach them to evaluate the information they find, help them to work independently and manage the process, in order to use their online time optimally and efficiently.

Killen (1998b:139) explains how computers can be used not only as a tool for obtaining information, but as a tool for processing, recording and reporting information. Word processors, drawing and design programmes, databases and spreadsheets may be used to manipulate, store and present data or solutions. Harris (1995) suggests that learners can also work co-operatively with peers at other schools or countries on solving problems via the Internet. Experts in the field of a particular problem may also be consulted for information or solutions to problems. Dyrli & Kinnaman (1996) caution that learners must realise that finding applicable information on the World Wide Web, is not always an easy, simple or quick process. Facilitators of learning should help learners to acquire the skills and encourage them to have resilience when their search does not produce the information they have anticipated.

In an interview conducted with four second year medical students at Pretoria University which also embraced a partly PBL approach, the students reported that the search for information on the intra- and internet, is a very time consuming process. Since so many users are accessing the network at their faculty, they report that they sometimes wait long periods to access a website with relevant information. They suggested that the frustration of wasting valuable study time while waiting will be solved if they can be issued with CD-ROM databases where the most recent and relevant information for solving a particular problem can be retrieved. This presupposed frustration might not be a problem at another institution, since the information might be managed and administered in a different way.

Designers of PBL might also decide to plan and compile their own resource packages or 'kits' as it was called in this particular research. In the South African context, where many of the schools and learners do not have access to electronic or extensive printed or multimedia services, facilitators might have to follow this route. In under-resourced schools, resource kits are vital for effective problem-solving. Schools and learners who do have access to various information resources are obviously not restricted to the resource kit only. On the contrary, learners are encouraged to expand and enrich the resource kit, and to share all newly retrieved information with their fellow group members and peers in the class.

3.3.9 Problem-solving in problem-based learning

Problem-based learning consequently implies that learners need to engage in problem-solving. To become effective problem-solvers learners need to develop competencies on how to analyse and understand a problem, how to plan and attack it, how to execute the plan and how to check if their process and solution are feasible (Killen, 1998b:125). Once learners have mastered various problem-solving strategies, they will use these as a means to learn about the content and skills of a learning programme such as technology education. These competencies are dependent on meta-cognitive processes which are responsible for controlling and managing the lower order execution or performance processes Nickerson, Perkins & Smith, 1985:20-21. "*There can be no doubt*" Sternberg says "*that the major variable in the development of the intellect is the metacomponential one. All feedback is filtered through these elements, and if they do not perform their functions well, then it won't matter very much what the other kinds of components do*" (1985:228). According to Sternberg (1981), thinking and learning skills which are used in academic and every day problem-solving, can be separately diagnosed and taught. See the discussion on meta-learning in Section 3.3.5.3. A general introduction regarding problem-solving will serve as a back drop against which the technological process as a problem-solving process, will be explored later in this chapter.

The purpose with problem-solving is to break down the complexity of a problem in order to focus on knowledge, skills and attitudes which will lead to a solution. There is no formula, routine or recipe for true problem-solving which prescribes exactly how to get from point A to B, else it will not be problem-solving. Problems differ both in complexity and in the nature of skills required to solve them. There are however, models and processes which have been developed in the form of generalised schemes, which might result in progress towards the solution. Some of these generalised schemes are called ***heuristics*** which means "serving to discover" (Nickerson, Perkins & Smith, 1985:74). Heuristics are the powerful tools by which problems may be solved – but are not absolutely guaranteed to work (Martinez, 1998:606). Martinez (1998:606) explains that there are generic and domain specific heuristics. Generic heuristics are cognitive "rules of thumb" which are content free and which can serve to guide the solution of a variety problems. An example of a specific heuristic is to apply the principle of energy conservation in a physics problem.

Algorithms, by contrast are straight forward and recipe like and are guaranteed to work every time. They are step-by-step prescriptions for accomplishing a task (Nickerson, Perkins & Smith, 1985:74). Substituting the numeric values into the formula for determining the volume of a sphere, is an example of using an algorithm.

A few of the general heuristics are mentioned below (Everwijn, Bomers & Knubben, 1993:430, Martinez, 1998:606 and Nickerson, Perkins & Smith, 1985):

- *The problem-solving cycle by* ***Polya*** *(1957, 1971)*. Polya, who was a mathematician himself, was interested in the teaching of mathematics. The heuristic he described is more generally applicable than to mathematics alone. This heuristic distinguishes four stages:

  - **Understand the problem:** This implies that a problem should be portrayed in an explicit external representation, in order to highlight the main features of the problem, such as the givens, the unknowns, the conditions, the goals state and the permissible operations. This can be accomplished by drawing a graph or a diagram and introducing applicable notation. Important features of this heuristic is that it allows more complexity to be presented than we can hold in the mind at once. The processing capacity of the brain is then not burdened with all the problem details and can be directed to solving the problem.

  - **Devise a plan:** This entails developing a general strategy, not a detailed proof. Formulation of this strategy is according to Polya an inductive one and not a deductive one.

  - **Carry out the plan:** This is the detailed proof and it is at this stage where deductive reasoning plays a role.

  - **Look back:** Results and the different steps used, have to be checked.

- *The "means-ends analysis" or the sub-goal analysis:* This heuristic means 'do something to get a little closer to your solution or goal'. Subsequently sub-goals should be formed which will reduce the discrepancy between the initial state and the ultimate goal. This heuristic assists in incremental advancement towards the ultimate goal, when applied repeatedly. The typical Tower of Hanoi problem is solved using this heuristic.

- *The "working-backwards" heuristic:* This heuristic implies that the ultimate goal should be considered first, and from there onwards a decision should be made about what would be a reasonable step just prior to that goal. This is useful when there are many possible operators and solution paths that could be applied to the initial state, but few that could lead from the last intermediate to the goal state.

- *The "successive approximation" heuristic:* This heuristic solves a problem by initially putting on the table a product that is not totally satisfactory. Over time it will gradually be moulded and polished into shape until the final product approximates the effect initially intended. Writing of manuscripts, a thesis or even creating a work of art primarily make use of this heuristic. Some technological design processes heavily rely on this heuristic.

These are just some of the heuristics which can be used to guide the problem-solving process. A culture to be cultivated by problem-solvers and designers of problem-based learning opportunities is that problem-solving ***by its very nature, involves errors, obstacles, doubt and uncertainty***. We live in times where everything comes in pre-packed quick fix parcels and where errors imply failure. Problem-solving however, implies taking risks, failing, experiencing frustration, demotivation and trying again showing resilience.

Devore (1988) and DeLuca (1992) also describe problem-solving strategies which may be divided into five broad categories. The unique nature and structure of different fields or Learning Areas will affect the way in which the general heuristics or problem-solving strategies are adapted and integrated to address particular problems. The following strategies are well suited for technology and science education. They are the following:

- **The scientific process:** This methodology deals with experimentation and attempts to quantify phenomena into measurable quantities in order to determine or predict **cause** and **effect** relationships. This method has the following procedure:

  - Observe and formulate the problem in such a way that a hypothesis can be formulated.
  - Formulate a hypotheses (H_0).
  - Design an experiment in which all the dependant and independent variables are clearly defined in which the hypothesis can be tested.
  - Select an experimental and control group which can be compared in terms of the predetermined variables. The experimental and control groups can also be compared in terms pre- and post tests.
  - Obtain the data.
  - Analyse the data using empirical-statistical methods.
  - Present the results in some statistical format.
  - Interpret the results.
  - Accept or reject the hypothesis (H_0). Accept an alternative hypotheses (H_1) if one was formulated.
  - Draw conclusions.

- **The design process:** In the field of technology and technology education, this problem-solving process may also be called the **technological process**. In this process learners are presented with a problem which requires that learners design a process, system or product as solution to the problem. Learners will have to generate ideas, suggesting possible solutions, select the most appropriate solution, make prototypes, evaluate and refine their initial design. This process will be elaborated on in Section 3.5.2.1.

- **The research process:** Learners will have to identify or be presented with a situation in which they have to develop an innovative problem solution. They will have to design a research plan, decide on an appropriate methodology, gather, analyse and report data, reach conclusions and evaluate the research project.

- **Project management:** After learners have identified project goals and objectives, they have to identify tasks that will enable the attainment of the goals. Following task identification, they have to develop strategic plans, implement and evaluate the plans.

- **Trouble shooting or debugging:** Here learners are presented with a problem related to equipment or the operation of a system. Learners have to trace the cause of the malfunction by taking measurements, making observations, isolating the problem, implementing correctional procedures and testing it.

Before the discussion can embark on the conceptualisation of the technological process as a problem-solving process, per se, technology as a field or a Learning Area has to be demarcated first. In the pursuit of exploring the nature and structure of technology, it will also become clear why PBL was identified as a strategy for training prospective technology teachers.

The rest of the chapter will focus on how technology and technology education are conceptualised, internationally and nationally.

3.4 What is technology education? Perceptions and definitions.

Existing perceptions of technology are unlimited. Due to the permeating nature of technology in the every day lives of people, a multi-facetted understanding of technology and technology education exists. Some of these understandings include the following:

- The high-tech cyber world of computers, software and electronic equipment.
- Technical-vocational orientated environments.
- Industrial arts, arts and design.
- Applied science and engineering.

It may well be that the collective understanding of technology and technology education is what it actually entails. For the purpose of practising technology education as a science, it is imperative to have a mutual understanding of this terrain, at least as it is conceptualised in South African education.

3.4.1 Defining technology

Herschbach (1995) traces the etymology of the word technology as being "reasoned application" of technical knowledge. He theorises that technology is epistemologically different from formal knowledge of academic disciplines, since it exists through activity. According to him it is the activity-based nature which establishes the framework within which technological knowledge is generated and utilised. Thomas (1988) however, places the "activity" within a broader context of creative human activity which is purposeful. A detailed definition is given by Thomas (1988:12):

> *Technology involves a creative human activity which brings about desired changes by making things, controlling things or making things work better by careful designing, making and evaluation using relevant knowledge and resources.*

Johnson (1989:3) formulates a more concise definition:

> *Technology is the application of knowledge, tools and skills to solve practical problems and extend human capabilities.*

The definition for technology contained in the South African Technology 2005 Draft National Framework Document (Department of Education, 1996b:12) is formulated as follows:

> *Technology is a disciplined process using knowledge, skills and resources to meet human needs and wants by designing, making and evaluating products and processes.*

This definition has a strong focus on the process nature of technology where the mind and hand work interactively. HEDCOM (1996: 28-29) reminds us that historically, technology has been mistakenly conceived as being associated with the acquisition of activity-related, motor skills and computer related activities. Waks (1993:i) suggests that it should be borne in mind that modern technology involves higher order cognitive processes in conjunction with practically based problem-solving activities. The implication of process thinking in technology will be discussed in more detail when technology education is defined in the next section.

3.4.2 Defining technology education in the curriculum

To provide a backdrop for the definition of technology education in the new South African curriculum, the general aims envisaged for technology education, will briefly be introduced. HEDCOM (1996:12) states that the study of technology education should stimulate learners' natural curiosity and interest in the man-made environment. It should enable them to understand and critically engage the challenges that technology presents in their future roles as workers, consumers, citizens and parents in a developing South Africa. The Department of Education (1996b:4) clarifies the role to be played by technology education even further when they state the following:

> *Technology's prime claim to a recognized place in the school curriculum lies in its contribution to the growth and development of individual learners. Both younger and older pupils enjoy taking part in the technological process, which makes the subject appropriate for all school phases as well for gifted and less gifted learners. Young people are entitled to a relevant education which will empower them to a meaningful existence. Technology has an important and specific role to play in achieving this aim.*

This quotation also refers to the scope of technology education in terms of equal opportunities, regardless of ability, race, gender or culture. One of the specific outcomes for the technology Learning Area reads that learners should demonstrate an understanding of how technology might reflect different biases, and create responsible and ethical strategies to address them (Department of Education, 1997a:86).

Inclusion of special education needs

Notwithstanding the existence of special schools in South Africa, regular schools also have to deal with issues of inclusion where learners who are physically and mentally challenged have to be accommodated – also in the delivery of technology education (Reddy, 1995:137). The definition and activities should be broad and flexible enough to enable all learners to participate in technological activities. The variety of routes for achieving technological capability should give all learners, especially those with special needs, the opportunity to experience a wider range of activities than in the more traditional approaches (Rodbard, 1992:124).

One of the benefits of focusing on technological capability for learners with special needs, is that it is creative and has a practical focus as well. The traditional approach of learning a large body of knowledge is replaced by the investigation of needs and opportunities, followed by the chance to make or modify something and then to evaluate the solution. According to Rodbard (1992:123-132) the change in nature and methodology envisaged for technology education spares those with special education needs the laborious academic assimilation of facts and gives more opportunities for their creative and practical talents to develop.

Multi-cultural education

Technology education should be particularly sensitive to the way culture and race issues are incorporated into the curriculum (Eggleston, 1992:64). Cultural diversity is a characteristic feature of life in South Africa. It is important therefore, that both teachers and learners are aware of the cultural diversity pervading modern society in South Africa and how this will be reflected in schools. The teaching of technology education will require perception and sensitivity because the meaning and interpretation of technology can vary significantly across cultures (Somerset Design and Technology Advisory Team, 1992:28). The curriculum should be flexible enough to acknowledge and accommodate indigenous forms of technology.

Gender

Technology education has a role to play in the widespread gender related division of labour. Gender related division of labour is one of the *"most marked and persistent of the patterns that characterize human society"* (Cockburn, 1991:41). Women are clustered into relatively fewer occupations. Men by contrast are engaged in a wider range of activities and there are few from which they are entirely absent. For example, while women constitute about 41% of the economically active population in South Africa, they are still clustered around the "poorly paid" community and social services sectors (The Star, 14 November 1994:10).

In the context of the school, although boys tend to dominate the "making" activities and girls are not given the necessary encouragement to work with construction materials (Benson, 1992a:100), there is no evidence to indicate that overall ability in technology activities is limited by gender variables (Eggleston, 1992:59). Technology should entail activities of equal relevance to girls and in a balanced range of contexts. It is important that teachers guide learners in the choice of technology activities which do not emphasise gender stereotypes (Somerset Design and Technology Advisory Team, 1992:28).

Technology education should give all learners the confidence to address needs and opportunities, solve problems and respond meaningfully to technological change. It should further contribute to the following (Department of Education, 1997a:84-85):

- The development of learners' ability to perform effectively in their changing environment and to stimulate them to contribute towards its improvement.

- The effective use of technological products and systems.

- The ability to evaluate technological products, processes and systems from functional, economic, ethical, social and aesthetic points of view.

- The designing and development of appropriate products, processes or systems to functional, aesthetic and other specifications set either by the learner or others.

- The delivery of quality education and access and redress through (1) relevance to the ever-changing modern world and (2) integration of theory and practice.

- The development of citizens who are innovative, critical, responsible and effective.

- The demystification of technology.

- The recognition of and respect for diverse technological solutions and biases that exist.

- Creating more positive attitudes, perceptions and aspirations toward technology-based careers.

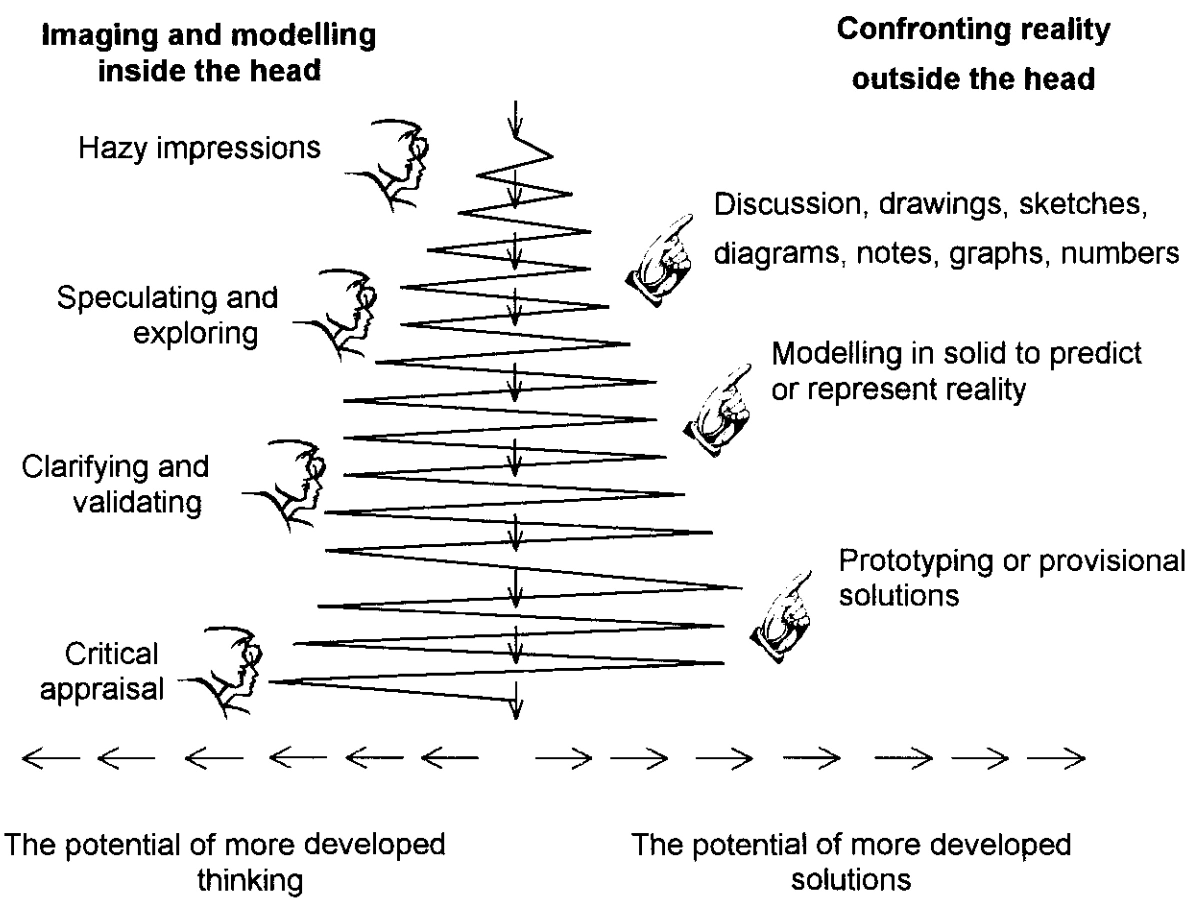
With these aims in mind for technology education, it is clear that technology education should no longer be confused with educational technology and technical education which is presented in technical schools. Technical education, according to Pena (1992:149) focuses on the practical knowledge needed to perform skilled jobs. Its purpose is vocationally orientated and its contents are defined according to the specific tasks to be performed in the workplace. Technology education, however, is none of the above. In different countries, different definitions of technology education exist, depending on their vision and agendas with this Learning Area. In South Africa, the following definition forms the corner stone of this new Learning Area in Curriculum 2005 (Department of Education, 1996b:12-13):

> *Technology education concerns technological knowledge and skills, as well as technological processes, and involves understanding the impact of technology on both the individual and society. It is ultimately designed to promote the capability of and to stimulate him/her to contribute towards its improvement. This capability should be reflected in:*
>
> – the effective use of technological products and systems;
>
> – the ability to evaluate technological products/processes from functional, economic, environmental, ethical, social and aesthetic points of view; and
>
> – the ability to design and build appropriate products to functional, aesthetic specifications set either by the learner or by others.

This definition reflects in itself the **interactive process of thinking and doing**. The why and how is just as important as the what – products, artefacts and systems, which are the results of a process. The technology in which learners have to be educated involves more than conceptual understanding only - but is dependent on it, and it involves more than practical skills only – but is dependent on it (McCormick, Murphy & Harrison, 1992:61). A model called the APU model visually represents the interplay between head and hand as it is intended in the South African technology curriculum. This model also forms a foundation for the technological process, which is the first specific outcome for this Learning Area in Curriculum 2005. The technological process will be attended to in more detail in Section 3.5.2.2.

This model came into existence when a team of the Goldsmith's College in the United Kingdom was commissioned by the Performance Assessment Unit to assess the technological capability of 15 year olds. These learners were exposed to the English and Welsh National Design and Technology curriculum (Stables, 1992:372-375). The strength of this model according to the researchers, is the fact that the interactive process between thinking and doing, remains intact. The thinking and doing modes are not fragmented into thinking on the one hand and final technological products on the other. This is important for assessment in technology education since this model highlights that it cannot only be the technological products which should be assessed but the process as well. This model claims to promote a holistic perception of how technology education should be conceptualised and which the South African definition of technology education also promotes.

Figure 3.2 The APU model of interaction between mind and hand



The left side of the triangle represents the imaging and modelling inside the head, while the right side represents the tangible actions which are the results of the mind actions and which may in turn feed back into the refinement of the mind's idea or speculation. For example, the process of trying to express a hazy idea or solution in the mind, actually forces the learner to clarify the idea. By trying to express ideas in words, pictures or concrete reality, the learner actually gets closer to seeing the difficulties and possibilities within it (McCormick, Murphy & Harrison, 1992:61).

The definition of technology education explained above is derived from the seven specific outcomes for technology education, their assessment criteria and range statements. All the specific outcomes are underpinned by the seven plus five critical outcomes. The relationships between these elements have been explained in detail in Chapter 2, Section 2.4.3. and Section 2.4.3.3. Only the seven specific outcomes will be presented below. The detailed assessment criteria and range statements are included as Appendix 3. The specific outcomes are the following:

SPECIFIC OUTCOME 1: Understand and apply the technological process to solve problems and to satisfy needs and wants.

SPECIFIC OUTCOME 2: Apply a range of technological knowledge and skills ethically and responsibly.

SPECIFIC OUTCOME 3: Access, process and use data for technological purposes.

SPECIFIC OUTCOME 4: Select and evaluate products and systems.

SPECIFIC OUTCOME 5: Demonstrate an understanding of how different societies create and adapt technological solutions to particular problems.

SPECIFIC OUTCOME 6: Learners will demonstrate an understanding of the impact of technology.

SPECIFIC OUTCOME 7: Learners will demonstrate an understanding of how technology might reflect different biases and create responsible and ethical strategies to address them.

The specific content for the technology curriculum, which is also briefly outlined as part of the range statements, will be divided into a specialist and general dimension. The specialist dimensions comprise of the following broad groupings of concepts and skills (HEDCOM, 1996:13 and Department of Education, 1997a:93):

- Systems and control (Mechanisms, Electrical, Hydraulic and Pneumatics).

- Structures.

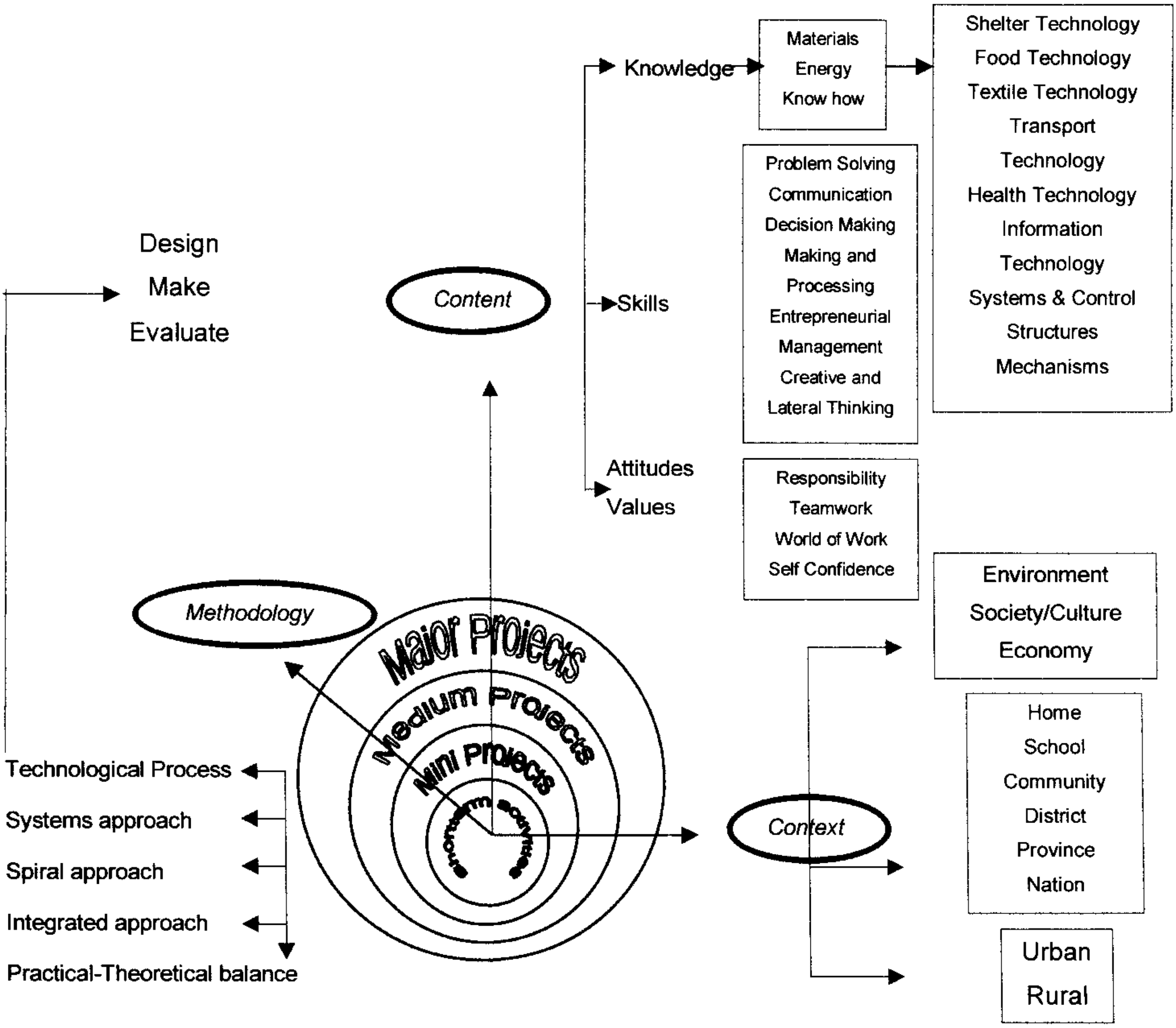
- Communication.

- Processing (Food, Textiles and other materials).

These specialist dimensions will form a basis upon which specialisation in the Further Education and Training Band can take place in technology education. In addition to the specialist dimensions are the **general dimensions** which are energy and power; materials and components; information and safety.

Although it was not initially intended this way, a model by Eisenberg (1992) representing the characteristic features of technology education provides a comprehensive overview of the curriculum framework for technology education as it has been taken up in the South African curriculum. In Figure 3.3 the three different axes showing methodology, content and contexts, represent the specific outcomes, assessment criteria and range statements specified in Curriculum 2005. What Eisenberg calls methodology does not imply teaching methodology, but methodologies associated with the processes of technology, which where formulated as specific outcomes in Curriculum 2005. The content axis includes other specific outcomes for technology education, as well as the specialist and general dimensions of content. The context axis is representative of the range statements which provide the detail of the contexts in which outcomes have to be demonstrated.

Figure 3.3: Eisenberg (1992) model representing the characteristic features of technology education



These dimensions represent understandings, knowledge and skills around which the technological process and learning opportunities can be designed. The idea with these dimensions is not to compartmentalise technology. As technology problems and projects become more complex and sophisticated, they should be integrated in a realistic range of ways. The general dimension "safety" for example, must be integrated in each of the other dimensions.

3.5 The nature and structure of technology education

Within the innate nature and structure of a discipline lie the foundations for an appropriate teaching methodology. The substantive structure of a discipline represents the "what" of a discipline, while the syntactical structure is representative of the "how". The syntactical structure provides the mechanisms and processes for generating new knowledge - the "what".

The following paragraphs will explore the nature and structure of this rather new field of study, which will then provide background knowledge when exploring appropriate methodologies and strategies for the training of pre-service technology teachers.

3.5.1 The synergy between mathematics, science and technology – a cross-disciplinary nature

Often technology is perceived as applied science, using mathematics as a language for expressing its manipulation of the material world in terms of its measurements. The disciplines of science and technology are often combined in a phrase "science and technology" as though they connote a single entity. A White Paper on 'Science and Technology' exists, and 1998 was the Year of "Science and Technology" in South Africa. Much has been written about the independence of science and technology as well as about their inter-dependence. The fact that science is always mentioned first might presuppose that science is logically prior to technology. However, science always preceding technology is not necessarily the truth when history is studied. The use of levers existed long before mechanics were described in terms of laws of mechanics, using mathematical formulae

(HEDCOM, 1996:26).

During the Renaissance the scientific method of empirical verification liberated humanity from superstition and opened new gateways to controlling the natural world. This resulted in the Industrial Era where machines were extending and replacing the work done by human hands. From there onwards the century has witnessed exponential growth in the manmade technological environment.

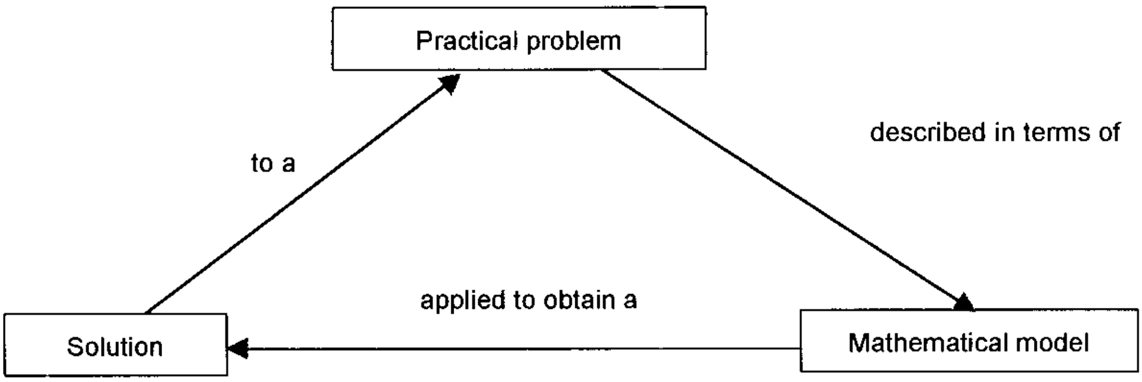
It would seem then that the differences between these two disciplines are to be found in the purpose of the activities involved, while the affinities reside in the practices. Unesco (1983:17-18) states that the purpose of science is to enlighten humanity by building up knowledge: to give an explanation of something, to provide a true description of some event or to diagnose the nature of some condition. The purpose of technology is to facilitate human aspiration and to serve humanity: to solve some practical problem, to put knowledge to good use and to extend the boundaries of existing possibilities. Thus, while technology draws upon scientific knowledge, it is also concerned with design, with considerations of social and legal issues, as well as costs and feasibility. While science will explain why air which moves rapidly over a surface exerts less pressure on that surface than slow moving air, technology will attempt to use this knowledge to make a machine that will fly.

At the JISTEC 1996 Conference held in Jerusalem on science and technology education, the differences between science and technology were illustrated as follows (Department of Education, 1996b:26):

SCIENCE	TECHNOLOGY
Curiosity-driven	Need or want-driven
Aim is to explore natural phenomena and reach ever improving understanding	Aim is to design and develop new products which solve new or existing problems
Works with idealised models of the world, based on certain assumptions	Works in the real, complex, human world
Internal criteria are truth, accuracy and the ideal	Criteria are solutions which are effective, efficient and within acceptable tolerances and

	standards
Looks for universal knowledge	Looks for optimal solutions for specific situations

Both science and technology are also related to mathematics. Mathematics plays a fundamental role describing problems and needs of the environment. It also plays a central role in the description of generalised and rigorous science theories, underlying technological innovations. When dealing with problems and needs it becomes necessary to investigate, collect, analyse, and communicate the quantitative data. This is usually done by using mathematical modeling, shown in the diagram below (HEDCOM, 1996:27):



After a practical problem has been modelled mathematically, the solution is obtained by using the appropriate techniques, sets of equations and formulae, to present a solution in some format or another. Mathematics thus becomes a vehicle for contributing towards a more theoretical, rigorous science as well as the solution to the problem. While developing an arithmetical system which uses just one symbol and a placeholder, instead of nine symbols and a place holder is a mathematical activity, using such a system to design a computer, is a technological activity. Furthermore, mathematics is used to estimate, compute, measure, predict and to scale in technology (Raat, 1992:362).

In schools in different countries the synergy between these subjects is acknowledged in different ways. The traditional curriculum in different countries caters intentionally for science and mathematics, while this is not the case for technology. Only in very recent years have a small number of countries taken technology education up in their curricula. Chapter 1 Section 1.3.1 gives a full account of various models which were used to accommodate technology education in their schools. In the Netherlands for example, the synergy between science and technology has been accommodated in three different ways in secondary education. Firstly, technological topics have been incorporated into the existing science curriculum. Secondly, a new curriculum called Science, Technology and Society (STS) has been introduced or added to existing science curricula. The third option was the introduction of technology as a separate curriculum (Eijkenhof, Franssen & Houtveen, 1998:667). Each of the options had its advantages and disadvantages in terms of competition between science and technology teachers, the lack of competent teachers in both areas, the different teaching methodologies associated with science and technology, etcetera (Eijkelhof, Franssen & Houtveen, 1998:688-689).

In Ontario, Canada, the curriculum innovation has gone beyond only integrating the mathematics, science and technology curriculum. They integrated the 'maths, science and technology' Learning Area also with Learning Areas such as arts, language and self-and-society. They organised the Learning Areas around broad themes or topics which were being dealt with in different Learning Areas at the same time (Black & Atkin, 1996:46). In Australia, science and technology are combined in the primary school, but separated in the secondary school. In the secondary school the Learning Area is actually called Technology and Applied Studies and it contains a subject called Design and Technology that is compulsory during the first two years of high school (Morgan, 1992:133-134). The debate of which implementation models will be most beneficial to learners in South Africa, is only in its beginning stages of research and will not be discussed further in this literature survey.

In South Africa, it was mentioned earlier that technology is part of the general science curriculum in the foundation, and intermediate phase in Curriculum 2005, while it will be treated as a separate Learning Area in the senior phase. Technology is compulsory in all of these phases. For the further education and training band (FET), it can only be speculated that technology will not be a fundamental or core subject, but a separate elective subject, which might offer dimensions for specialisation (Department of Education, 1997d:49).

However, current research proposed that the compulsory core Learning Areas in the FET phase should include science, technology, social sciences, a work related area and citizenship (Department of Education, 1997d:50).

Although technology has strong cross-curricular relations with mathematics and science, it is not the only cross-curricular relationship that exists. Several authors, notably Dacey (1986:19), Young (1991: 236-237) Benson (1992a:8) and Raat (1992:362) agree about the inter-disciplinary nature of technology education. They have identified the following few examples, apart from mathematics and science, which display this cross-curricular connection:

- From **Industrial Arts** and handicraft, technology education draws on the knowledge of (1) materials and the way they can be worked (2) tools, their use and safety (3) aesthetic and ergonomic factors.

- From **Home Economics** it draws on (1) experience of working with materials associated with food and textiles (2) experience of packaging, presentation and nutritional value of food (3) knowledge of dyeing, weaving and packaging of textiles.

- From **Business Economics** it draws on (1) knowledge of business and economic awareness (2) entrepreneurship.

- From **Economics** it draws on (1) considerations on the availability of materials (2) considerations of the costs of materials, the processes used and the time taken to complete a task.

- From **Technical Drawing** it draws on (1) knowledge and drawings of two and three dimensional shapes (2) spatial awareness.

- From **Art** it draws on how technology cannot only meet the technical needs of people, but also their aesthetic needs.

With the understanding of the inter-disciplinary and cross-curricular nature of technology education, we can proceed to another characteristic feature in the nature and structure of technology education.

3.5.2 The problem-based nature of technology education

In the previous section it was seen that science and technology are inter-dependent but contrasting activities. The one undeniable characteristic of technology is its need-driven and problem-orientated nature (Pucel 1992, Johnsey, 1995 and Williams & Williams, 1997). Technologies being used to address problems in turn create new problems such as pollution, health hazards, job displacement and others. Although technology contributes to new types of problems, technology will be used to address possible solutions to the problems it created (DeLuca, 1992:26).

In the technological endeavour to solve a problem or need, technology draws not only on scientific knowledge, but also concerns itself with social, environmental, legal and economical issues. Real life problems never exist in isolation, but draw on a variety of resources from different areas. It seems then that successful technological activities are integrated and multi-disciplinary. The implication of this for education is that it has natural links to most of the other curriculum Learning Areas: language, communication, social studies, arts, humanities, environmental studies and technical studies. Technology education brings down the artificial boundaries between subjects (HEDCOM, 1996:4). Technology, with its focus on real life problems, can motivate learners to learn science, mathematics and other subjects, since it makes these Learning Areas relevant for real life.

To seek solutions for real life problems, the solvers need to embark on a journey of problem-solving processes. In Section 3.3.9 problem-solving in general was addressed. The typical mode of thought of a technologist is lateral, implying that scientific materials and knowledge have to be used in a creative, inventive but responsible ways – 'this' does not work, lets try "that". This does not mean that the technologist will not need the typical mode of thought of the scientist, which is longitudinal, meaning that the principle of causality is adhered to – "this" logically follows "that" (Unesco, 1983:18).

The first specific outcome for technology education in Curriculum 2005 (Department of Education, 1997a:84), links problem-solving for technological purposes directly with the technological process:

> *Understand and apply the technological process to solve problems and satisfy needs and wants.*

In different technology education curricula the technological process is often mentioned in conjunction with the concept "design". In the United Kingdom the new Learning Area is called Design and Technology (Johnsey, 1995:199). In Australia, Design and Technology is one of the subjects resorting under the Learning Area Technology and Applied Studies, as was mentioned earlier as well. Often in the literature "design", "the technological process" and "solving open-ended problems" are used interchangeably. In the aforementioned paragraph the design process was proposed by Devore (1988:2) as a problem-solving process with the following stages:

- Ideation/Brainstorming
- Identify possible solution
- Prototype
- Finalise design

Johnsey (1995:199) explains that the process followed to achieve a solution to a open-ended problem, is called a problem-solving process. Once the problem-solving process is executed to fulfil a need or want, it is called the design process.

Design, however can also be interpreted in different ways. Often it is used to refer only to the planning of a product or system in terms of a drawing or diagram. Sometimes it is used in its broadest sense to include the planning phase, making, testing and evaluation. In this research the term 'technological process' will be used when the broadest sense of design is referred to.

The following paragraphs will attempt to give an in-depth understanding of the technological process. The main reason for analysing the constituent phases in the technological process lies in the need to make it possible to teach and assess it (Kimbell, 1994:19). This will be done by giving an overview of different models for the technological process.

The overview will start by giving in table format the processes associated with different models. The models referred to in the table were models that developed over a period form 1971 to 1995 in the National Curriculum of England and Wales (Johnsey, 1995:208). It provides a useful overview of the similarities between various design processes. The table will present the general processes in linear form while in the original presentation they might be circular or have other diagrammatic formats. Different process skills which emerged as common denominators in the different models will be listed in the left hand column. These skills are the following: **Identifying; clarifying; specifying; researching; generating; selecting; modelling; planning; making; testing; evaluating; selling** (only present in one model).

Table 3.2: Models of the design/problem-solving process (*Johnsey, 1995*).

Process skill	1 Design and craft education project, Design for Today (1971)	2 Understanding design and technology, Assessment of Performance Unit (1981)	3 Craft, design and technology from 5 to 16, Department of Education and Sciences for England and Wales (1987)	4 APU Design and Technological Activity – A framework for assessment, (1987)	5 The assessment of performance in Design and Technology. Kimbell (1991)	6 Design and Technology in the National Curriculum (Key Stage 1), (1995)
Identifying	Identify problem area. Identification of needs from given set of circumstances observations resulting in design brief.	Recognising the existence of a problem which might be amenable to solution through D&T activity.	Recognise the general problem area.		Hazy impressions inside head.	... generate ideas
Clarifying	Identification of control factors. Imposition of control factors.	Employing knowledge, analysis, skills and judgement in clarifying the problem.	Specify the exact need. Write the brief	Speculating in the mind's eye together with informal sketch-drawing and modelling.		... clarify their ideas
Specifying	Specification. Translation of design problem into appropriate terms.	Matching the proposed product with its purpose.	Write 'the specification'.			

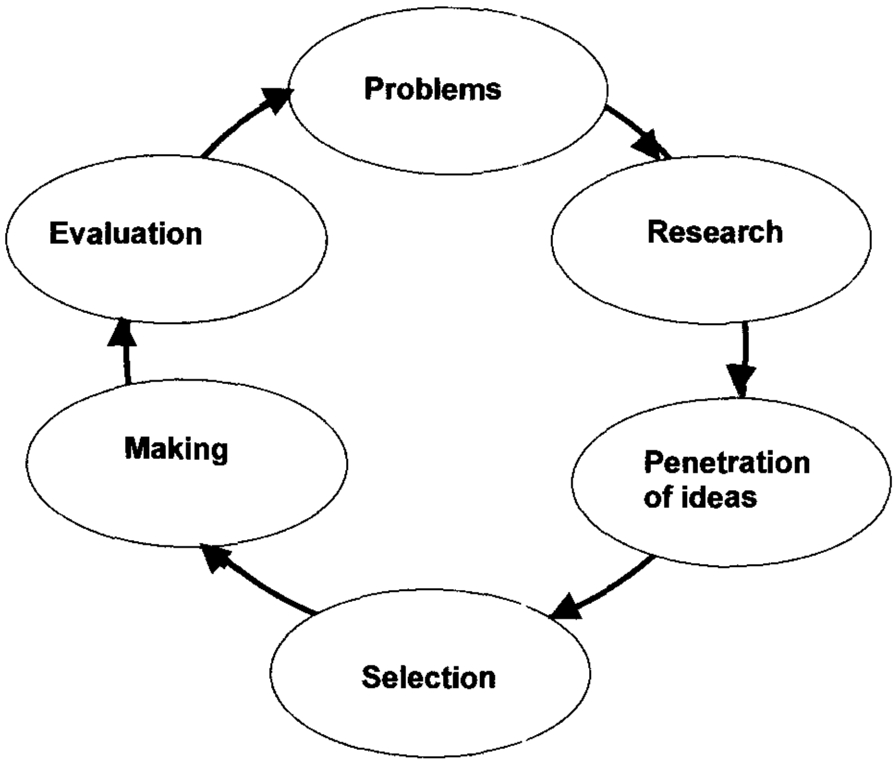
Researching	Gathering of specific information related to problem.	Looking for relevant information and resources.	Research. Collect data.			
Generating	Production of outline solutions.	Thinking of alternative solutions.	Generate ideas and share thoughts with other helpful agencies.			
Selecting	Selection from possible alternatives.	Choosing the best from these.	Select and formulate the design proposals.	Exploring and developing ideas inside the head.	Discussion, drawings, sketches, diagrams, notes, graphs, numbers outside head. Speculating exploring inside head.	
Modelling	Foundation work through "soft" materials, i.e. card, clay etc. Production of models.	Initiating and developing ideas and images and manipulating those images modelling these images in a variety of ways.	Model ideas and test them.	More formalised sketching drawing and experimental modelling.	Modelling in solid to predict or represent reality outside head.	...develop ideas through shaping, assembling and rearranging materials ... ... develop and communicate ideas by modelling ...

Planning		Planning the practical activity. Selecting resources.	Detail intentions and plan manufacture. Relate the methods of making to the facilities and resources available, making any necessary adjustments.			... make suggestions about how to proceed ... select materials, tools and techniques.
Making	Consolidation of workable solutions towards realisation.	Using tools, instru-ments, materials, components, appliances and energy resources.	Make the solution, refining the proposal as necessary.	Refining and detailing in the head together with prototyping	Prototyping or providing solutions outside head.	... measure, mark out, cut, shape, assemble, join and combine a range of materials .... apply simple finishing techniques.
Testing	Judgements and decisions.	Testing the performance of a given product.	Test the outcome.	Validating and judging inside the head together with testing.	.	
Modifying			Adjust if possible.	Modifying		

Evaluating	Assessment of goal achievement. Judgement of the solution in terms of the brief and the specification.	Monitoring effects of operations controlling outcomes understand-ing context in which product to be used; identifying the criteria by which it should be judged: choosing measures; forming judgements; distinguishing needs assigning priorities; appraising efficacy and design activity.	Evaluate the outcome against the original need.		Critical appraisal inside head	. . . consider design ideas as these develop and identify strengths and weaknesses . . . evaluate their products, identifying strengths and weaknesses.
Selling			'Sale and use'.			

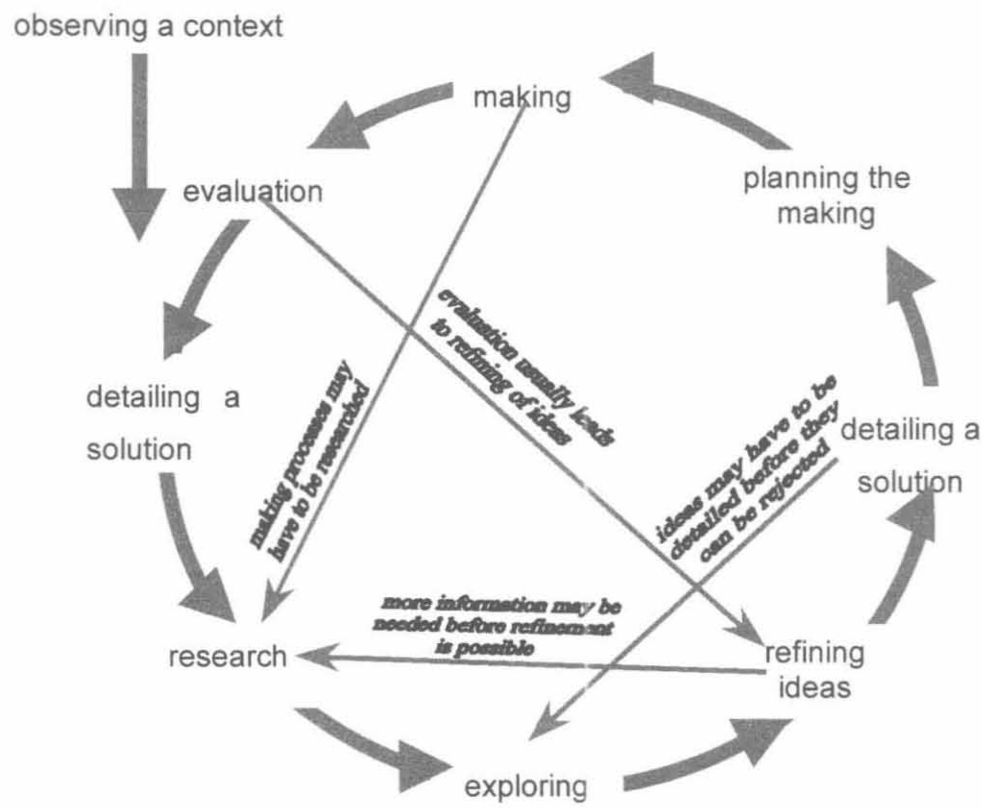
A circular representation of different stages in the technological process may be depicted as follows (Williams & Williams, 1997:91):

Figure 3.4: An example of a technological design model



Although these models are helpful guides as to what sorts of activities need to go on in the technological process, they can cause misinterpretations in terms of the sequential stages to be followed in the process. The research or investigation stage for example, does not have to be executed only in the beginning of the technological process, but while making the product as well. Learners actually need to be investigative throughout the different processes (McCormick, Murphy & Harrison, 1992:60). Kimbell (McCormick, Murphy & Harrison, 1992:60 and Williams & Williams, 1997:95) suggests an interactive design loop for the technological process where different stages are linked in the following way:

Figure 3.5: An example of a technological design model



(Cuthbertson, 1990:191)

The overview provided in both table and diagrammatic format, illustrates that differences exist among these models, but that the general stages and processes associated with them are actually similar. The literature, however, gives a cautionary note regarding displaying the design process as a fixed, simplistic linear or cyclical process. Baynes (1992:1) makes it clear that

> *the processes involved in designing are not linear, they do not always start from human needs, and they do not always proceed in an orderly way. They are iterative, spiralling back on themselves, proceeding by incremental change and occasional flashes of light.*

Furthermore it is argued by Hennessy & McCormick (1994) that problem-solving used either by novice problem-solvers or expert problem-solvers depends heavily and is strongly influenced by the **context** of the design. In other words all problems and needs to be addressed are not alike and the research approach (dissection, fact gathering, testing and selecting) is not applicable to all situations. Flowers (1998:21) mentions that few of today's technological products are actually designed to meet actual needs. They are almost always designed for open markets and only then are human wants engineered around the product availability, using the science of effective marketing.

Flowers (1998:20) advocates another avenue of problem-solving all together in technology education, which is a departure from the western (or stereotypical male) approach to technology. Western definitions accentuate that the goal of technology is to gain control over the environment to meet human needs and wants. Flowers (1998:220) suggests that technology education should accommodate different belief systems. He explores the Taoist philosophy translated by Lao Tsu (1972) from the Tao Te Ching document in the 6th Century BC China. He identifies some principles from the document which may be considered when teaching technological problem-solving.

Although bias against the Taoist doctrines may exist, a few of the doctrines which have meaning for technology education will be discussed. Doctrine 46 states "*who knows that enough is enough will always have enough*". One "*who is attracted to things will suffer much*" (doctrine 44). "*One gains by losing and loses by gaining*" (doctrine 42). This implies that the technology learner should be sensitised that the best solution to a problem may be non-action and acceptance of a situation or system without change. This means that technology learners should use their problem-solving skills to improve the human and also the non-human condition, in spite of what some people think they need or want (Flowers, 1998:13).

The implication for technology education is that different belief systems, cultures and their concurrent models should rather be viewed as frameworks for the technological process which should maintain the necessary flexibility to be modified as required by a specific problem context or need.

3.5.2.1 The technological process used in South African curricula

The technological process referred to in the first specific outcome for technology education in Curriculum 2005 refers to a cycle of investigating problems, needs and wants, as well as the designing, developing and evaluating of solutions in the form of products and systems. This process is the basis of all technological endeavour. Understanding the process is fundamental to the acquisition of technological literacy (Department of Education, 1997a:86). The technological process is an integrated and indivisible one and therefore, assessment should apply to the whole process. This integrated notion of assessing process and products is in line with the assessment theory and practices promoted by the inter-active APU assessment model which was addressed in Section 3.4.2. This process is represented in more detail in the following table (Department of Education, 1997a:86 and De Swardt & Ankiewicz, 1996:30-31):

Table 3.3: The technological process as conceptualised in South African curricula

THE TECHNOLOGICAL PROCESS	
NEEDS ANALYSIS AND DESCRIPTION	• identifying a need or problem • writing a design brief • analysing the problem • drawing up specifications
DESIGN AND DEVELOPMENT	• doing research • generating ideas • developing ideas and selecting the best ideas • communicating your idea

PLANNING AND MAKING	• planning: – choosing material, equipment and processes – working out costs – making a working drawing • making: – quality of construction – accuracy – finishing – appearance – safety
TESTING AND EVALUATING	• testing • evaluating
RECORDING, COMMUNICATING	• portfolio to be completed • displaying

This process shows strong resemblance with the design models which were presented earlier in Section 3.5.2. Technology teachers are challenged to teach the technological process both as an end, but also as a means of learning technological content and using that to solve problems.

3.6 Appropriate methodology for facilitating learning in technology education

An appropriate teaching methodology for facilitating the technological process can be deduced from the syntactical structure of technology. *Cognisance should be taken of the fact that the methodology suggested for teaching technology is similar to the methodology advocated by OBE.* To present a methodology for facilitating learning in technology in detail, will be the same as repeating the strategies and methods which would operationalise the principles of an OBE approach in practice. In conclusion the main common denominators in technology and OBE methodology will briefly be highlighted below:

- The methodology of both are based on principles of learner-centredness in its broadest sense. These principles and their meaning for planning and facilitating learning were described in detail in Section 3.2.1.

- Both methodologies value and promote creative problem-solving while critically showing responsibility towards environments, society and the health of others. This characteristic directly acknowledges SAQA critical outcomes number one and six. See Section 2.4.3.2 for the SAQA critical outcomes.

- Problems to be solved should be relevant and authentic. Section 3.3.8.1 provided the criteria for appropriate problems.

- Knowledge and skills are valued equally important for effectively solving problems and performing real life roles.

- Both methodologies draw on and promote cross-curricular problem-solving and learning experiences.

It was the purpose of this chapter to describe and propose PBL as a curriculum model, methodology and strategy for the following various reasons:

- To operationalise the philosophy and principles of OBE in classroom practice and pre-service training programmes.

- To describe PBL as an appropriate methodology for facilitating learning in technology education.

- To describe and design a PBL model which can be used in the pre-service training of teachers who will have to facilitate this new Learning Area also through a PBL methodology. The designed model will be called the OBE-PBL model and will be presented in the next section.

In the qualitative component of this research where the pre-service teachers were interviewed, valuable information is given regarding how teaching technology through PBL has clarified the conceptualisation of outcomes-based principles.

Although the OBE-PBL methodology had been explored intensively in this chapter, it is never the less valuable to take cognisance of the HEDCOM Technology 2005 Project suggestions which need to be considered for technology teacher training programmes. Some are very generic and coincide with roles and competencies described in the Norms and Standards for all Educators which were given in Section 3.2.2. They (HEDCOM) are adamant that technology teacher training programmes should ensure that prospective technology teachers should demonstrates the following competencies regarding methodology (1996:9-13):

- Facilitate learner-centred classroom practice by employing a range of teaching strategies appropriate to technology education.

- Employ methods which encourage the child to engage in creative and innovative activities.

- Employ methods which will develop skills in problem-solving.

- Select and use in a considered way a variety of resources, including information technology.

- Make use of cross-curricular concerns within subject related teaching.

- Create learning contexts in which there is a paradigm shift in emphasis from teacher initiated and determined activities to ones in which learners are encouraged to reflect and to make their own critical choices.

- Develop the skills of technology education.

- Encourage and challenge learners to take initiatives and become responsible for their own learning.
- Develop learning environments that will develop learners' ability to use knowledge, skills and resources to:
    - design solutions to technological problems and needs
    - work collaboratively in groups
    - plan, manage and assess their own activities
    - integrate thinking and action within the context of technological solving
    - make their own decision, to justify choices made and to do self assessment.

- Link school work with authentic technological activities in the wider community.

Project work should therefore form the basis for facilitating learning in technology education (Department of Education, 1997a:84-106 and HEDCOM, 1996:14). Project work can be made up, but does not necessarily have to be, of a combination of case study tasks, resource tasks and capability tasks.

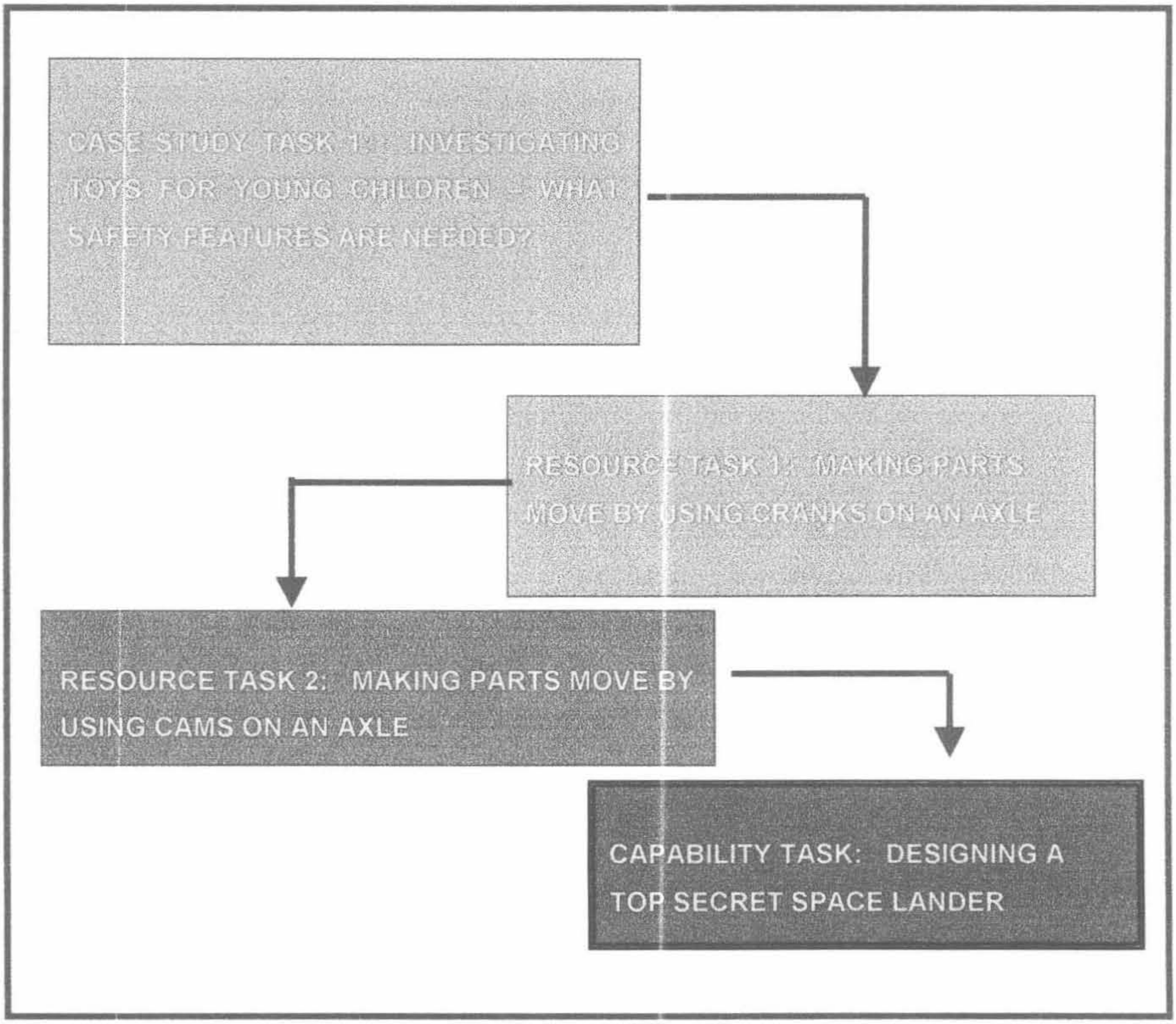
Case study tasks are generally short, structured tasks which aim to link learning in schools with technological experience in the wider community where the community includes post offices, power stations, factories, farms, etc. They should provide a vehicle for examining the ethical, social and environmental issues related to the development of technology and its application.

Resource tasks are generally short-term, structured tasks which aim to develop learners' resources of technological knowledge and skill. An example of a specific skill which learners might need to demonstrate before designing and making a technological device, is how to make a linkage, the mechanism for connecting levers. These tasks may nevertheless include some elements of design and problem solving.

Capability tasks are extended, open-ended tasks in which learners are required to use a range of resources (including the knowledge and skill acquired in earlier activities) to design, realise and evaluate solutions to technological problems. These tasks represent the authentic problem or need which is to be addressed. This is the typical type of problem which was described as the problems to be designed in a PBL approach.

The following figure shows how these three types of tasks may be connected:

Figure 3.6: Project work in technology education (Combining case study, resource and capability tasks to form complete projects: an example from grade 4)

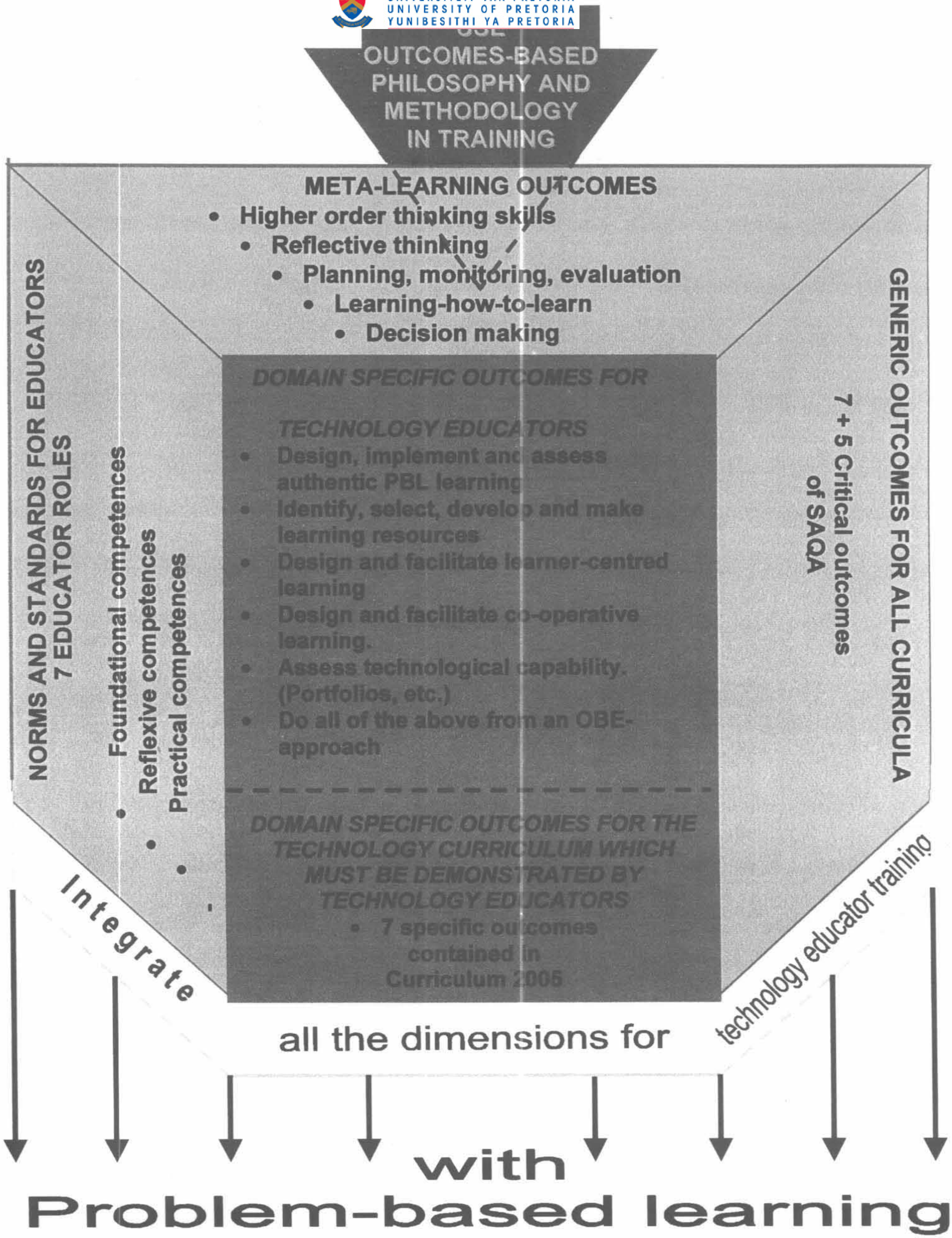


Any teacher training initiatives for prospective South African technology educators should accommodate these lines of thinking in their professional preparation programmes. In the section to follow, the OBE-PBL model will be presented.

3.7 The OBE-PBL model

From the literature on OBE, PBL and technology education which was reviewed in this chapter, a model can be designed as the collective outcome of this chapter for the purposes of this research. The proposed model will be titled the OBE-PBL model, since PBL is hypothesised to operationalise OBE in the training of pre-service technology educators in such a way that they can successfully transfer their competencies to the real job. This model will serve as a meta-curriculum model and not as a blueprint for a pre-service technology teachers' training programme. It highlights the declarative (know-what) and the procedural (know-how) competencies (Everwijn, Bomers & Knubben, 1993:433), which need to be integrated into contextual demonstration (outcomes) during training and classroom interactions through PBL. Figure 3.7 represents the OBE-PBL model.

Figure 3.7: The OBE-PBL pre-service technology teachers' training model


OUTCOMES-BASED
PHILOSOPHY AND
METHODOLOGY
IN TRAINING
META-LEARNING OUTCOMES
• Higher order thinking skills
• Reflective thinking
• Planning, monitoring, evaluation
• Learning-how-to-learn
• Decision making
DOMAIN SPECIFIC OUTCOMES FOR
TECHNOLOGY EDUCATORS
• Design, implement and assess authentic PBL learning
• Identify, select, develop and make learning resources
• Design and facilitate learner-centred learning
• Design and facilitate co-operative learning.
• Assess technological capability. (Portfolios, etc.)
• Do all of the above from an OBE-approach
DOMAIN SPECIFIC OUTCOMES FOR THE
TECHNOLOGY CURRICULUM WHICH
MUST BE DEMONSTRATED BY
TECHNOLOGY EDUCATORS
• 7 specific outcomes contained in Curriculum 2005
NORMS AND STANDARDS FOR EDUCATORS
7 EDUCATOR ROLES
• Foundational competences
• Reflexive competences
• Practical competences
GENERIC OUTCOMES FOR ALL CURRICULA
7 + 5 Critical outcomes
of SAQA
Integrate
all the dimensions for
technology educator training
with
Problem-based learning

The first dimension of this model acknowledges the starting point of design of all future curricula and learning programmes in South Africa. This dimension is represented by the right façade of the model and refers to the seven plus five critical outcomes proposed by SAQA – the real life roles which have to realise the vision of lifelong learning of the NQF. Reinforcing the critical outcomes, are the competencies which promote self-directed and reflective learning. These are the meta-cognitive skills, without which a learner or professional teacher cannot do effective action research to enhance their practice performance. These are represented by the top façade of the OBE-PBL model.

The left façade of the model acknowledges the seven educator roles as described by the Norms and Standards for Educators (Department of Education, 2000a). These roles should be taught in an embedded, integrated approach if teachers have to transfer these roles to real life classrooms. The middle façade is separated into two sections. The one deals particularly with the specialist role of being a technology teacher. That means that a teacher of technology education must know the content and processes of the Learning Area. The second part deals with the methodology particularly related to the nature and structure of technology education. This implies, according to this research, that a pre-service teacher must become competent in the design of PBL learning environments and the use of the PBL strategy.

For the pre-service teachers to practise and demonstrate the outcomes in the OBE-PBL model in and integrated way, the PBL strategy was used in their training. After their training period of six months, the pre-service teachers had to operationalise the OBE-PBL model in real classrooms. This means that they had to facilitate learning in technology education through the PBL strategy.

3.8 Summary

Since OBE was described as a philosophy and system for housing the OBE philosophy in Chapter 2, this chapter has mainly started off by focusing on the practical actions that need to be implemented to operationalise the OBE theory in teaching and training practice. One of the strategies which was studied in detail since it showed tremendous potential to operationalise OBE, was problem-based learning. On the other hand PBL as a strategy for training future technology educators was also explored and selected since similarities exist between the nature and structure of this new Learning Area and PBL. The nature and structure of technology education was the primary focus of the last part of this chapter. While discussing the nature and structure of technology education, the similarities between technology education and PBL were highlighted and clarified.

This intensive literature review on OBE, PBL and technology education was undertaken to clarify the main curriculum dimensions which need to be considered when developing a curriculum for the training of prospective technology teachers who have to work from an OBE perspective. The OBE-PBL model was designed as a meta-curriculum model and was used as the training model for the pre-service teachers. This is the model that the pre-service teachers had to internalise to such an extent that they could transfer the outcomes entailed in the model to the real context.

The next chapter will describe the PBL training interventions in the university classrooms, as well as the pre-service teachers' interventions with the pre- and post-groups in real classrooms. The instrumentation which was used to get information on the extent of competency transfer by the pre-service teachers will also be a point of focus.