Supporting the Tutor in a Tutor-Tutee Adaptive Educational System

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Declaration

The work presented in this thesis is, except where otherwise stated, entirely that of the author and has not been submitted as an exercise for a degree at this or any other university.

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Executive Summary

Adaptive educational systems have been successful in providing personalised support in a myriad of domains (Melias & Siekmann, 2004). To provide such support, the adaptive educational system builds an internal representation of the user by analysing the user's behaviour including their knowledge and traits (Brusilovsky & Peylo, 2003). The resulting model is used to adapt the learning environment to that which best suits the individual learner. Furthermore, within a tutoring environment where there are two users, tutor and tutee, working collaboratively to reach a common goal, there may be a need to provide personalised domain support for both users.

One particular environment where there may be a need for such a system is home tutoring. Despite the large body of research, which suggests a high correlation between home tutoring and a child's academic success (Greenwood & Hickman, 1991; Dornbusch & Ritter, 1988), parental involvement in learning activities in the home may not occur spontaneously due to self-believed lack of ability, knowledge and skills (Hoover-Dempsey & Sandler, 1995). However, research indicates the benefit of supporting the tutor in the development of tutoring strategies (Cotton & Savard, 1982). Hence, the need for the development of an adaptive educational system, which supports both, tutor (parent) and tutee (child) during the home tutoring process. Such a system could in particular be of most benefit in supporting the tutor in the development of tutoring strategies.

There are many unresolved issues in developing such an adaptive educational systems. Research questions still outstanding include: (1) how can an adaptive engine simultaneously support dual users (tutor and tutee) (2) what is the appropriate educational theory from which to elicit a set of rules, which define tutoring best practice and (3) what is an appropriate basis for adapting to the needs of the tutor and tutee? This thesis describes how the Parent and Child Tutor (P.A.C.T.) adaptive educational system addresses these challenges.

Firstly, the thesis describes how P.A.C.T.'s architecture differs from that of a traditional adaptive educational system in an endeavour to provide dual user adaptivity. Secondly, the thesis describes how Talent Education philosophy (Suzuki, 1986) informs a set of tutoring rules, which define tutoring best practice. Thirdly, the thesis describes how self-efficacy (person's belief in their ability to accomplish a particular task) can be used to determine the appropriate level of support required by the tutor and how affect (the emotional state) can be used to determine the type of support required by the tutee.

Empirical studies were conducted to explore the effect of using an adaptive educational system to support the home tutoring process in the domains of Suzuki violin and mathematics. In particular, these studies explored the effect of P.A.C.T. on parents' (1) self-efficacy (2) knowledge and (3) perception of their role as home tutor. In addition, studies investigated the effect of providing affective support for the child throughout the home tutoring process. Results suggest that P.A.C.T. may be of benefit in increasing parental self-efficacy and parents' knowledge of home tutoring skills. They also indicate that P.A.C.T. may have a positive effect on parents' perception of their role as home tutor. Results also suggest that adapting the tutoring process based on the affective needs of the child may have a positive effect on the home tutoring process.

In summary the main contributions of this thesis are:

- The design and development of an architecture, which supports dual user adaptivity in the domain of home tutoring.
- The articulation and development of a set of novel tutoring rules based on Talent Education philosophy, which defines tutoring best practice.
- Empirical evidence, which indicates the effectiveness of adaptive strategies based on self-efficacy in supporting the parent as tutor and strategies based on affect in supporting the child as tutee.

Related Publications

Lahart, O. & Weibelzahl, S. (2004). Music Matters an ITS for Violin students. In G. Richards (Ed.), Proceedings of World Conference on E-Learning in Corporate, Government, Healthcare, and Higher Education 2004. Chesapeake, VA: AACE, 1662-1666.

Lahart, O. (2005). An ITS that provides Positive Feedback for Beginning Violin Students. AIED 2005. In: Proceedings of the Twelfth International Conference on Artificial Intelligence in Education, AIED'05, Amsterdam, Netherlands, 964.

Lahart, O., Kelly, D. & Tangney, B. (2006). P.A.C.T. - Scaffolding best practice in home tutoring. IN: Proceedings of the Eight International Conference on Intelligent Tutoring Systems (ITS'06), 26-30 June, Jhongli, Taiwan. Berlin, Springer, 615-625.

Lahart, O., Kelly, D. & Tangney, B. (2007a). Tutoring Strategies to facilitate positive emotional states during home tutoring. Workshop on Modeling and scaffolding Affective experiences to impact Learning Supplementary Proceedings of the 13th International Conference of Artificial Intelligence in Education (AIED 2007), Los Angeles, U.S.A. July 2007, 85-93.

Lahart, O., Kelly, D. & Tangney, B. (2007b). Ask the Tutor - Supporting the Home Tutoring Process. CIANEI 07, Portugal. Oct. 2007, 257-265.

Lahart, O., Kelly, D. & Tangney, B. (2007c). Towards Personalised Support for Home Tutors: Identification of Tutoring Rules. EdMedia, Vancouver, Canada. June, 2864-2870.

Lahart, O., Kelly, D. & Tangney, B. (2007d). P.A.C.T. - Coaching the Parent in Home Tutoring Best Practice. ELearn , Quebec City, Canada. June, 7205-7212.

Lahart, O., Kelly, D. & Tangney, B. (2008a). Development of a Dual User Adaptive Education System. In Proceedings of World Conference on Educational Multimedia, Hypermedia and Telecommunications 2008. Chesapeake, VA: AACE, 1768-1778.

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Lahart, O., Kelly, D. & Tangney, B. (2008c). Eliciting Emotion – When & How? Workshop on Emotional and Cognitive Issues in ITS. International Conference on Intelligent Tutoring System (ITS), Montreal , Canada , June. Available at http://www-etud.iro.umontreal.ca/~chaffars/its2008_fichiers/WECITS2008.pdf accessed on 10th October 2008.

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1 Introduction

1.1 Motivation

Adaptive educational systems have been successful in providing personalised support in a myriad of domains (Melias & Siekmann, 2004). To provide personalised support, adaptive educational systems build an internal representation of the user by analysing the user's behaviour including their knowledge and traits (Brusilovsky & Peylo, 2003). Subsequently, the resulting model is used to adapt the learning environment to that which bests suits the individual learner. Furthermore, within a tutoring environment where there are two users, tutor and tutee, working collaboratively to reach a common goal, there may be a need to provide personalised domain support for both users.

One tutoring environment where there may be a need for such a system is the area of home tutoring. Despite the large body of research, which suggests a high correlation between home tutoring and a child's academic success (Greenwood & Hickman, 1991; Dornbusch & Ritter, 1988), parental involvement in learning activities in the home may not occur spontaneously due to self-believed lack of ability, knowledge and skills (Hoover-Dempsey & Sandler, 1995). However, research indicates the benefit of supporting the tutor in the development of tutoring strategies (Cotton & Savard, 1982). Hence, the need for the development of an adaptive system, which supports both, tutor (parent) and tutee (child) working collaboratively throughout the home tutoring process. Such a system could in particular be of most benefit in supporting the tutor in the development of tutoring strategies.

1.2 Background

Several adaptive educational systems that adapt to individual needs have been developed (Melias & Siekmann, 2004; Mitrovic, 2003; De Bra & Calvi, 1998). However, there is limited research in adaptive systems that support tutor and tutee working together to achieve a common goal. One area of research that may be of relevance is that of adaptive collaborative systems. Such systems can be broadly categorised in terms of research, which supports the collaboration process itself (e.g., promoting deep collaborative discourse (Kumar et al., 2007)) and research, which supports domain learning through collaboration (e.g. providing hints on domain knowledge for the tutor (Walker et al., 2008)). In an adaptive system, that simultaneously supports both tutor and

tutee throughout the home tutoring process, there may be most benefit in providing adaptive domain support, as the nature of learning activities in the home will naturally promote parent-child collaboration.

Building an adaptive system that simultaneously supports dual users (tutor and tutee) working collaboratively is non-trivial and includes two important considerations. Firstly, what is the appropriate educational theory from which to elicit a set of rules that define tutoring best practice and secondly what is an appropriate basis for adapting to the needs of the tutor and tutee?

A number of educational theories exist supporting both the home and school contexts. Home schooling comprises numerous approaches (Mason, 1993; Holt & Farenga, 2003) and in parallel, a number of educational theories support the traditional classroom context (Schunk, 2000). However, few educational theories bridge the gap between home and school. Talent Education philosophy is one such theory, which defines a learning environment where the parent complements the classroom teaching through learning activities in the home (Suzuki, 1986). Shinichi Suzuki (1898-1998) believed that every child has talent, which can be developed if the proper learning environment exists. Suzuki was one of the founding members of a music school, which later became known as the Talent Education Research Institute. Since then Talent Education philosophy (also known as the Suzuki method) has been found to be useful in a number of domains (general education (e.g. The Suzuki Charter School, Alberta, Canada) and teaching programming (Lui et al., 2004)). However, it has predominantly been applied to teaching music. One aspect of Talent Education philosophy that differs from other educational philosophies is the importance of the role of the parent as home tutor, hence, its suitability for informing a set of tutoring rules that inform home tutoring best practice.

Despite the emphasis that Talent Education philosophy places on the role of the parent, there may still be a lack of parental involvement due to self-believed lack of ability, knowledge and skills (Hoover-Dempsey & Sandler, 1995; Hoover-Dempsey et al., 2005). However, research suggests that parents with high levels of self-efficacy (Bandura, 1995) tend to make positive decisions about active engagement in the child's education while parents with weak self-efficacy are often associated with less parental involvement (Hoover-Dempsey & Sandler, 1997; Desforges & Abouchaar, 2003). Therefore, it may be of benefit to develop an adaptive educational system that adapts the level of support provided for the parent based on their self-efficacy. Such a system may provide high levels of supports for parents with low self-efficacy and low levels of support for parents with high self-efficacy.

In a tutor-tutee, adaptive system there is also a need to provide personalised support for the tutee. In the domain of home tutoring, in parallel to adapting support to the parent based on self-efficacy, there is also a need to provide personalised support for the child. This support can comprise cognitive, affective and motivational support (Parkinson & Coleman, 1995). The importance of the provision of affective support is clearly outlined in Talent Education philosophy ("circumstances surrounding the repetition (practice) must be happy" (Suzuki, 1981 p14)), and therefore, this research will also focus on providing affective support for the child. Providing affective support for the child involves adapting the tutoring process based on the child's affective states where such states include happy, sad, fearful and angry (Kort et al., 2001).

1.3 P.A.C.T. Adaptive Educational System

P.A.C.T. is an adaptive educational system that endeavours to address the challenge of building an adaptive system, which simultaneously supports both tutor and tutee in the home tutoring environment. Firstly, P.A.C.T.'s design uses a novel dual user architecture that comprises dual user models and domain models. Secondly, P.A.C.T. provides an instantiation of Talent Education philosophy, which defines tutoring best practice. Thirdly, using two levels of adaptivity P.A.C.T. provides varying levels of support based on parental self-efficacy while simultaneously providing affective support for the child.

The overall architecture of P.A.C.T. is illustrated in Figure 1.1. Typically, an adaptive educational system comprises student, domain, pedagogical and presentation models (Wenger, 1987). In order to provide a personalised learning path, P.A.C.T. comprises a number of additional features; a dual user architecture, which comprises dual domain models and dual user models in order to simultaneously support both parent and child, a novel adaptive engine that comprises a set of rules and the use of the Talent Education philosophy to define tutoring best practice.

The different components have the following functions:

- The domain model is a representation of the material to be learnt. In P.A.C.T. the ***parent domain model*** comprises an instantiation of the Talent Education philosophy in an endeavour to support the parent in the development of tutoring best practice. Currently the ***child domain model*** provides support for the child in two domains, Suzuki violin and mathematics.
- In P.A.C.T., the ***parent model*** maintains a log of parents' self-efficacy values as they proceed through the tutoring process. It also records information that describes

parents' interactions with P.A.C.T.. The ***child model*** represents the affective experience, a record of the child's affective states such as happy, sad, fearful and angry (Kort et al., 2001) as they progress through the system. It also maintains information on students' knowledge-level.

- The presentation model monitors the interactions between the user and the system and handles the flow of information.
- The pedagogical model, informed by the adaptive engine, uses adaptive presentation and adaptive sequencing techniques to determine what next to present to the parent and child.

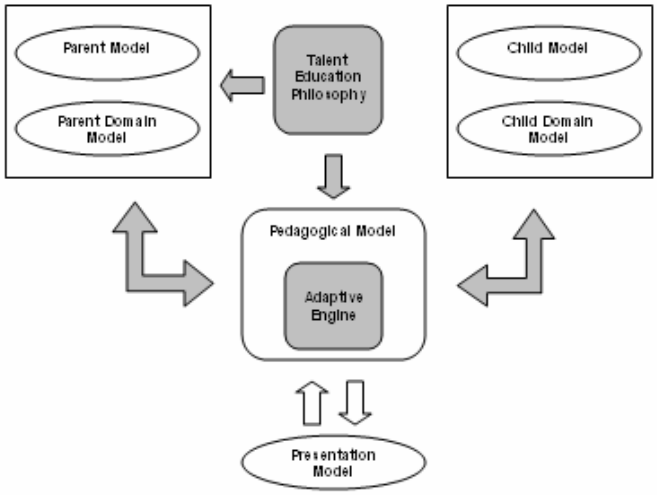

Figure 1.1 P.A.C.T. Architecture

P.A.C.T. provides personalised support through its adaptive engine, which comprises a set of pedagogical rules. The pedagogical rules are categorised in terms of:

- Tutoring rules informed by Talent Education philosophy define tutoring best practice. The rules are constructed using a set of tutoring tactics (e.g. Positive Reinforcement), which denote Talent Education philosophy, the key phase in a Suzuki lesson (i.e. beginning, review, new material and repetition) and a set of affective states (namely, happy, sad, fearful and angry (Kort et al., 2001)). The tutoring rules use the tactics in order to promote positive affective states in the child while simultaneously supporting the parent in the development of tutoring best practice.

- Content rules determine the specific content to display.
- Efficacy rules based on parental self-efficacy, determine the level of support required by the parent. High levels of self-efficacy receive low levels of support while low levels of self-efficacy receive high levels of support.

Based on feedback from the presentation model and input from the user models P.A.C.T. deciphers the type and level of support required by both parent and child.

1.4 Research Goals & Contributions

As previously stated, the research goal was to develop an adaptive educational system, which supports both tutor (parent) and tutee (child) working collaboratively throughout the home tutoring process. In order to achieve such a goal a number of specific research questions were identified.

- **How can an adaptive engine simultaneously support dual users (tutor and tutee)?**

This was addressed through the design and development of P.A.C.T., which uses adaptive technology and contains a novel dual user architecture that comprises dual user models and domain models.

- **What is the appropriate educational theory from which to elicit a set of rules, which define tutoring best practice?**

This was addressed using Talent Education philosophy. In particular, this philosophy informs the set of tutoring rules, which encapsulate tutoring best practice.

- **What is an appropriate basis for adapting to the needs of the tutor and tutee?**

This was addressed through the use of adaptive strategies, which enable P.A.C.T. to provide the correct level of support for the parent based on their self-efficacy, while simultaneously adapting to the affective needs of the child. In particular, empirical studies were conducted to investigate:

- The effect of using adaptive strategies on parents' self-efficacy, knowledge and their perception of their role as home tutor.
- The effect of adapting to the affective needs of the child throughout the home tutoring process.

Therefore, the primary contributions of this research can be summarised as:

- The design and development of an architecture, which supports dual user adaptivity in the domain of home tutoring.
- The articulation and development of a set of novel tutoring rules based on Suzuki's Talent Education philosophy, which define tutoring best practice.
- Empirical evidence, which indicates the effectiveness of adaptive strategies based on self-efficacy in supporting the parent as tutor and strategies based on affect in supporting the child as tutee.

1.5 Structure of Dissertation

There are a number of requirements in the design and development of an architecture, which supports dual user adaptivity in the domain of home tutoring. Firstly, there is the need to develop a dual user architecture, which can simultaneously support both the parent and child. Secondly, there is a need to derive a set of tutoring rules, which using the principles of Talent Education philosophy define tutoring best practice. Additionally, there is a need to develop adaptive technologies that can simultaneously support the needs of both parent and child. Finally, there is the need to analyse, using empirical studies, the effect of P.A.C.T. on the home tutoring process. The following chapters describe in detail each of these different stages.

Chapter 2 provides the literature review of the home tutoring paradigm and adaptive educational systems. It also describes how self-efficacy and affect may be of benefit during the home tutoring process. It provides discussion on these areas in order to support the architecture, design and implementation of P.A.C.T.

Chapter 3 describes the principles, architecture, design and implementation of P.A.C.T.. It outlines the empirical studies involved in incorporating Talent Education philosophy into its design (Lahart et al., 2004, 2005, 2006, 2007b, 2007d). It outlines P.A.C.T.'s novel dual user architecture (Lahart et al., 2008a) and demonstrates how traditional adaptive educational systems can be exploited to support dual users.

Chapter 4 describes P.A.C.T.'s adaptive engine. It describes how the adaptive engine consists of a rule-based system comprising a novel set of pedagogical rules. These rules can be categorised in terms of tutoring rules, content rules and efficacy rules (Lahart et al., 2007c).

Chapters 5 describes the empirical studies that were carried out to validate the design and development of P.A.C.T.. It describes the validation process to ensure the tutoring

rules reflected the principles of Talent Education philosophy (Lahart et al., 2006, 2007a, 2008b, 2008c).

Chapter 6 describes the experimental design of the studies carried out in order to explore the effect of the adaptive educational system on the home tutoring process.

Chapter 7 presents an analysis and discussion of the experimental results. In particular, it evaluates the results in terms of its effect on the parents' (1) self-efficacy (2) knowledge of home tutoring best practice and (3) perception of their role as home tutor. In addition, it evaluates the effect of adapting to the affective needs of the child. Results suggest that P.A.C.T. can have a positive effect on parental self-efficacy and learning performance. In addition, adapting to the affective needs of the child may have a positive effect on the home tutoring process.

Chapter 8 concludes with an overview, summary and directions for future work.

2 Literature Review

2.1 Introduction

The following chapter provides the research context for this thesis. In addressing the challenge of building an adaptive educational system, which supports both tutor (parent) and tutee (child) working collaboratively throughout the home tutoring process there are a number of research considerations. Given that adaptive educational systems have been of benefit in adapting to individual needs (Melias & Siekmann, 2004; Mitrovic, 2003; De Bra & Calvi, 1998), it is necessary to investigate how this technology may be of benefit in supporting dual user adaptivity. In particular, it is important to determine how emergent adaptive collaborative technologies may be further exploited in order to provide the necessary support during the home tutoring process. It is also necessary to investigate how, given the known benefit of parental involvement in learning activities in the home (Greewood et al., 1991; Dornbusch, 1988), adaptive educational systems may be of benefit in encouraging such involvement. Educational theories provide a number of approaches, which may be relevant, and in particular, Talent Education philosophy (Suzuki 1986) is identified as being an educational theory of particular relevance in developing greater parental involvement. Research suggests a myriad of reasons why parental involvement may not occur spontaneously. This research focuses on one in particular, parental self-efficacy. Within the context of home tutoring, it is also necessary to provide support for the child; this research also investigates the use of affective support to encourage a positive learning environment.

This research investigates the question of how best can we support both tutor and tutee throughout the home tutoring process through the use of an adaptive educational system. More specifically, there is a need to investigate the following research questions:

- How can an adaptive engine simultaneously support dual users (tutor and tutee)?
- What is the appropriate educational theory from which to elicit a set of rules, which define tutoring best practice?
- What is an appropriate basis for adapting to the needs of the tutor and tutee?

Subsequently, to answer this it is necessary to review:

- How adaptive educational systems and adaptive collaborative systems through the use of appropriate adaptive strategies can support the tutor and tutee during the tutoring process.
- Educational theories that indicate home tutoring best practice.
- How self-efficacy can be used to determine the level of support required by tutors (parent) when tutoring and in what ways is it possible to provide affective support for tutees (child) during the tutoring process.

In this chapter, section 2 outlines educational theories that support the home and school contexts. In particular, Talent Educational philosophy is described as a philosophy that may be of particular relevance in the home tutoring paradigm. Section 3 describes the concept of self-efficacy, one of the reasons why parental involvement in learning activities in the home may not occur spontaneously. Within the home tutoring context, it is also necessary to provide support for the tutee (child), section 4 outlines how the provision of affective support for the child may promote a positive learning environment. Section 5 describes the role that technology can play in supporting the home tutoring process and in particular, it outlines how adaptive systems may be of benefit.

2.2 Education Theory

A myriad of educational theories exist supporting both the home and school contexts. Home schooling comprises numerous approaches from highly structured to unstructured; from those, which are based on conventional schools to those, which are far removed from conventional practice (Holt & Farenga, 2003). In parallel, there are a number of educational theories, which support the traditional classroom context (Schunk, 2000). This section will firstly discuss the educational approaches, which have influenced the paradigm of home schooling. Subsequently there will be a discussion of some of the educational theories, which have influenced conventional teaching. Finally, we will discuss Talent Education philosophy an educational theory that may be best placed to bridge the gap between home and school.

2.2.1 Home Schooling

John Holt (1923 – 1985) is widely recognised as the founder of the modern home schooling movement. From observing the school system Holt believed that some of the reasons for underachieving students included fear, boredom and confusion (Holt, 1964). He was also a critic of children being forced to learn subjects that were of little interest to

them. He believed that if children were provided with the freedom to follow their own interests and were provided with a rich assortment of resources learning would naturally follow. Over the past number of years a multitude of home schooling approaches have emerged including unit studies and classical education. Unit studies is based on the concept that knowledge is interrelated and if presented and studied in a related way may result in a deeper understanding (Bennett, 1996). Classical education is based on a particular pattern called the Trivium, which comprises grammar, dialectic, and rhetoric. It is based on the premise that if the tools of learning are taught they can be used in the study of any subject (Wilson, 1991). However, this section will focus on two of the most popular home schooling approaches namely, unschooling (Holt & Farenga, 2003) and the Charlotte Mason approach (Mason, 1993).

Unschooling involves learning based on the child's interests, needs, and goals where parents play the role of facilitator as opposed to teacher. Learning does not follow a strict curriculum but rather is as a result of every day life. Holt observed that children are born inquisitive, with an inherent desire to experiment and explore the world around them (Holt, 1967). Young children learn to walk, to talk, and to formulate ideas and opinions with little instruction from adults. He believed that the same natural learning process should be applied to learning at all levels.

Charlotte Mason (1842–1923), believed in three instruments of education, namely education is an atmosphere, education is a discipline and education is a life (Mason, 1993). By atmosphere, she believed that the ideas that entwine the life of the parent have a profound impact on the children. She believed that exposure to the natural environment was of great benefit to the child and attempts to provide a rose-tinted unrealistic view of the environment were unhelpful. However, she also stated, “the strong must not lay their burden on the weak” (Mason, 1993 Vol. 6, p97) meaning the relations must be maintained where the parent is in authority and the child in obedience. By discipline, she believed that it was important that children were trained in good habits. If so, these habits would serve them as they grow. Mason drew a parallel between good habit and railway tracks. It is the responsibility of parents to lay down tracks upon which the child may travel with ease into their adult life. Good habits are a powerful influence on our children and must play an important part in their education. “It rests with [the parent] to consider well the tracks over which the child should travel with profit and pleasure” (Mason, 1993 Vol. 1, p109). By life, Mason reminds us that “all the thought we offer to our children shall be living thought; no mere dry summaries of facts will do” (Mason, 1993 Vol. 2, p277). Each subject should be presented as living ideas. Particular importance was placed

on living books. Living books (often referred to as classics) promote imagination, originality and noble thoughts.

In summary, home schooling approaches promote the idea that learning should begin with curiosity in the child. It should be as a result of everyday life. The child should be presented with interesting material to learn from and it should be a natural process.

2.2.2 Classroom context

A myriad of educational theories have been applied in the classroom context. Arguably, the most commonly used educational theories include behaviourism and constructivism. However, there are numerous others including Cognitivism (Piaget, 1928) and Multiple Intelligence (Gardner, 1983). Cognitivists are concerned with exploring mental processes such as thinking, memory, knowing, and problem solving. They believe knowledge can be viewed as schema or symbolic mental constructions where learning can be defined as a change in a learner's schemata. The theory of Multiple Intelligence challenges the conventional view of intelligence as a single general capacity. Instead, Gardner (1983) proposes eight different intelligences to account for a broader range of human potential in children and adults. These intelligences are linguistic, logical-mathematical, musical, bodily kinaesthetic, spatial, interpersonal, intrapersonal and naturalist. The theories of behaviourism and constructivism will now be described in detail.

Behaviourism is based on the idea that behaviours are acquired through conditioning where conditioning can occur through interaction with the environment (Watson, 1913). There are two major types of conditioning: classical conditioning and operant conditioning. Classical conditioning, involves presenting a neutral stimulus (i.e. a stimulus that does not result in an overt behavioural response) along with a significant stimulus (i.e. a stimulus that evokes a reflexive response). The neutral stimulus is referred to as a conditioned stimulus while the significant stimulus is referred to as the unconditioned stimulus and unconditioned response respectively. If the conditioned stimulus and the unconditional stimulus are repeatedly paired, eventually they become associated and produce the behavioural response to the condition, referred to as the conditioned response (Pavlov, 1963). Operant conditioning is the use of consequences to modify the occurrence and form of behaviour. Operant conditioning is distinguished from classical conditioning in that operant conditioning deals with the modification of operant behaviour. Learning is a function of change in overt behaviour where change is as a result of a response to a stimulus that occurred in the environment. Reinforcement is central to

this theory where reinforcement is anything that strengthens the desired response e.g. verbal praise (Skinner, 1968).

Constructivism is based on the premise that learning occurs as a result of the processes of accommodation and assimilation. Assimilation involves incorporating new experiences without modification into exiting frameworks. However, accommodation involves reframing one's mental representation of the external world as a result of new experiences (Piaget, 1950). Social constructivism is based on the premise that much learning can take place in the Zone of Proximal Development (ZPD). The ZPD is described as the distance between actual development during independent problem solving and the learner's potential development if assisted by a more able peer or adult (Vygotsky, 1978). Much of Vygotsky's (1978) work highlights the benefits for the learner of working in collaboration with a more able peer, adult or domain expert.

Educational theories from both home and school contexts provide great insights into how knowledge is acquired by the learner and to some extent, how this can be facilitated. However, there is little research to support the home-school relationship. One educational theory, which may go some way in bridging the gap between home and school, is Talent Education philosophy (Suzuki 1986).

2.2.3 Talent Education Philosophy

Talent Education philosophy is based on the premise that talent is a product of environment rather than heredity (Suzuki, 1986). Shinichi Suzuki (1898-1998) believed that every child has talent, which can be developed if the proper environment exists. He observed that all children learn to speak their own language with relative ease and suggested that if the same natural learning process is applied in teaching other skills, these skills could also be acquired as successfully. The learning process is broken down into the smallest possible steps, which allow the child to achieve success at every level and learn at their own pace. The actual process of teaching the young child to play the instrument involves a trio of players: the child, the teacher and the Suzuki parent. The Suzuki parent provides daily home tutoring for the child. People have described this three-way relationship as a tripod: if one leg is missing, nothing can be achieved. Research suggests that the support of both parent and teacher at the beginning of the learning process can be of benefit (Davidson, 1995). The Suzuki parent works at home with the child and tries to mimic the lesson environment. However, due to lack of tutoring experience Suzuki parents can find it difficult to motivate their child to practice.

There are a number of principles of Talent Education. Firstly, there is a belief that every child can be educated. Talent Education has often been misunderstood as education for gifted children; however, this is not the case. Secondly, there is a belief that learning begins the day a child is born. Suzuki believed that beginning the child's education at the traditional school age was far too late (Suzuki, 1981). The third principle of Talent Education philosophy is intuition. Suzuki believed that if a child did not receive love and encouragement from its mother it might not develop the mother tongue. Suzuki believed that children should never be forced to practice or rehearse, as it is not a good basis for education. He believed that given a nurturing environment, children would develop their own ability. Repetition should occur every day where possible. Finally, it is important that children feel confident in their abilities and thoroughly master what they are learning. Initially, children learn simple skills through repetition. Once the skill is mastered, the child is given another challenge. This motivates the child to continue learning.

2.2.4 Education Theories Summary

A myriad of research exists on education theories, which support the home and school context. Home schooling provides a myriad of approaches to education in the home context including the Charlotte mason approach (Mason, 1993) and unschooling (Holt, 1964). Both approaches highlight that learning is a natural process and if the child is presented with interesting resources, there will be a natural tendency to learn. In parallel, there are a number of educational theories, which have been applied in the school context, including behaviourism (Watson, 1913) and constructivism (Piaget, 1950). Such theories provide great insights on how students learn and how best this can be facilitated. However, there is little research, which explores the home-school relationship and how teacher, parent and child can work together to create a nurturing environment. One philosophy, which provides some insights into this, is Talent Education philosophy (Suzuki, 1986). Talent Education philosophy involves the teacher, child and Suzuki parent. Therefore, Talent Education philosophy maybe an appropriate educational theory to inform tutoring best practice, in an adaptive system, which supports both tutor and tutee throughout the home tutoring process.

2.3 Self-Efficacy

As mentioned previously there is a strong relationship between parental involvement in learning activities and a child's academic success. However, despite this, parental involvement may not occur spontaneously for numerous reasons including but not limited

to (1) lack of parental self-efficacy (Desforges & Abouchaar, 2003) (2) a perception that it is not part of the parental role (Desforges & Abouchaar, 2003) (3) negative attitude towards school (Heystek & Louw, 1994) (4) time (Russell & Granville, 2005). This research attempts to overcome one of these reasons, lack of parental self-efficacy. With this in mind, an overview of the research, which exists on self-efficacy, is now presented.

Firmly situated in social cognitive theory, Bandura believed that the beliefs people have about themselves are key elements in their ability to achieve desired outcomes (Bandura, 1986; Bandura, 1997). Consequently, he believed that how people behave might be as a result of their beliefs and therefore behaviours may be better predicted by these beliefs than by the result of their previous performances. Research has indicated that self-beliefs may have an impact on cognitive engagement, which suggests that enhancing self-beliefs may have a positive effect on learning (Pintrich & De Groot, 1990). An individual's self-efficacy is included in such self-beliefs.

The following section will provide a detailed description of self-efficacy. Section 2.3.1 will provide a description of the sources of self-efficacy. Section 2.3.2 provides a discussion on the effect of self-efficacy and finally section 2.3.3 provides some guidelines on measuring self-efficacy.

2.3.1 Sources of Self-Efficacy

Self-efficacy beliefs are developed from four sources: mastery experiences, vicarious experiences, verbal persuasion and physiological state (Bandura, 1986). Bandura suggests that mastery experiences are the most influential source of these beliefs as successful experiences boost self-efficacy, while failures erode it. However, easy successes can lead to an expectation of quick results therefore leading to a lack of resilience when faced with more difficult challenges (Bandura, 1986). This suggests the need to present content at the correct level so students are faced with challenges, which they can overcome. The second source of self-efficacy beliefs are vicarious experiences. Observing similar individuals succeed by sustained effort raises observers' beliefs that they too possess the capabilities to master comparable activities required to succeed. Pajares (1997) suggests that this is a weaker source of self-efficacy than mastery experiences, however, if individual's have little previous experience with the given task they may become more sensitive to it. The impact of success or failure of the observed on the perceived self-efficacy of the observer is strongly influenced by their perception of the extent of their similarity. If the observer believes their capabilities are superior to the observed then failure of the model does not have a negative effect (Brown & Inouye, 1978). This

suggests that vicarious experience may be most influential when peers with similar abilities are working together. Verbal persuasion is another source of self-efficacy. Albeit that this source of self-efficacy is weaker than the previous two, verbal judgements that others provide have an influence on self-efficacy beliefs (Zeldin & Pajares, 1997). Bandura (1986) suggests that it is often easier to weaken self-efficacy beliefs through negative appraisals than strengthen them through positive appraisals. The final source of self-efficacy beliefs is physiological states. Physiological states such as anxiety, stress, fatigue and affective states provide insights on self-efficacy beliefs where positive moods enhance perceived self-efficacy and despondent moods diminish it (Bandura, 1997). It is important to note that with all the aforementioned sources of self-efficacy it is the interpretation of the experience that form the judgements of self-efficacy and not that the sources themselves are directly translated into judgments of competence.

2.3.2 Effects of Self-Efficacy

Research informs us that self-efficacy beliefs can have effect on four process namely cognitive process, motivational processes, affective processes and selection processes (Bandura, 1997).

- Cognitive processes: self-efficacy can increase or diminish problem-solving and reasoning capabilities (Bandura, 1995; Schunk & Pajares, 2002 & Zimmerman, 2000). Self-efficacious students pose the ability to set ambitious future goals and a commitment to achieve them.
- Motivational processes: levels of self-efficacy will influence the amount of effort individuals expend on any activity, the degree of perseverance when faced with challenges and level of resilience in adverse situations. Self-efficacious students are more likely to visualise successful outcomes. Those who doubt their self-efficacy, visualise unsuccessful scenarios dwelling on the many things that can go wrong.
- Selective processes: self-efficacy beliefs play a role in the course of individuals' lives as it influences the types of activities and the environments they choose. Students with high self-efficacy often select challenging activities and environments while individuals with low self-efficacy choose to avoid challenges or activities and situations, which they believe, exceed their competency.
- Affective processes: perceived self-efficacy plays a role in individuals' ability to regulate their own affective states. An ability to control one's thought processes is

a key factor in regulating thought patterns around stress and depression. It is the perceived inability to disengage in such thoughts and not the frequency of disturbing thoughts that is the major source of distress.

2.3.3 Measuring Self-Efficacy

Self-efficacy is not a global trait but a differentiated set of self-beliefs linked to distinct sets of tasks. The "one measure fits all" approach to self-efficacy provides little valuable insight and poor predictive value (Bandura, 2006). On measuring self-efficacy, it is important that it is measured in terms of perceived capability. Items should be measured in terms of *can do* rather than *will do*. Bandura (2006) indicates that can is a judgement of capability where will is a statement of intention. The development of effective self-efficacy scales relies on a deep analysis of the domain of functioning. Identifying which aspects of self-efficacy should be measured arises from a thorough understanding of the domain. If scales are created around factors, which in fact have little or no impact on the domain of functioning, the results will have little predictive power. However, activities that may be measured include:

- Regulating one's motivation - e.g. get yourself to keep trying when things are going really badly.
- Thought processes - e.g. take you mind off upsetting experiences.
- Performance level - e.g. increase your memory of what has been taught in the previous lesson.
- Emotional states - e.g. overcome discouragement when nothing you try seems to work.
- Altering environmental conditions - e.g. get neighbourhood groups involved in working with schools.

Standard methodology for measuring self-efficacy involves presenting individuals with different tasks and requesting a measure of their belief in their ability to execute the tasks. Bandura (2006) suggests the use of a 100-point scale, ranging in 10 units from 0 ("Cannot do") through 50 ("Moderately certain can do") to 100 ("Highly certain can do"). The scale can also be collapsed to a 0 to 10 scale. Scales with too few steps should be avoided as individuals usually avoid extremes using a scale with few steps could easily result in it shrinking to one or two points. Additionally, self-efficacy judgment should be recorded in private in an endeavour to reduce evaluative concerns and consistency expectations.

2.3.4 Self-Efficacy Summary

Self-efficacy involves individuals' belief in their capability to produce desired outcomes. There are four main sources of self-efficacy namely, mastery experiences, vicarious experiences, verbal persuasion and physiological states. It is understood that self-efficacy can have an effect on our cognitive, motivational, social and affective processes. Self-efficacy should be measured in terms of perceived capability, with measurements of generalised self-efficacy best avoided. Self-efficacy judgements should be recorded in private to reduce evaluative concern. Due to the potential effect of self-efficacy on learning, there is a need to investigate how it can be measured and supported through the use of an adaptive system. This will be described in section 2.5.4.

2.4 Affect

In a tutor-tutee, adaptive system there is also a need to provide personalised support for the tutee. This support can comprise cognitive, affective and motivational support (Parkinson & Coleman, 1995). As the importance of providing affective support is clearly outlined in the Talent Education philosophy ("circumstances surrounding the repetition (practice) must be happy" (Suzuki, 1981 p14)), this research will also focus on providing affective support for the child.

Research suggests an integral link between emotion and cognition (Schute, 2006; Goleman, 1996; Block, 1995; Bower, 1992). A student's emotion towards learning can have an effect on the learning experience (Dweck, 1999; Craig et al., 2004). The need to study emotion as part of the learning process is understood (Picard, 1997; Porayska-Pomsta & Pain, 2004; Boekaerts, 2003; Pekrun et al., 2002). Goleman suggests that learning does not take place when there is anxiety, depression or anger (Goleman, 1995). Suzuki suggests that "Children learn abilities best when they are having fun" (Suzuki, 1981, p20) and that the "circumstances surrounding the repetition (practice) must be happy" (Suzuki, 1981, p14). The suggestion of such an integral link between emotions and learning suggests the need for adaptive systems that accommodate students' affective experiences and promote positive affective states.

2.4.1 Basic Emotions

Diversity among proponents of the basic emotion concept can be observed from Table 2.1 with emotion theories proposing there are from two to twenty basic or prototype emotions (Plutchik, 1980; Leidelmeijer, 1991). However, there is evidence to suggest a

central list of six basic emotions comprising happiness, surprise, fear, sadness, anger and disgust/contempt (Fridlund et al., 1987; Ekman et al., 1982). There is some debate around the inclusion of surprise, as many believe it to be a cognitive component that could be present with any emotion (Oatley & Johnson-Laird 1987; Power & Dalgleish, 1997). In addition, as can be observed from Table 2.1 Parrot (2001) suggests that disgust and contempt are secondary and tertiary emotion concepts of the basic emotion anger. This suggests that fear, anger, sadness, and joy are the four basic emotions (Kort et al., 2001).

Table 2.1 Major Basic Emotion Theorists (Based on Ortony & Turner, 1990)

Theorist	Basic Emotion
Arnold (1960)	Anger, aversion, courage, dejection, desire, despair, fear, hate, hope, love, sadness
Ekman et al. (1982)	Anger, disgust, fear, joy, sadness, surprise
Frijda (1986)	Desire, happiness, interest, surprise, wonder, sorrow
Gray (1985)	Rage and terror, anxiety, joy
Izard (1977)	Anger, contempt, disgust, distress, fear, guilt, interest, joy, shame, surprise
James (1884)	Fear, grief, love, rage
McDougall (1926)	Anger, disgust, elation, fear, subjection, tender-emotion, wonder
Mowrer (1960)	Pain, pleasure
Oatley & Johnson-Laird (1987)	Anger, disgust, anxiety, happiness, sadness
Panksepp (1982)	Expectancy, fear, rage, panic
Plutchik (1980)	Acceptance, anger, anticipation, disgust, joy, fear, sadness, surprise
Tomkins (1984)	Anger, interest, contempt, disgust, distress, fear, joy, shame, surprise
Watson (1930)	Fear, love, rage
Weiner & Graham (1984)	Happiness, sadness

Table 2.2 Categories of Emotions (Based on Parrot, 2001)

Primary	Secondary	Tertiary
Joy	Cheerfulness	Amusement, bliss, cheerfulness, gaiety, glee, jolliness, joviality, joy, delight, enjoyment, gladness, happiness, jubilation, elation, satisfaction, ecstasy, euphoria
	Zest	Enthusiasm, zeal, zest, excitement, thrill, exhilaration
	Contentment	Contentment, pleasure
	Pride	Pride, triumph
	Optimism	Eagerness, hope, optimism
	Enthrallment	Enthrallment, rapture
	Relief	Relief
Anger	Irritation	Aggravation, irritation, agitation, annoyance, grouchiness, grumpiness
	Exasperation	Exasperation, frustration
	Rage	Anger, rage, outrage, fury, wrath, hostility, ferocity, bitterness, hate, loathing, scorn, spite, vengefulness, dislike, resentment
	Disgust	Disgust, revulsion, contempt
	Envy	Envy, jealousy
	Sympathy	Pity, sympathy
Fear	Horror	Alarm, shock, fear, fright, horror, terror, panic, hysteria, mortification
	Nervousness	Anxiety, nervousness, tenseness, uneasiness, apprehension, worry, distress, dread
	Torment	Torment
Sadness	Suffering	Agony, suffering, hurt, anguish
	Sadness	Depression, despair, hopelessness, gloom, glumness, sadness, unhappiness, grief, sorrow, woe, misery
	Disappointment	Dismay, disappointment, displeasure
	Shame	Guilt, shame, regret, remorse
	Neglect	Alienation, isolation, neglect, loneliness, rejection, homesickness, defeat, dejection, insecurity, embarrassment, humiliation, insult

The prevalence of these four emotions throughout emotional theories (or their associated secondary/tertiary concepts as outlined in Table 2.2) is highlighted in Table 2.1. Table 2.1 provides an overview of different emotional theories and associated emotions. The emotions are colour coded in terms of joy/happy (yellow), sad (blue), fearful (green) and angry (red). These colour codes are used throughout the rest of this thesis in conjunction with these emotions. Table 2.2 provides a list of each of the emotions and their associated secondary/tertiary concepts, which suggests the range of concepts that fall within each of the four categories of emotions.

2.4.2 Affect Summary

In summary, the need to study emotion as part of the learning process is understood with research suggesting an integral link between both. In addition, research suggests the need for positive affective states in order for learning to take place. However, consensus has not been reached as to which emotions constitute the set of basic emotions. Emotional theories propose anything from two to twenty basic emotions. However, a review of the literature suggests that happy, sad, angry and fearful may be amongst the most common among those theories reviewed. Therefore, this suggests that there is a need for adaptive systems that accommodate students' affective experiences and promote positive affective states. This will be described in section 2.5.5.

2.5 Adaptive Educational Systems

2.5.1 Introduction

Technology may be of benefit in providing the necessary support for both parent and child. Previously, technology has played a role in supporting the home tutoring process through the provision of on-line learning resources (National ParentNet Association, 2008, NumberWorks@Home, 2008, Moravian Academy Suzuki Violin Website, 2008). However, little research exists which investigates how personalised learning environments may be used effectively in the domain of home tutoring (Brusilovsky, 2003). This section provides an overview of adaptive educational systems. Firstly, an overview of the area of adaptive educational systems is presented. Secondly, it reviews a number of adaptive collaborative systems illustrating the design issues in building such systems, and in particular, how adaptive techniques can be used to support the learning process. Thirdly, it reviews a number of sample systems, which incorporate user's self-efficacy. Finally, it describes a number of adaptive educational systems, which

incorporate the learner's affect. Particular emphasis is placed on how affect can be elicited and adapted to.

Educational systems that treat all students in the same way by providing the same level of support and instructional approach may be ineffective where there are students with various goals, levels of knowledge, and preferences. Adaptive and Intelligent Educational Systems attempt to overcome this problem by building a model of the goals, preferences and knowledge of each individual student, and by subsequently using this generated model to dynamically adapt the learning environment for each student in a manner that best supports their needs (Brusilovsky, 2001). This may involve the provision of scaffolding, identifying misconceptions. (Mitrovic, 2003), or modifying the presentation in order to adapt to the knowledge level of the student (De Bra & Calvi, 1998).

Adaptive educational systems and intelligent educational systems share similarities, however, each have distinct emphasis. In adaptive systems, the emphasis is on providing a personalised environment for each student using information collected in the student model. Intelligent systems place the emphasis on the application of techniques from the field of Artificial Intelligence in the provision of greater support for the student (Brusilovsky & Peylo, 2003).

The term 'technologies' is used to describe the myriad of approaches to the inclusion of adaptive and intelligent functionality, which can be used (Brusilovsky, 1998). Brusilovsky & Peylo, (2003) propose five major groups of technologies: intelligent tutoring, adaptive information filtering, intelligent class monitoring, intelligent collaboration support and adaptive hypermedia.

The major intelligent tutoring technologies are curriculum sequencing, problem solving support and intelligent solution analysis. The purpose of curriculum sequencing is to help the student find the most suitable path through learning material by making decisions on what content to present next (Weber & Brusilovsky, 2001). The goal of interactive problem solving support is to provide help with problem solving by giving hints or executing the next step (Melis et al., 2001). With intelligent solution, analysis attempts are made to find out what exactly is wrong or incomplete, identify what piece of incorrect knowledge that may be responsible for the error and provide suitable feedback (Mitrovic, 2003).

Adaptive information filtering (AIF) selects a subset of items, which are relevant to a user's interests from a large pool of information. It adapts the search by ordering and

filtering the results, and subsequently recommends the most relevant documents. Two categories of AIF technologies exist, namely content based filtering and collaborative filtering. With the content-based approach, the behaviour of a user is predicted from their past behaviour (e.g. MLTutor, Smith & Blandford, 2003). While with the collaborative approach, the behaviour of the user is predicted from the behaviour of other like-minded people, for example (e.g. WebCOBALT, Mitsuhara et al., 2003).

Intelligent collaborative learning technologies can be used in an endeavour to support collaboration between students. Collaborations are supported using three types of technologies: adaptive collaboration support, adaptive group formation and peer help and virtual students. Adaptive collaboration support technologies provide interactive support to help collaboration using knowledge about good and bad collaborations (Soller & Lesgold, 2003). Adaptive group formation and peer help technologies use knowledge about collaborating peers to form matching groups for different tasks (Greer at al, 1998). Virtual student technology attempts to introduce virtual peers into the learning environment (Chan & Baskin, 1990).

Intelligent class monitoring technologies recognize students who need support or extra challenges. These technologies use Artificial Intelligence techniques to explore large amounts of information that is collected when tracking student actions (Maceron & Yacef, 2003).

Adaptive hypermedia includes two major technologies: adaptive navigation and adaptive presentation. Adaptive navigation supports the student by changing the appearance of links. For example, it can adaptively sort, annotate, or partly hide the links of the current page to make it easier to choose where to go next (de Bra, 1996). Adaptive presentation adapts the content to be presented by dynamically generating the content for individual students according to their needs (Weber & Brusilovsky, 2001).

As has been described, there is a diverse range of technologies, which can be used in the development of adaptive and intelligent educational systems. Clearly, this research falls under the umbrella of collaborative learning as there are two users (parent and child) working together to achieve a common goal (home practice). However, instead of focusing on the collaborative process this research will focus in particular on how adaptive hypermedia technologies can be incorporated in order to provide personalised domain support for both users throughout their collaborative activities.

2.5.2 Adaptive Hypermedia

Static hypermedia applications present the same page content and set of links to all users. On the other hand, adaptive hypermedia systems construct a model of the knowledge, goals, and preferences for each individual user, and use this model to adapt the presentation to the users needs. Adaptive hypermedia systems include on-line information systems, on-line help systems, information retrieval hypermedia, and systems for managing personalized views (Brusilovsky, 2001).

Adaptive decisions are informed by the user's characteristics, which may comprise the user's knowledge, goals, tasks, background, preferences and interests. Adaptive educational systems capture and represent these characteristics in a learner model for each individual learner and subsequently predict different characteristics such as knowledge level and interest (Kobsa, 2001). For example, knowledge can be based on the visited web pages (history-based) or assessment results (knowledge-based) (Eklund & Sinclair, 2000).

Adaptation decisions are made based on the information in the learner model. Two distinct areas of adaptation exist, adaptive presentation and adaptive navigation support. Both encompass a broad range of techniques (Brusilovsky, 1998, 2001). Adaptive presentation includes text, multimedia and modality adaptation. Adaptive navigation support includes direct guidance, link hiding, sorting, generation, annotation, and hypertext map adaptation. Figure 2.1 displays the different adaptive hypermedia technologies and their associated techniques.

Adaptive presentation and navigation techniques provide a rich basis for developing adaptive educational systems, which support dual users in achieving a common goal. In order or develop an adaptive educational system, to support home tutoring there are a number of considerations.

- How can we exploit adaptive educational technology to simultaneously support two users tutor (parent) and tutee (child)?
- How can self-efficacy be incorporated in adaptive educational systems in order to provide personalised support for the tutor (parent)?
- How is it possible to elicit the tutee's (child's) affective state in order to adapt the learning environment to best suit their needs?

A discussion of how systems developed to date have attempted to answer these questions is now presented.

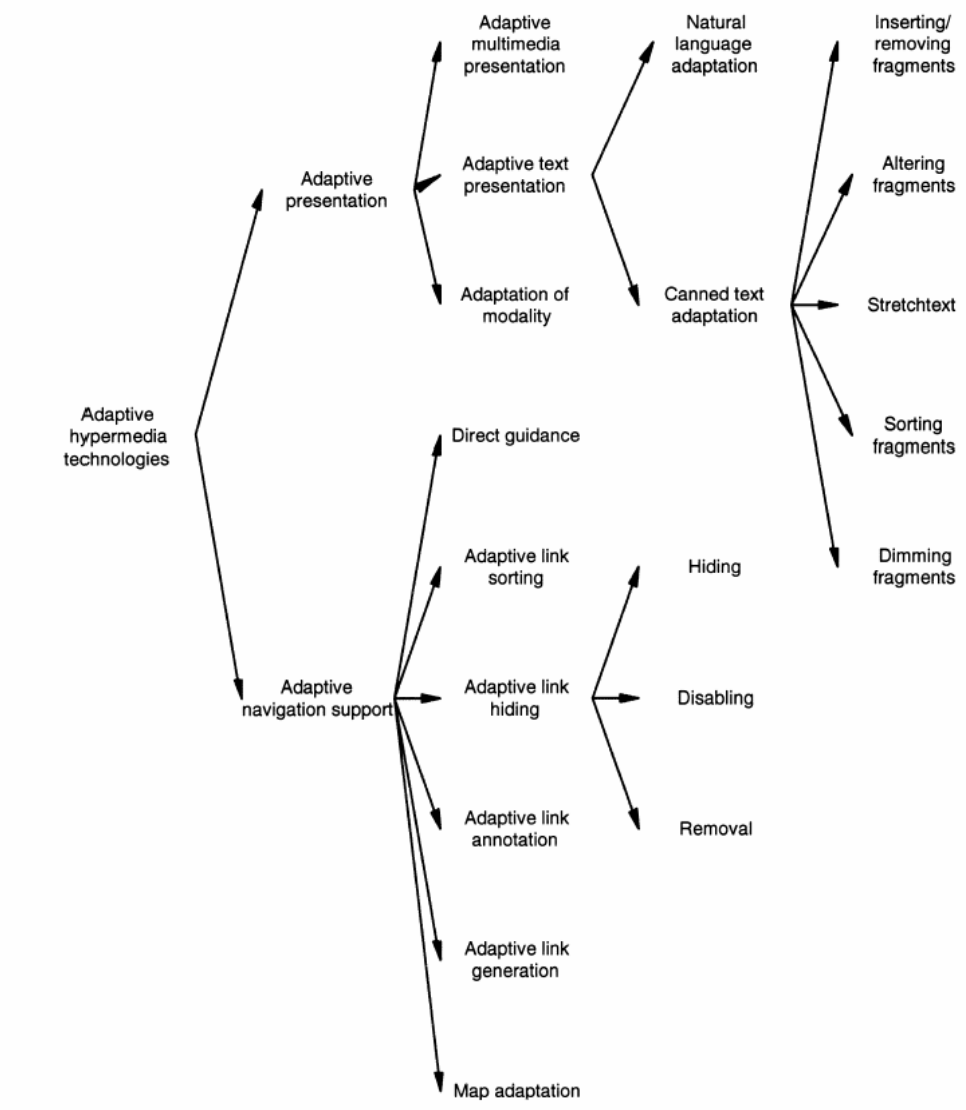

Figure 2.1 The taxonomy of Adaptive Hypermedia Technologies, (adapted from Brusilovsky, 2001)

2.5.3 Adaptive Collaborative Systems

Recently, there have been attempts to exploit adaptive techniques in order to support user activities. One example where it is necessary to provide activity support is in collaboration, when two or more people work together toward a common goal. Work on adaptive collaborative learning systems is still at an early stage and can be broadly categorised into two groups. Research exists that supports the collaboration process itself (e.g., promoting deep collaborative discourse, group establishment etc (Kumar et al., 2007; O'Connor et al., 2005)) and research that promotes domain learning through

collaboration (Walker et al., 2008; Biswas, 2005). Although these categories are by no means mutually exclusive, they do exhibit significant differences in their approach. Research from both categories will be described with emphasis on the latter due to its particular relevance. A summary of the research described in this section is listed in Table 2.3.

2.5.3.1 Supporting the Collaborative Process

The following sections describe research conducted in order to investigate the benefits of providing support to encourage deep collaborative discussions and the effect of support group collaboration.

2.5.3.1.1 Supporting Deep Collaborative Discussion

Kumar et al. (2007) present research, which suggests the benefits of providing dynamic support, which is triggered, based on observed need and fades over time as students acquire the skills necessary to collaborate productively. In particular, this research presents a new adaptive support mechanism specifically designed to draw out reflection using conversational agents that engage students in direct lines of reasoning. 87 undergraduate students took part in an experiment where students were divided across six conditions comprising three levels of support (no support, static support or dynamic support) and two levels of collaboration (working with partner or working alone). Static support involves prompts, which stimulate thinking towards an idea without giving the idea away. Dynamic support involves a dialogue system engaging with pairs of students in direct lines of reasoning in order to increase learning. Results indicate that students learnt most when working in pairs and supported with dynamic support. However, there is a need for further research to develop a more effective approach and overcome student frustration with the dialogue system.

Research by O'Connor et al. (2005) indicates how discussion prompts may be of benefit in scaffolding parent-child collaboration around a computer-based activity in the home environment. In particular, this research reports on an experiment where ten volunteer parent and child dyads (age 6 and 7 years) interacted with Frankie's Fruitful Journey, a learning environment, which encourages parent-child collaboration around mathematics activities. Albeit that Frankie's Fruitful Journey is not an adaptive system this research is of interest in so far as the participants involved in this study, parent and child dyads, is the same type of population used in experimental studies presented for this thesis. Results indicate that inclusion of discussion prompts significantly increased the incidence of explained hypotheses made by both parent and child. In addition results

suggest that the discussion prompts may have taught parents when and where to intervene appropriately in the absence of prompts. There is a need to develop this research further to include intelligent conversation prompts tailored to the needs of the collaborators.

2.5.3.1.2 Supporting Group Collaboration

Vizcaíno et al. (2000) provide insights on how best to support the collaboration process and how systems can adapt based on the profile of the group. HabiPro is a system designed to develop good programming habits. It adapts the environment by proposing different pedagogic methodologies and different exercises depending on the features of the group. The features of the group are stored in the group model along with a number of predefined social and pedagogic patterns. When the group is working with HabiPro data is collected on the group's characteristics. These characteristics are categorised in terms of social (motivation based on type of help selected and participation) and pedagogical (group ability, exercise preference and mistakes made).The group model attempts to classify the group in terms of one of the stored patterns. Once the group is classified, the pattern indicates which exercises and work methodology is most suited to that particular group. Therefore, the group model in this case is not only the representation of the characteristics of the group. It is also the component that permits the system to be adaptive. Two experiments were conducted with HabiPro. The first experiment comprised twenty-three students divided into different sized groups completing twenty exercises. Each student used a computer, and communicated via chat. When students agreed on an answer one person had to submit it and then everyone progressed to the next exercise. However, feedback on this approach suggests that students were not happy, as often an individual student would submit an answer, which resulted in students being prematurely progressed to the next exercise. Therefore, the second experiment involved a slight change to the approach in so far as it included a turn protocol. Only the student whose turn it was could submit the solution. The student's turn remained until another student requested a turn. This experiment comprised 23 participants divided into groups of different sizes: five groups formed of two students, three groups of three and one group with four people. Results indicate the difficulty in collaborating when group size is large e.g. 4 members. In addition, groups with three members solved less exercise than groups with two members due to time spent in consultation & negotiation. Finally, a turn protocol increased performance & facilitated collaboration.

2.5.3.2 Supporting Domain Learning through Collaboration

Meccawy & Blanchfield (2008) report on a case study in which (domain) adaptation was provided to groups of students on an individual basis. Students were also provided with collaborative and interactive learning tools through a learning management system (Moodle) which was used in conjunction with the WHURLE 2.0 integrated learning environment. 88 students (comprising first years and masters students) interacted with WHURLE2.0 over a five-week period as a supplementary resource to their lectures for exam preparation. Students completed pre and post tests prior to and after the intervention. The pre test allowed students to be categorised in terms of ability (beginning, intermediate and advanced). Adaptivity involved presenting less material to more able students and more material to weaker students. The collaboration and interactive tools made available comprised Forums, Chat Rooms or Wikis. Results indicate that although there was an increase in learning between pre and post tests there was little use of collaborative and interaction tools. This research is limited in so far as it does not advance the area of adaptive collaborative learning or indeed adaptive education systems as the research involved little effort to promote collaboration. However, it does provide insights into the need for the use of explicit strategies if students are to collaborate when learning.

Ghali et al. (2008) describe a modified version of MOT, My Online Teacher, an authoring system for adaptive delivery of content, called MOT 2.0. The new version includes collaborative authoring and social annotation between communities of authors, as well as applying adaptivity based on users' activities. It provides a useful insight into how collaborative strategies can be used for learning. The collaborative strategies allow for recommendations between users with similar user models by harnessing the Web 2.0 strength and its characteristics (i.e., tagging, voting, commenting, and user-generated content). For example *for all users in the "Web programming" group who have an interest in 'AJAX' items; display the recommended 'AJAX' items (items with vote >=90%).* Further research is required in terms of implementation and evaluation in order to identify the effect of such an approach.

Betty's Brain system is designed to teach students about interdependence and balance in a river ecosystem and provides another promising approach that is using an intelligent agent as one of the collaborators (Biswas et al., 2005). It was necessary in the design of such a system that there was consideration for students with little prior domain experience and no teaching experience. Students teach Betty by creating a concept map and can query or quiz her on what they have taught. The system also contains a mentor agent Mr.

Davis. An experiment was conducted with two fifth grade classes divided into three groups of 15 students in order to compare three versions of the system. An intelligent tutoring system (where students were taught by Mr. Davis) a learning by teaching system (where students taught Betty but got help from Mr. Davis) and a self-regulated learning system (where students had to teach Betty who had self-regulated behaviour e.g. Betty decided when she was ready to take a test). Mr. Davis was equipped with a wider variety of help including how to be a better learner/teacher but students had to explicitly query Mr. Davis to get feedback. The experimental design comprised pre test, intervention and post test. In addition, two other post tests were conducted about seven weeks after the experiment. Results indicate learning across all conditions. Additionally, students in the self-regulated learning group outperformed the other two groups on an activity involving such skills as independent learning and transfer of knowledge. Further research might focus on improving collaboration by providing the capability to communicate through natural language.

Walker et al. (2008) provide an example of domain learning through collaboration in their study, which involved 62 high school students from five algebra classes taught by the same teacher. Students used the Cognitive Tutor Algebra as part of regular classroom practice. Students from each class were randomly assigned to one of the three conditions. The conditions comprised fixed collaboration condition, adaptive collaboration condition and individual condition. In the fixed collaboration condition students tutored each other with fixed domain support in addition to the peer tutoring script. In the adaptive collaboration condition students tutored each other with adaptive domain support in addition to the peer tutoring script and in the individual condition students used the Cognitive Tutor Algebra individually. Fixed domain support comprises the provision of answers to the problem in a separate tab in the interface, which could be accessed at any time by peer tutors. Adaptive support comprised tutors being provided with support if (1) the peer tutor requests a hint from the cognitive tutor to give to the tutee (2) the peer tutor has marked something incorrectly (3) the tutor and tutee believe a solution is complete but it is actually incomplete. Interaction with the Cognitive Tutor Algebra took place during two 70-minute class periods, each one week apart. Results indicate that both individual use of the Cognitive Tutor Algebra and peer tutoring activities lead to significant learning gains. In addition, results indicate no significant differences in quantitative measures of student progress and feedback across all three conditions. Finally, results suggest that in order for the tutor to improve, the tutee must struggle. This research is beneficial in so far as it provides an insight into the effect of using adaptive

collaboration support in a natural learning environment. However, there is a need for further research into strategies, which might support both tutor and tutee to avoid situations where the tutee must struggle in order for the tutor to improve.

Indeed, research to date has provided insights on how the collaborative learning process can be supported using adaptive technologies. However, to date personalisation of the learning environment has been explored at the group level or in terms of supporting one of the collaborators in the process e.g. tutor or tutee. Albeit, that this in itself is beneficial there is also a need to explore the possibility of providing personalised support for all collaborators. That is to support both tutor and tutee, where the tutor may need to be supported in developing effective tutoring strategies while the tutee may need to be supported in an academic domain.

Table 2.3 Adaptive Collaborative Systems

System	Brief Description	Adaptive Support	Key Findings
Kumar et al., (2007)	87 undergraduate students were involved in a study to investigate the effect on learning of a new adaptive support mechanism specifically designed to draw out reflection using conversational agents that engage students in direct lines of reasoning	Dynamic support involves a dialogue system engaging with pairs of students in direct lines of reasoning in order to increase learning	Results indicate that students learnt most when working in pairs and supported with dynamic support
O'Connor et al. (2005)	10 parent & child dyads (age 6 and 7 years) interacted with Frankie's Fruitful Journey, a learning environment, which encourages parent-child collaboration around mathematics activities	Non-adaptive discussion prompts were presented to all users at all times.	Discussion prompts were effective in helping both parent and child to use more exploratory talk
Vizcaíno et al. (2000)	Students interact with HabiPro a system designed to develop good programming habits which adapts the environment by proposing different pedagogy &	Social (motivation based on type of help selected and participation) `Pedagogical (group	Collaboration is difficult in large groups e.g. 4 Groups of 3 solved less exercises than groups of

	different exercises depending on group features	ability, exercise preference and mistakes made).	2 due to consultation A turn protocol increases performance & facilitates collaboration
Meccawy & Blanchfield (2008)	88 (first years and masters) students used WHURLE2.0 over a five week period where they were provided with adaptive domain support and opportunities to collaborate with peers	Adaptive content based on categories of users (beginner, intermediate, advanced) derived from pre test scores	Increase in learning between pre and post test. Little use of collaborative tools available to them e.g. Forums, Wikis, or Blogs
Ghali et al. (2008)	Participants interact with MOT 2.0. an adaptive and collaborative authoring tool, which can be used to author adaptive courses through social annotation between communities of authors.	Collaborative adaptive strategies provide recommendations based on commonalities between user models	Proposition paper no experimental results
Biswas et al. (2005)	Participants teach a pedagogical agent about balance in river ecosystems.	Adaptive domain & collaboration support in terms of self-regulated learning group e.g. Betty refused to take a test until she had been adequately taught.	Increase in learning across all conditions However, students in the self-regulated learning group outperformed the other two groups in the far transfer test
Walker et al. (2008)	62 students were involved in an experiment with the Cognitive Tutor Algebra to investigate the benefit of adaptive collaborative support. Where adaptive strategies support the tutor through the provision of adaptive domain support	(1) Peer tutor can request hints from the cognitive tutor, which are relayed to the tutee (2) If the peer tutor marked something incorrectly the intelligent tutor highlight it and gives	Results indicate that both individual use of the Cognitive Tutor Algebra and peer tutoring activities lead to significant learning gains Results suggest that in order for the tutor to improve, the tutee must

	an error message (3) For incomplete answers the tutor is notified and instructed to ask for a hints to complete it	struggle

2.5.4 Adaptive Education Systems & Self-Efficacy

Research has reported that students' self-efficacy beliefs are correlated with students' academic performance (Zimmerman, 2000). However, limited research exists, which investigates the role of self-efficacy within adaptive educational systems. To date, the majority of research has explored techniques for eliciting self-efficacy with little focus on how learning environments might use such information this is illustrated in Table 2.4.

Bica et al. (2006) investigate the possibility of inferring self-efficacy through a user's interaction with the system. A model of self-efficacy is employed, which comprises three variables effort, persistence and performance. The student's intrinsic personal pattern is mapped through the effort variable and is calculated based on the time the student takes in performing a task. The student's extrinsic personal pattern is mapped through the persistence and performance variables. Persistence is calculated based on the percentage of selected tasks completed. Performance is calculated based on the mean of correct answers in the exercises. A set of inference rules, comprising fuzzy logic, are used to determine the student's self-efficacy. Self-efficacy is categorised in terms of low, medium or high. The system also comprises a pedagogical agent, which provides a coherent animation (e.g. encouragement, congratulations, increase student effort) based on the student's self-efficacy. Two experiments are conducted. The first experiment comprised 25 students aged 17-19 completing a questionnaire to determine which forms of presentation stimulates learning interest. The second experiment involved 12 students aged 17- 20 were involved in an experiment to investigate the effect of the pedagogical agent on students' self-efficacy. Although the approach followed is of interest in terms of inferring self-efficacy without scales or questionnaires the research is limited in so far as there is little discussion of results obtained therefore providing little insight into (1) the effectiveness of the model in inferring self-efficacy (2) the effect of the pedagogical agent on students' self-efficacy.

McQuiggan & Lester (2006) describe an inductive approach for automatically constructing models of self-efficacy that can be used at runtime to inform pedagogical decisions. The experiment involved thirty-three participants (6 female and 27 male) of varying age, race, and marital status. The experimental procedure comprised completing a demographic survey, reading the on-line genetics tutorial and completion of a Problem-Solving Self-Efficacy Scale. The Problem solving Self-Efficacy Scale asked participants to rate their level of confidence (static self-efficacy model) in their ability to successfully complete certain percentages of the upcoming problems in the problem solving system. Participants were then outfitted with biofeedback equipment on their left hand, which measured heat rate and galvanic skin response. The problem-solving systems involved participants answering randomly selected, multiple-choice questions. Participants were also asked to manipulate a self-efficacy slider representing the strength of their belief in their answer being correct (dynamic self-efficacy model). Finally, participants were asked to complete the post-experiment survey at their own rate before concluding the session. Results indicate that induced decision tree models that learn from demographic data and data gathered with a validated self-efficacy instrument administered prior to problem solving and learning episodes can make reasonably accurate predictions about students' self-efficacy. In addition, if runtime physiological data is available, it can significantly enhance self-efficacy modelling allowing self-efficacy to be predicted more accurately. This study guided the design of a second evaluation that investigated self-efficacy modelling in an interactive learning environment, CRYSTAL ISLAND (McQuiggan et al., 2008). The interactive learning environment evaluation results confirm the findings of the first study and suggest that self-efficacy can be modelled within an ITS. Although these findings reported, contribute to the growing body of work on self-efficacy and adaptive educational systems there may be a need to consider the possibility of eliciting self-efficacy from student behaviour without using (importable, expensive) biofeedback apparatus. Secondly, now that self-efficacy can be accurately modeled at runtime, the effect of specific pedagogical actions on students' self-efficacy needs to be investigated.

Beal et al. (2005, 2005a) present a pedagogical model that considers student motivation, mood and cognitive processes in making instructional decisions. This pedagogical model is incorporated in the Wayang-West intelligent tutoring system for secondary school mathematics, specifically SAT-Math problem solving. Self-report instruments are integrated within the intelligent tutoring system and comprise a number of question including questions on self-efficacy. Based on the submitted self-efficacy value the pedagogical model can select the appropriate level of problems for the student.

(E.g. the use of a random problem selection mechanism for high achieving students while the tutor may present easier problems for students with lower self-efficacy). Additionally, a student's self-efficacy may be enhanced through the provision of student progress reports with positive feedback for example "I know you can do this". Albeit that the design of such a pedagogical model is of benefit to the research community there is a need for implementation of such a pedagogical model within an intelligent tutoring system in order to investigate its validity. To the author's best knowledge further advancements in this research have not been reported to date.

Kim (2005) investigated the effect of empathetic response and gender of pedagogical agents as learning companions on a number of variables including self-efficacy. 56 pre-service teachers were involved in an experiment, which was implemented as a mandatory course activity for students enrolled in an introductory educational technology class. The experiments involved participants interacting with a web-based instructional module, which included a pedagogical agent. A responsive and non-responsive version of the pedagogical agent was developed. Responsive refers to the ability of the agent to respond with empathy to the learners' affective state. On commencing the experiment, participants entered demographic information and completed a pre test questionnaire. The pre test included five items in relation to self-efficacy, which were scaled from 1 (Strongly disagree) to 5 (Strongly agree) (e.g. How well can you write a lesson plan?). After the intervention, participants complete a post test questionnaire, which also included items relating to self-efficacy. Results indicate that students who worked with the responsive pedagogical agent showed significantly higher self-efficacy than students who worked with a non-responsive pedagogical agent. A possible limitation of this research is that it was a one-time implementation therefore the long-term impact of pedagogical agents as learning companions on interest is unknown. In addition, this research uses a static model of self-efficacy, which has a limiting effect on the depth of the results.

A similar study was conducted by Kim et al. (2007) in the domain of Algebra. 83 high school girls interacted with MathGirls, a pedagogical agent-based environment for one lesson each day over two consecutives days. A questionnaire of six items was developed, the items were scaled from 1 (strongly disagree) to 7 (strongly agree) and was completed by students before and after the intervention. Participants were randomly assigned to one of three groups; choice, randomisation or control. In the choice condition, participants were allowed choose the agent they wished to work with. The choice comprised four agents; female peer, female teacher, male peer and male teacher. Those assigned to the randomization condition were randomly assigned to one of the four agents. In the control

condition, the participants worked through the lesson without an agent, reading text-based messages. Results reveal an increase in self-efficacy for those who worked with the pedagogical agent. Furthermore, results indicate that for those who worked with the peer pedagogical agent there was a significant increase in self-efficacy. However, due to the nature of the experiment it is unclear if these results can be sustained over a longer period as similarly to Kim (2005) it was a one-time implementation.

In summary, work to date in incorporating self-efficacy into adaptive educational systems is still at its early stages. Predominantly research has focused on eliciting self-efficacy with some suggestions on how this information may be used. There is a need for further research into how self-efficacy can be used to adapt the learning environment to meet the needs of individual learners.

Table 2.4 Adaptive Educational Systems and Self-Efficacy

System	Brief Description	Techniques for eliciting self-efficacy	Key Findings
Bica et al. (2006)	Investigates the possibility of inferring self-efficacy through user interaction based on effort, persistence and performance	Based on user behaviour (1) time taken to perform task (2) % of selected tasks completed (3) mean of correct answers	Fuzzy inference machine is an appropriate technique for the mapping of student self-efficacy.
McQuiggan & Lester (2006) McQuiggan et al.(2008)	Describe an inductive approach for automatically constructing models of self-efficacy that can be used at runtime to inform pedagogical decisions.	self-efficacy questionnaire real-time self-reports biophysical sensors (heart rate and galvanic skin response	The effectiveness of rule-based models (decision trees) in predicting self-efficacy
Beal & Lee (2005a)	The use of a pedagogical model in making instructional decisions based on motivation, mood and cognitive processes	Self-report - students provide ratings on items such as, "This year I expect to < fail, barely pass, pass, do pretty well in, be one of the top students in > math class."	No experimental results obtained. However, authors propose an original idea in using a pedagogical model in making instructional decisions
Kim (2005)	56 pre-service teachers were involved in an experiment to investigate the effect of pedagogical agents on participants self-efficacy	Self-efficacy questionnaire	Results indicate significant increases in self-efficacy of students who worked with the responsive pedagogical agent
Kim et al. (2005)	83 high school girls interacted with MathGirls, a pedagogical agent-based environment to investigate the effect of agents on self-efficacy	Self-efficacy questionnaire	Increase in self-efficacy for those who worked with the pedagogical agent in particular peer pedagogical agent

2.5.5 Adaptive Education Systems & Affect

There has been significant progress in the advancement of adaptive educational systems to incorporate affect. Overall, this has been approached as a three-dimensional problem (1) determining the role of emotion in learning and deriving a subset of emotions, (2) identifying appropriate techniques for eliciting such emotions (3) using this information in an effective manner to adapt the learning environment appropriately. Section 2.3 has provided a detailed discussion on the role of emotion and deriving a subset of basic emotions. With this in mind, this section will predominantly focus on the identification of appropriate techniques for eliciting emotion and using the resulting information to adapt the learning environment.

2.5.5.1 Techniques for eliciting emotion

To date, the collection of data in relation to participants' emotional experiences has predominantly been conducted using one of three methods or a combination of such. These comprise (1) biophysical sensor recordings (D'Mello et al., 2008; Picard, 1997) (2) self-reports (Scherer, 2005) and (3) observer-reports (Rodrigo et al., 2007).

A number of systems exist which elicit effect using biophysical sensor recordings; these are illustrated in Table 2.5. In terms of biophysical sensor recordings research has investigated the possibility of eliciting emotion based on heart rate, blood pressure, skin conductance, colour and temperature (Picard, 1997). Although, this research may be of benefit when designing decision-theoretic pedagogical agents aimed to improve the effectiveness of educational games, it remains unclear whether a similar approach may be taken when designing educational tutorials. In parallel, works is beginning on eliciting emotion using a bimodal approach based on speech and text, however, this research faces challenges in terms of overcoming individual variability thus allowing for generalisation (Milat et al., 2008). In addition, there has been some research in the use of posture to infer affect (Bianchi-Berthouze et al., 2006; D'Mello et al., 2007). Albeit that this research provides insights on the relationship between a learner's posture and the affective states related to engagement it is still uncertain whether relationships between cognition, affect, and bodily movement generalise above and beyond individual differences in experiencing and manifesting affect.

Table 2.5 Eliciting Emotion Using Biophysical Sensor Recordings

System	Brief Description	Affective States	Techniques Used	Key Findings
Picard (1997)	Experiment investigates if a wearable computer could be designed to recognise affect	Neutral, hatred, anger, romantic love, reverence, platonic love, joy	4 skin-surface sensors: electromyogram, skin conductance, blood volume pulse, and respiration	Recognisable physiological differentiation identified
Milat et al. (2008)	Investigate the possibility of emotional recognition using bimodal analysis	Joy, sadness, anger, fear and neutral	Voice and text	Emotion detection is not perfect but research provides hope for future developments
Bianchi-Berthouze et al. (2006)	Postures analysis of 20 participants playing a low-immersion, first person shooter &music game	Immersion and engagement	Post-analysis of video data, Immersion questionnaire (Cairns et al., 2006), Engagement questionnaire, (Chen et al., 2005)	Use of body to control technology may encourage expression of affect & improve engagement
D'Mello et al.(2007)	Investigate correlation between self & observer-reports of 28 under-graduates using AutoTutor	Boredom, confusion, flow, frustration, delight, neutral and surprise	Self-report & observed-report (every 20 seconds.) based on post-analysis video data of learner's screen and face. Body Posture Movement system	Identified physical indicators of boredom (e.g. stretching) & flow (e.g. heightened pressure in the seat of the chair)
Dragon et al. (2008)	Observational study of 34 students to identify physical behaviours that are linked to emotional states.	Concentrated & satisfied, excited & joy & actively engaged, angry & frustrated, bored & tired	Real–time observed-reports (15 seconds) by trained judges. Judges coded one students at a time recording the first and second behavioural state observed	May be possible to predict post test scores & attitudes from on/off task behaviour erratic affective states & & to detect states with sensors

There may be benefit in eliciting effect using biophysical sensors due to the un-portable nature of technology such research for the most part has been confined to research laboratories. However, one notable exception has focused on the development of low cost multimodal sensor platforms (which comprise a custom produced Pressure Mouse, a Wireless BlueTooth Skin Conductance sensor, a Posture Analysis Seat, and a Facial Expression system.) that can be used in natural learning context (e.g. the classroom) as opposed to within laboratory sessions (Dragon et al., 2008). However, this work is at its early stages and there is a need for further research using these behaviours to predict emotions and desirable/undesirable learning states.

Alsmeyer et al. (2007) obtained similar results where 13–14 year olds and 16-17 year olds were videoed during German language classes based on student-teacher interaction and peer-peer interaction. Analysis of video data comprised self-reports (every 30 seconds), observed-reports and coded video data (based on changes in facial expression, body language eye gaze direction & vocalisations). Results indicate little correlation between self-reports and either observed reports or coded video data of emotional experiences. Research by D'Mello et al. (2008) and Alsmeyer et al. (2008) performs post-analysis of students' affective states using stimulated recall. Clearly, there is a need for research to explore the effect of real-time self-reports and observed-reports.

Rodrigo et al. (2007) provides insights into conducting real-time observations. Twenty-six students (14-19 year olds) interact with The Incredible Machine: Even More Contraptions (Sierra Online, 2001). Observers were trained and assigned to three students and alternated between them. Since each observation lasted twenty seconds, each student was observed once per minute Observers coded both behaviour and affect using predefined coding schemes. If two distinct behaviours were observed only the first was coded. Although the approach followed provides insightful possibilities correlation between observers' judgements was not calculated due to the nature of the process. Therefore, additional studies to explore the correlation between real-time observed judgements may be of benefit.

McQuiggan et al. (2008) conducted a study where real-time self-reports were collected. Albeit that the purpose of the study was to investigate affective transitions that occur throughout narrative-centred learning experiences the approach used in collecting self-report data is of interest. Thirty-five graduate students ranging in age from 21 to 60 interacted with a narrative-centred learning environment (CRYSTAL ISLAND) with computer-based characters to solve microbiology and genetic problems. Students provided self-report through an in-game dialog.

Table 2.6 Emotion Using Self-Reports/Observed-Reports

System	Brief Description	Affective States	Techniques for eliciting emotion	Key Findings
Alsmeyer et al. (2007)	Analysis of emotional experience of 22 students during student-teacher & peer-peer interaction in language classes	Motivation, enjoyment, hope, pride, relief, anger, anxiety, confidence, embarrassment and Boredom	Self-report (every 30 seconds) & observed-reports during stimulated recall using video data. Coded video data based on changed in posture	Little correlation between self-reports and either observed reports of coded video data of emotional experience
D'Mello et al. (2008)	28 undergraduates interacted with AutoTutor to compare self-reports & observer-reports	Boredom, confusion, flow, frustration, delight, neutral and surprise	Self-report (every 20 seconds) & observed-reports during stimulated recall interview based on video data	Little correlation between teachers judgements and teachers and student's judgements
Rodrigo et al. 2007	36 students participate in problem solving activities to analyse relationship between student's affective state and their behaviour	Boredom, confusion, delight, surprise, frustration, flow and neutral	Observed-reports carried out in pairs (each report lasting 20 seconds. Both behaviour and affect was coded using predefined coding schemes	Boredom and confusion both co-occur with gaming behaviour and serve as antecedents to it.
McQuiggan et al. (2008)	35 students interact with a narrative-centred learning system to solve micro-biology & genetic problems	Anger, anxiety, boredom, confusion, delight, excitement, fear, flow, frustration, and sadness	Self-report (by selecting an affective state from the list of 10) throughout the learning process	Empathetic feedback, in particular reactive empathy, may have an impact on affective transitions

Participants were asked to select the affective state that best described their feelings at that time from a set of 10 affective states (anger, anxiety, boredom, confusion, delight,

excitement, fear, flow, frustration, and sadness). No results were presented on the effectiveness of the approach used in eliciting emotions as this was outside the scope of the research. However, there may be benefit in identifying the effectiveness of such an approach and in particular in identifying the effect on participants of being asked to self-report on affect during the learning process.

Albeit, that it may be that some emotions are best classified by learners and others by observers (e.g. boredom, as learners may not want to admit feeling bored) results to date clearly indicate a need for further research to investigate how best self-reports and observer-reports can be used to elicit affect.

2.5.5.2 Adapting the Learning Environment Based on Affect

Based on the premise that it is possible to elicit effect it is then necessary to identify how best this information can be used to benefit the learning environment. Interestingly, much of the research to date has focused on deriving a subset of emotions and identifying appropriate techniques for eliciting such emotions with little research focusing on how such information can be used to positively influence the learning environment. However, the research, which exists predominantly, rests in one of two categories: using affect enhance feedback or using affect to influence tutorial selection this is illustrated in Table 2.7.

As mentioned previously, McQuiggan et al. (2008) report on research where students interact with a narrative-centred learning environment in order to solve microbiology and genetic problems. This narrative environment, CRYSTAL ISLAND, comprises a number of characters, which when participants interact with them react empathetically based on participants self-reported affective state. Two types of empathy are defined: parallel and reactive. Parallel empathy involves the character expressing an emotion similar to that of the target by demonstrating an understanding of the participants situation and identifying with how they are feeling. Reactive empathy focuses on the participant's affective state in addition to their situation. The character displays emotions that are different from the participants in an attempt to alter or enhance the participant's affective state. In CRYSTAL ISLAND, empathetic responses are short, text-based responses consisting of 1 to 2 sentences. Results indicate that in certain situations, parallel and reactive empathy has significant influence on affective transitions. More specifically, results suggests that parallel empathy is helpful if there is a need to maintain the current affective state while reactive empathy is useful if there is a need to change the current affective state (e.g. to transition from boredom to flow). This research provides exciting possibilities for

affectively enhanced feedback. However, there is a need for further research to gain a clearer understanding of the benefit of such feedback as much of the data to date has not reached statistical significance.

Hermández et al. (2007, 2008) report on a study where students used Prime Club an educational game to learn number factorization. Prime Club comprises an Affect Behaviour Model, which influences the tutorial selection process. Emotion is elicited based on the OCC cognitive model of emotions (Ortonyet al., 1988) which relies on cognitive appraisal of the current situation based on one's goals (a player's personality and interaction patterns). In addition, Prime Club employs a pedagogical model, which selects affective actions in addition to pedagogical actions (e.g. conciliating expression and extending his arms trying to explain and motivate the student). To date results suggest that there may be some benefit in using such approach with younger students however, overall the approach did not have a significant effect on learning.

Table 2.7 Adapting the Learning Environment based on Affect

System	Brief Description	Affective States	Techniques for eliciting emotion	Key Findings
McQuiggan et al. (2008)	35 graduate students interact with a narrative-centred learning environment to solve microbiology and genetic problems	Anger, anxiety, boredom, confusion, delight, excitement, fear, flow, frustration, and sadness	Self-report (by selecting an affective state from the list of 10) throughout the learning process	Empathetic feedback, in particular reactive empathy, may have an impact on affective transitions
Hernández et al. (2007, 2008)	Students interact with Prime Climb where tutorial actions are based on the student's affective and pedagogical model	Joy, distress, pride, shame, admiration and reproach	Based on the OCC cognitive model of emotions (Ortony, 1988) emotion is elicited based on cognitive appraisal of the current situation based on one's goals	No increase in learning (2007) Increase in learning for grade 6 students where agent was influenced by the ABM (2008)

In summary, the predominance of work to date has focused on the identification and elicitation of emotion within the learning environment. There has been some research in relation to adapting to affect. This has comprised adapting the type of feedback provided and adapting the tutorial. The former has proved somewhat successful with the need for further research to gain a clearer understanding of its potential. The latter has had little overall impact on learning. Perhaps this may be due to the use of OCC model in eliciting emotions and may benefit from a different elicitation approach.

2.5.6 Adaptive Education Systems Summary

Research to date has illustrated how adaptive systems may be of benefit in providing personalised support. In particular, adaptive collaborative systems provide insights into how the collaborative learning process can be supported using adaptive technologies. However, to date personalisation of the learning environment has been explored at the group level or in terms of supporting one or other of the collaborators e.g. tutor or tutee. Albeit, that this in itself is beneficial there is also a need to explore the possibility of providing personalised support for all collaborators. That is to support both tutor and tutee, where the tutor may need to be supported in developing effective tutoring strategies while the tutee may need to be supported in an academic domain.

In terms of self-efficacy, work to date in incorporating self-efficacy into adaptive educational systems is still at its early stages. Predominantly research has focused on eliciting self-efficacy with some suggestions on how this information may be used. Thus, there is a need for further research into how self-efficacy can be used to adapt the learning environment to meet the needs of individual learners.

Substantially more research exists on eliciting and adapting to affect. Elicitation techniques include the use of biophysical sensors, self-reports and observer reports. The predominance of work to date has focused on the identification and elicitation of emotion within the learning environment. There has been some research in relation to adapting to affect. This has comprised of adapting the type of feedback provided and adapting the tutorial. However, there is a need for further research to investigate the effect of using self-reports (tutee reports) and observer-reports (tutor reports) in eliciting affect in the tutoring environment and in addition, there is a need to identify the effect of adapting the learning environment based on the tutee's affective state.

2.6 Discussion

Given the nature of the home tutoring environment and the parent-child dynamic, it offers a rich basis for the development of an adaptive educational system. Indeed, for a number of reasons, which will now be summarised, adaptive educational systems may be of great benefit within the home tutoring context. As previously described, research indicates a high correlation between parental involvement and a child's academic success (Greenwood et al., 1991). The term parental involvement is used to describe a myriad of parent behaviours from attending school functions to actively tutoring their child at home (Hickman et al., 1995). However, the most effective parental involvement is in working directly with their children on learning activities in the home (Dornbusch, 1988). Despite this parental involvement in learning activities may not occur spontaneously for a myriad of reasons. These include but are not limited to (1) lack of parental self-efficacy (Desforges & Abouchaar, 2003) (2) a perception that it is not part of the parental role (Desforges & Abouchaar, 2003) (3) negative attitude towards school (Heystek & Louw, 1994) and (4) time (Russell & Granville, 2005). However, research indicates that teaching parents specific strategies to support their children's' development can be effective in encouraging greater parental involvement (Kaiser & Hancock, 2003).

A number of educational theories provide a variety of educational strategies for use in both the school and at home. For example, the field of Home Schooling provides us with a number of educational strategies (e.g. Charlotte Mason Approach (Maison, 1993), Unschooling approach (Holt & Farenga, 2003)) which define home schooling best practice. Research also informs of the myriad of educational philosophies which have been used within the classroom context (e.g. Constructivism (Schunk, 2000), Behaviourism (Skinner, 1966), etc.). However, few education philosophies bridge the gap between school and home. One such theory, which may go some way in bridging the gap, is Talent Education philosophy (Suzuki 1986).

Talent Education philosophy is a teaching philosophy that places great importance on the role of the parent as home tutor (Suzuki 1986). Suzuki believed that the actual process of teaching the young child involves a trio of players: the child, the teacher and the so-called Suzuki parent. The Suzuki parent is the parent who provides daily home tutoring for the child. However, within the Suzuki method, there is no formalised training for parents and support is unstructured and ad hoc, despite the inherent complexity associated with the task. Albeit that Suzuki parents have a clear understanding of their role as home tutor, a commitment to parental involvement in their child's learning and a positive

attitude towards education, a resistance to practice may still prevail due to low levels of self-efficacy (Desforges & Abouchaar, 2003). For this reason, this thesis examines in particular the impact of self-efficacy on parental involvement.

Self-efficacy is described by Bandura as "beliefs in one's capability to organize and execute the courses of action required to manage prospective situations" (Bandura, 1995, p.2). Self-efficacy has four main influences, mastery experiences, vicarious experiences, verbal persuasion and physiological states (Pajares, 1997). Self-efficacy is best measured as a domain specific, task specific value with global or generalised assessments best avoided. As individuals' self-efficacy have been found to be a highly accurate predictor of ones' motivational state and indeed learning effectiveness (Zimmerman, 2000) it may be of great benefit in determining the type and level of support required by the parent during the home tutoring process.

The domain of home tutoring brings with it an added complexity insofar as there are two roles parent and child. Therefore, in parallel to supporting the parent there is also a need for the provision of appropriate support for the child. This support can comprise cognitive, affective and motivational support (Parkinson & Coleman, 1995). As the importance of providing affective support is clearly outlined in the Talent Education philosophy ("circumstances surrounding the repetition (practice) must be happy" (Suzuki, 1981 p14)), this research will also focus on using affective support to promote learning within the child. Emotion theories propose that there are from two to twenty basic emotions (Leidelmeijer, 1991). However, it is believed that the four most common emotions are fear, anger, sadness and joy (Kort et al., 2001).

Technology may be of benefit in providing the necessary support for both parent and child. Previously, technology has played a role in supporting the home tutoring process through the provision of on-line learning resources (for example, National ParentNet Association, 2008, NumberWorks@Home, 2008, Moravian Academy Suzuki Violin Website, 2008). However, little research exists which investigates how personalised learning environments may be used effectively in the domain of home tutoring (Brusilovsky, 2003). This may be a result of the dual user (parent and child) nature of the domain and the difficulties in supporting both users.

Recent research has explored the benefits of adaptive collaborative learning systems. Such systems are concerned with the exploitation of traditional adaptive educational technology in environments where two or more people work together toward a common goal. Current research can be broadly categorised into two groups. Research that supports the collaboration process itself (e.g., promoting deep collaborative discourse (Kumar et

al., 2007; O'Connor et al., 2005)) and research that promotes domain learning through collaboration (Walker et al., 2008; Biswas, 2005). However, this work is still at the early stages and in particular, there has been little focus on developing pedagogical knowledge within the tutor or on the provision of adaptive support for both users (tutor (parent) and tutee (child)).

In terms of technology and self-efficacy, research to date can be broadly categorised in terms of the use of static self-efficacy models or dynamic self-efficacy models. Static self-efficacy models comprise building a model, learned solely from pre test data (Baylor and Kim, 2004, Kim, 2005). Dynamic self-efficacy models include data collected during interaction with the system (McQuiggan et al., 2008). Some work has commenced on using models of self-efficacy for tutorial selection (Beal and Lee, 2005), however there is a need for further insights into its effect.

In terms of technology and affect, there are a number of decisions to consider when providing adaptive support. Firstly, when is it appropriate to elicit emotion and secondly, what is the best way in which to elicit such emotion. Much of the research to date has focused on students' general affective state before and/or after the learning experience rather than their affective states at key points in the learning process. Studying affect only in general, rather than at specific times, limits the type of emotional support a tutor can provide. Predominantly, eliciting emotion has been conducted using one of three methods or a combination of such. These comprise (1) biophysical sensor recordings (D'Mello, 2007) (2) self-reports (Scherer, 2005) and (3) observer-reports (Rodrigo, 2007). One of the problems with the use of biophysical sensors when eliciting emotions is they may not be readily available in natural learning contexts for example the home. Although work has commenced on using affect to adapt the learning environment (McQuiggan et al., 2008; Hernández et al., 2008) there is a need for further research in this area.

2.7 Research Challenges

Adaptive systems that provide personalised support for both tutor and tutee offer great opportunities to enhance learning through collaboration. However, building such systems is a non-trivial task and outstanding research issues include how can an adaptive engine simultaneously support dual users (tutor and tutee), what is the appropriate educational theory from which to elicit a set of rules, which define tutoring best practice and what is an appropriate basis for adapting to the needs of the tutor and tutee?

This review suggests that adaptive educational systems and adaptive collaborative systems may be further exploited to provide dual user adaptivity. Furthermore, it suggests that Talent Education philosophy may be of benefit in defining tutoring best practice. Finally, the review indicates that self-efficacy may be an appropriate basis for adapting to the needs of the parent with affect being an appropriate base for adapting to the needs of the child. This thesis proposes that the adaptive educational system P.A.C.T. addresses these challenges in a novel manner. In summary, it demonstrates:

- How P.A.C.T.'s novel dual user architecture comprising dual user models and domain models can provide simultaneous adaptive support for tutor and tutee (Chapter 3).
- How Talent Education philosophy can be used to inform a set of tutoring rules, which encapsulate tutoring best practice (Chapter 3 & Chapter 4).
- How self-efficacy and affect can be used as an appropriate basis for adapting to the needs of the tutor and tutee respectively (Chapter 3 & Chapter 4).

Using P.A.C.T., it is possible to explore a range of educational issues and this thesis using empirical studies investigates (Chapter 7):

- The effect of using adaptive strategies on parents' self-efficacy, knowledge and their perception of their role as home tutor.
- The effect of adapting to the affective needs of the child throughout the home-tutoring process.

2.8 Summary

This chapter has reviewed how adaptive systems may be of benefit in supporting tutor and tutee throughout the tutoring process. Firstly, it reviewed the myriad of educational theories, which support the home and school contexts. In particular, it focused on Talent Education philosophy, one educational theory that may be of benefit in bridging the gap between home and school. Secondly, it reviewed research carried out in the area of self-efficacy and suggested how it may be of benefit to provide personalised support for tutors based on their level of self-efficacy. Thirdly, it described the integral link between affect and cognition and illustrated how tutees may benefit from personalised support based on their affective state. Finally, it argued that P.A.C.T. addresses, in a novel manner, the challenges in developing an adaptive system that simultaneously provides adaptive support for tutor and tutee throughout the tutoring process.

3 P.A.C.T.

3.1 Introduction

Chapter 3 describes the design and development of P.A.C.T. an adaptive educational system that simultaneously supports dual users (tutor and tutee). It describes P.A.C.T.'s novel dual user architecture comprising domain models, user models, presentation model, and pedagogical model. The adaptive engine, a sub-component of the pedagogical model is described in Chapter 4. Additionally, the technical implementation of P.A.C.T. is outlined.

3.2 Overall Architecture

Typically, adaptive educational systems support individual users and comprise user, domain, pedagogical and presentation models (Wenger, 1987). However, the domain of tutoring provides an added complexity in so far as there are two users, tutor (parent) and tutee (child).

Figure 3.1 illustrates P.A.C.T.'s overall architecture, which comprises a domain model, user model, pedagogical model and presentation model. The different components include the following functions:

- The domain model is a representation of the skills to be learnt.
- The user model represents the user's knowledge of the domain and builds a profile of the user based on behaviour and navigation.
- The presentation model handles the flow of information and monitors the interactions between the users and the system.
- The pedagogical model uses adaptive presentation and navigation techniques to determine what next to present to the student in terms of content and style using different pedagogical strategies.

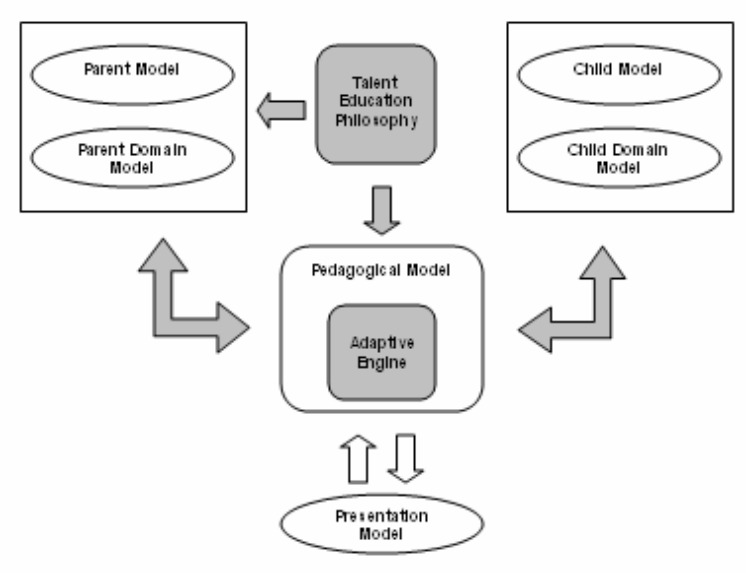

Figure 3.1 P.A.C.T. Architecture

P.A.C.T. differs from other adaptive systems in so far as it contains dual domain models and dual user models. P.A.C.T. maintains a profile for both tutor and tutee through the use of dual user models. As a result of its dual domain models, P.A.C.T. can simultaneously provide support for both users in different domains. This is conceptualised in Figure 3.2.

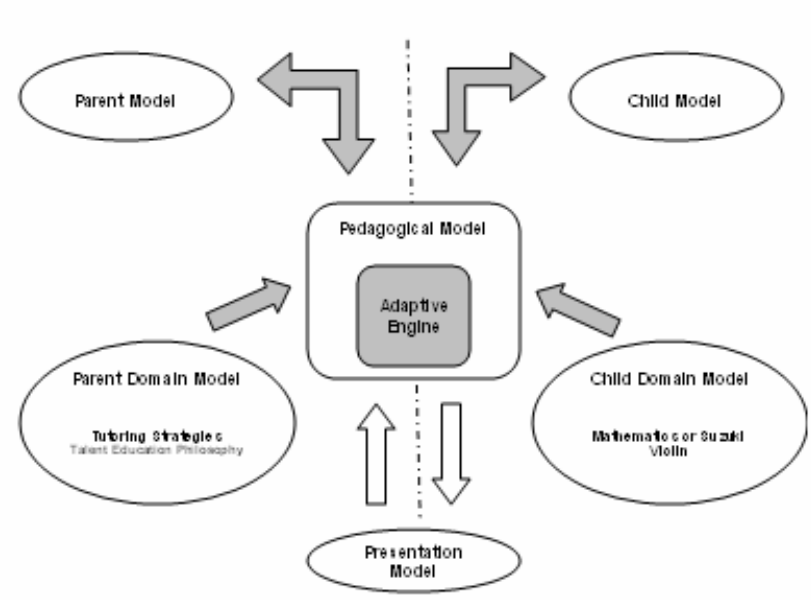

Figure 3.2 Tutor-Tutee Support

3.3 Domain Model

As a result of P.A.C.T.'s dual user architecture, there are two domain models within P.A.C.T. one, which comprises the skills to be learnt by the parent, and the other, which comprises the skills to be learnt by the child. The skills to be learnt by the parent is home tutoring best practice, which is informed by Talent Education philosophy. Current implementations of P.A.C.T. allow for the development of Suzuki violin and mathematics skills within the child. P.A.C.T. attempts to develop domain independent home tutoring skills within the parent while simultaneously developing domain specific skills within the child. Together both models assist in providing robust support for both parent and child. Firstly, the parent domain model is described. Subsequently, the child domain model will be described.

3.3.1 Parent Domain Model

The parent model comprises an instantiation of the Talent Education philosophy in an endeavour to develop home tutoring best practice within the parent. Moving from a philosophy of education to implementation as a pedagogical practice requires an act of interpretation. Consequently, a considerable amount of research was undertaken in articulating a set of tutoring tactics to denote Talent Education philosophy (Suzuki, 1978; Lahart et al., 2006). This process comprised interviews with a Suzuki expert (a teacher who had in excess of ten years experience of the Talent Education philosophy) and observation of in excess of 20 Suzuki lessons. This process proposed a set of seven tutoring tactics as is illustrated in Figure 3.3. These comprise expert demonstration, mastery learning, motivational game, positive reinforcement, repetition, review and tutoring variation. The validation of these tutoring tactics is described in Chapter 5.

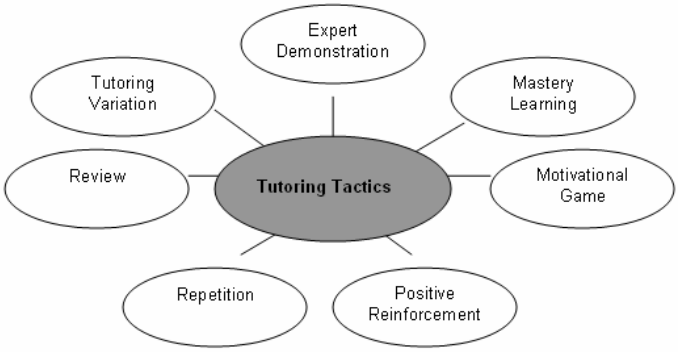

Figure 3.3 Tutoring Tactics

Expert Demonstration involves the provision of the very best examples from which the child may learn. Examples may be given by the parent if they have expertise in the domain or may be given by an external influence. For example, with music, this may be listening to a CD or with mathematics, it may be observing a video/computer simulation.

Mastery learning promotes the provision of learning material in small simple steps so that the child can achieve at each level. It is easier for a child to master new skills when each step is mastered before the next is encountered. For the parent this may mean asking the child to complete the first step as opposed to the entire task.

Motivational game(s) are used to increase motivation. The games may be domain dependent or independent. Domain independent games may be used to promote concentration or to motivate the young child. An example of a domain independent game is the Colours game. The so-called Colours game assists in improving the child's concentration. The parent begins by calling out a colour the child must repeat this colour and adds their colour to the list. The game progresses with each taking their turn until someone is unable to call the list of colours. An example of a domain dependent game for music might be playing snippets from previously learnt songs. This may encourage review of previously acquired material.

Positive Reinforcement is used to recognise the child's efforts and to encourage and motivate students to do better. Phrases such as "That was very good, now, can you do better?" are useful in encouraging students.

Repetition is necessary in acquiring new skills. Repetition should be structured, that is, a child should be asked to repeat the skill a finite number of times. Unstructured repetition may decrease motivation. It may be useful to involve the child in deciding the number of repetitions to complete.

Review is an important aspect of Suzuki's Talent Education philosophy. Continuous review of previously acquired knowledge is necessary for mastery and can be used as a building block in learning new skills. Review should be carried out on a daily basis.

Tutoring variation involves changing the instruction in order to suit your child's learning style. A myriad of research exists in assessing and supporting different learning styles and learning preferences (Fleming & Bonwell, 2008). For the purpose of this research, implicit reference is made to VARK's four learning styles read/write, aural, visual and kinaesthetic (Fleming & Bonwell, 2008).

As with any adaptive educational system it was necessary to develop an array of learning content for each of the skills, (tutoring tactics) represented in the domain model.

This content comprised explanation, example and reflection resources. Explanation resources comprise an explanation of the tutoring tactic and/or suggestions of an appropriate domain specific activity. Example resources provide a specific example of how the activity can be achieved. Reflection resources are domain independent and provide an explanation of how the particular tactic can benefit the child's learning. An example is provided in Table 3.1 where the tutoring tactic is motivational game and the domain is mathematics. In this scenario, the explanation involves a mathematics race ("Let's have a Mathematics Race"). The example involves finding x objects of y colour, where the child suggests x the number of objects and y the colour ("Ask your child to pick a colour and then pick a number between 1 and 5. Then see who can find that many items of that colour first. For example you might have to find two blue objects."). The reflection involves gaining a deeper understanding of the purpose of motivational games ("Motivational Games can relax your child, increase concentration and therefore promote learning.").

Table 3.1 Learning Content (Explanation, Example & Reflection)

Explanation	Example	Reflection
Let's have a Mathematics Race!	Ask your child to pick a colour and then pick a number between 1 and 5. Then see who can find that many items of that colour first. For example, you might have to find two blue objects.	Motivational Games can relax your child, increase concentration and therefore promote learning.

The explanation and example resources are domain specific, and therefore are related to the skills represented in the child domain model. They will be discussed in section 3.3.2. The reflection resources are related to the skills represented in the parent domain model. Figures 3.4 through 3.10 provide examples of reflection resources for each of the tutoring tactics. The learning content comprises 24 reflection resources in total the breakdown of resources across tutoring tactics is illustrated in Table 3.3.

Figure 3.4 Expert Demonstration

Figure 3.5 Mastery Learning

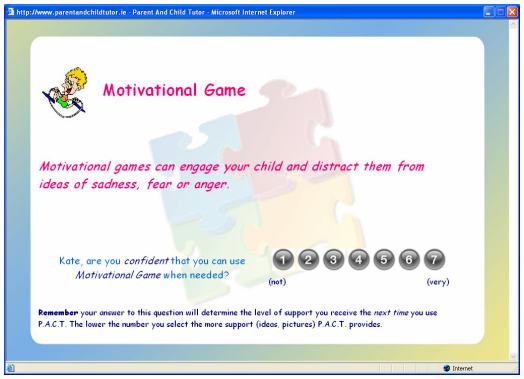

Figure 3.6 Motivational Games

Figure 3.7 Positive Reinforcement

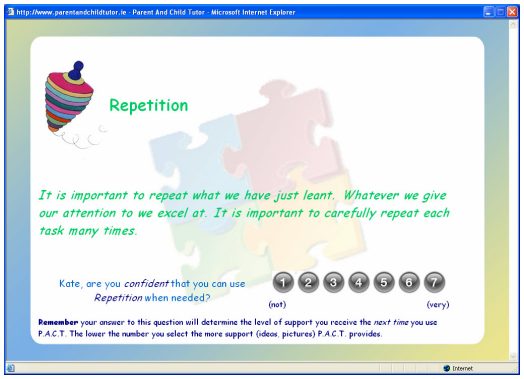

Figure 3.8 Repetition

Figure 3.9 Review

Figure 3.10 Tutoring Variation

3.3.2 Child Domain Model

As previously, stated P.A.C.T provides support for the child in two domains, Suzuki violin and mathematics. Initially Suzuki violin was selected as it is taught using Talent Education philosophy and anecdotal evidence suggests the need for further parental support. Subsequently, it was decided to develop content in the domain of mathematics, the reason being two-fold. Firstly, there was a need to investigate the effect of using P.A.C.T. to support home tutoring of a more mainstream subject. Secondly, it may provide answers on whether an adaptive educational system informed by Talent Education philosophy could be of benefit in a domain where parents may not have previous exposure to the education philosophy or may not be inclined to take on extra home tutoring duties (e.g. music lessons). A description of the mathematics domain model will follow a description of the Suzuki violin domain model.

3.3.2.1 Suzuki Violin

The domain model for Suzuki violin is complex in so far as the set of skills to be developed are embedded in a set of Suzuki pieces (Suzuki, 1978). The beginning Suzuki repertoire comprises the first 12 pieces in Book 1 through which a number of key techniques (based around posture and tone) are developed. Each Suzuki piece is taught with a view to mastering a particular skill. Therefore, with the Suzuki violin model the distinction between the domain model and learning content is perhaps less transparent. Figures 3.11 through 3.17 illustrate examples of learning content for each of the tutoring tactics can be instantiated (through the use of explanation and example resources) within the domain of Suzuki Violin. 127 (60 explanation resources and 67 example resources) Suzuki violin resources were developed. The breakdown of resources across each tactic is illustrated in Table 3.3. Figure 3.11 illustrates the expert demonstration tutoring tactic where it is suggested that the child listens to their current, this will be ascertained based on the child's user model (explanation resource). The multimedia object provides a mechanism for listening to it (example resource). The mastery learning tactic is instantiated in Figure 3.12 where it is suggested that the child play through this weeks notes once, the parent is reminded to use small simple steps (explanation resource). In particular, it is suggested that the child concentrate on the notes while the parent does the bowing (example resource). The motivational game tactic is illustrated in Figure 3.13 where it is suggested to have a spider race to develop co-ordination and flexibility (explanation resource). The parent is also provided with specific instructions on how to have a spider race (example resource). Figure 3.14 provides an example of how to

provide domain specific positive reinforcement where it is suggested the parent observe the child and praise something they are doing well (explanation resource). In particular, it is suggested that the parent praises the child's posture (explanation resource). Figure 3.15 provides an example of how to carry out repetition in an effective manner. Here it is suggested to carry out a finite number of repetitions based on some criteria (explanation resource). The criteria used maybe based on the child's age (example resource). An example of how the review tutoring tactic may be instantiated is illustrated in Figure 3.16 where particular review exercises are suggested based on input from the child's user model (explanation resource). In this example, it is suggested that when the child is reviewing these exercises they concentrate on developing particular techniques (example resource). The multimedia animation reinforces the idea that the Suzuki repertoire should be viewed as a set of building blocks for skill development. Finally, Figure 3.17 provides an instantiation of the tutoring variation tactic where it is suggested that the child may be an aural learner (explanation resource) and therefore should be provided with an aural educational resource (example resource).

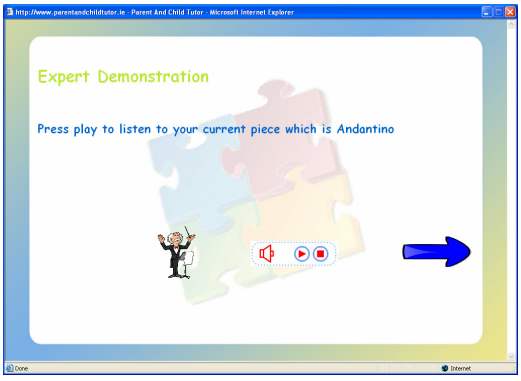

Figure 3.11 Expert Demonstration

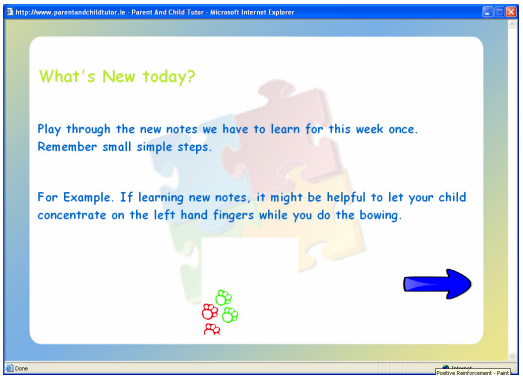

Figure 3.12 Mastery Learning

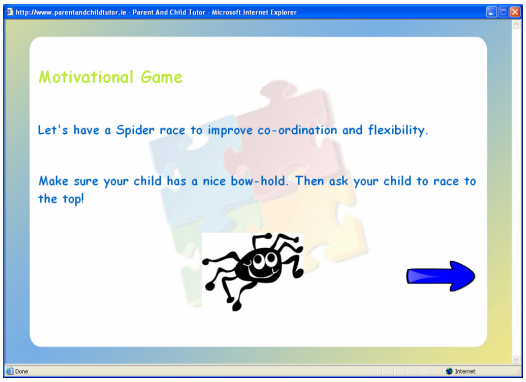

Figure 3.13 Motivational Games

Figure 3.14 Positive Reinforcement

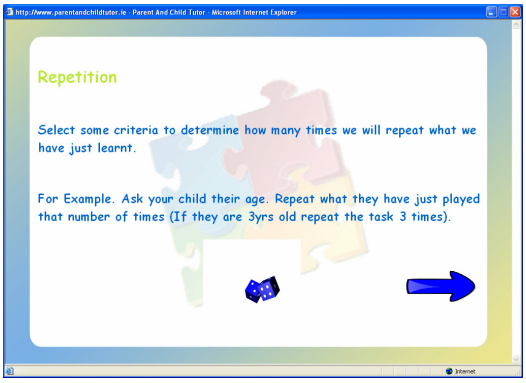

Figure 3.15 Repetition

Figure 3.16 Review

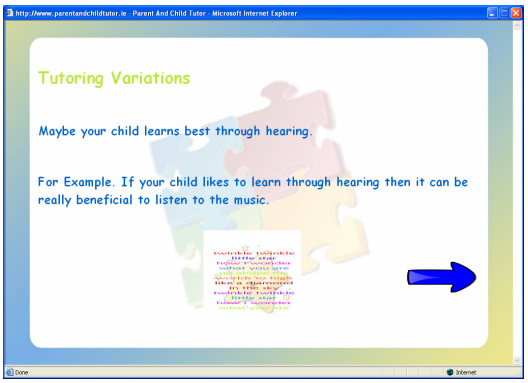

Figure 3.17 Tutoring Variation

3.3.2.2 Mathematics

The mathematics domain model within P.A.C.T. comprises a set of skills based on a set of strands and strand units presented in the Irish Primary School Mathematics Curriculum for Junior Infants (aged 4-5 years) issued by the Department of Education. The strands include early mathematics activities, number, algebra, shape and space, measure and data (Mathematics Primary School Curriculum, 1999). Each strand comprises a number of strand units these are detailed in Table 3.2.

Table 3.2 Junior Infants Mathematics Strands and Strand Units

Strands	Strand Units
Early mathematics activities	Classifying
	Matching
	Comparing
	Ordering
Number	Counting
	Comparing and ordering
	Analysis of number (Combining, Partitioning, Numeration)
Algebra	Extending patterns
Shape and space	Spatial awareness
	3-D shapes
	2-D shapes
Measures	Length
	Weight
	Capacity
	Time
	Money
Data	Recognising and interpreting data

Learning content was developed for each strand and strand unit. 126 mathematics resources (comprising 63 explanation resources and 63 example resources) were developed. Table 3.4 provides a breakdown of the number of resources available for each tactic. In particular, a large quantity of resources was developed for the review tutoring tactic, as it was necessary to have a number of review exercises for each strand and each strand unit. The review exercises comprised a textual instruction and a multimedia element to work with. Sample review exercises for each strand are illustrated in Figures 3.18 through 3.23. Figure 3.18 illustrates the early mathematical activities strand and in particular suggests a review exercise for reviewing the concept of matching pairs of identical objects in one-to-one comparisons. In this activity, the child is presented with pairs of objects, when the two matching objects appear on screen they must call out SNAP. Figure 3.19 exemplifies the Number strand, here the child is asked to review the concept of partitioning. P.A.CT. suggests the parent engage the child in discussion around

the flash animation, which firstly shows five players on the pitch and then partitions the set of objects by drawing a centre field line to show the component parts. The Algebra strand is instantiated in Figure 3.20 where students are given a pattern (shape and colour) and asked to extend the pattern. Figure 3.21 illustrates the Shape and Space strand with an activity on 2-D shapes. The child is presented with an animation and asked to name the 2-D shapes square, circle, triangle and rectangle. The Measures concept is instantiated in Figure 3.22 where the child is asked to develop an understanding of the concept of time through the use of appropriate vocabulary such as morning/evening, night/day, lunchtime, bedtime, early/late, days of the week, school days and weekends. The purpose of the multimedia animation is to encourage the child to discuss what happened today using the aforementioned vocabulary. Finally, Figure 3.23 exemplifies an instantiation of the Data strand, where the child is encouraged to recognise and interpret data in terms of equal and unequal (enough/more/as many as/less). Here it is suggested that the child observe the multimedia animation and determines which ball bounces most often.

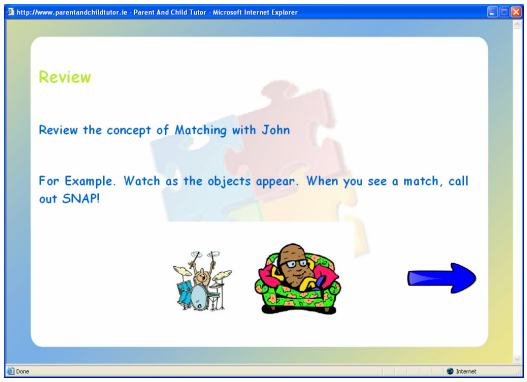

Figure 3.18 Early Mathematical Activities – Matching

Figure 3.19 Number - Portioning

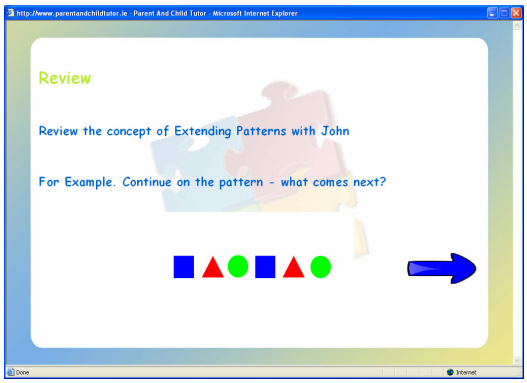

Figure 3.20 Algebra – Extending

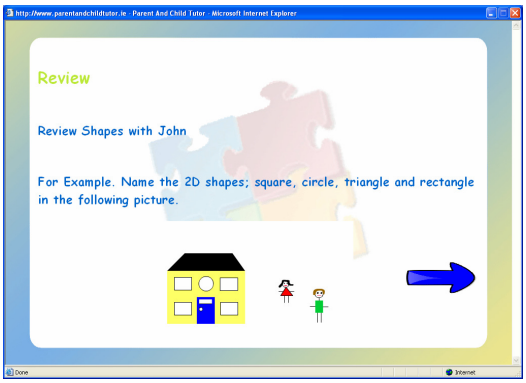

Figure 3.21 Shape and Space – 2-D

Patterns

Figure 3.22 Measures – Money

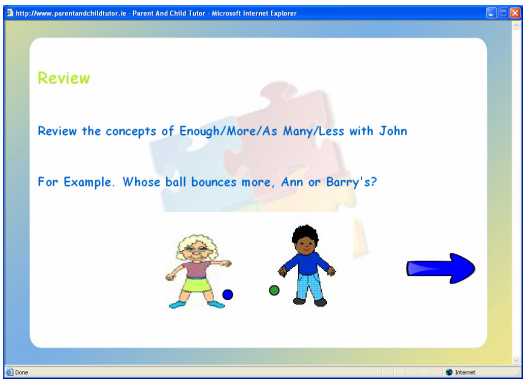

Figure 3.23 Data

Figures 3.24 through 3.28 illustrate mathematics content to support the other tutoring tactics comprising expert demonstration, mastery learning, motivational game, positive reinforcement and the tutoring variation tactic. Content was not developed for the repetition tutoring tactic. The reason for this is that the number of repetitions necessary for a child to internalise the skill is reflected in the number of mathematics problems given by the teacher for homework. Therefore, with mathematics it was not necessary to support the parent in developing the repetition tutoring tactic as the teacher implicitly provides such support.

Figure 3.24 illustrates an example of an instantiation of the expert demonstration tactic, in this example it is suggested that the parent demonstrates the first step (explanation resource). Due to the level of Junior Infants mathematics, it is assumed that the parent will have expert knowledge. The wizard multimedia object is used to engage the child (example resource). An example of the mastery learning tactic is instantiated in Figure 3.25 this is quite similar to that for the Suzuki violin domain except it suggests to take out the homework for that day. The motivational game tactic illustrated in Figure 3.26 suggests a domain dependent game based on the Measure strand from the syllabus. It encourages the parent and child to play shop (explanation resource). The parent is also provided with instructions on what to do (example resource). Figure 3.27 illustrates how positive reinforcement may be domain specific. A scenario is suggested whereby a parent might praise a skill, which the child has developed (explanation resource) in this instance the skill is in identifying numbers (example resource). This skill falls under the Number strand of the Numeration strand unit, where a child must be enabled to read, write and order numerals 1-5. Figure 3.28 illustrates how the tutoring variation tactic may be

instantiated. Here it is suggested that the child may benefit from visual stimulus (explanation resource) and that it may be of benefit to make a poster and hang it in the room where they do their homework (example resource). Similarly, to the previous example this activity is concerned with the Number strand and numeration strand unit. In terms of the VARK learning style, this activity might be of benefit to visual/read-write children (Fleming & Bonwell, 2008).

Figure 3.24 Expert Demonstration

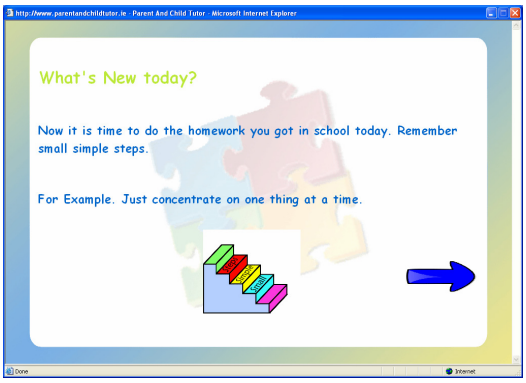

Figure 3.25 Mastery Learning

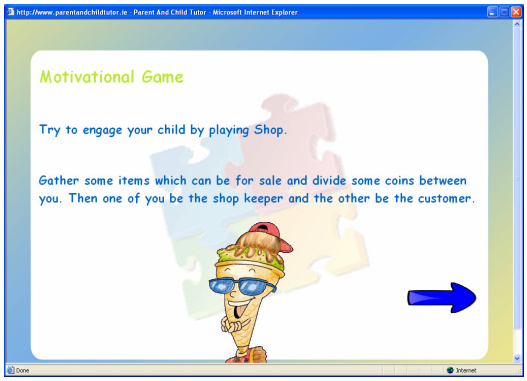

Figure 3.26 Motivational Games

Figure 3.27 Positive Reinforcement

Figure 3.28 Tutoring Variation

3.3.3 Domain Models Summary

The parent domain model comprises the set of skills (tutoring tactics) based on Talent Education philosophy to be learnt by the parent. The child domain model comprises the set of skills necessary for Suzuki violin and mathematics. The domain model for Suzuki violin is complex as the skill set is embedded in a set of Suzuki pieces. The mathematics domain model is based on a set of strands and strand units presented in the Irish Primary School Mathematics Curriculum for Junior Infants (aged 4-5 years) issued by the Department of Education. A set of learning content was developed for each of the skills in the parent and child domain models. The learning content was developed with the help of subject experts. The content comprised explanation, example and reflection resources. Explanation resources comprise an explanation of the tutoring tactic and/or suggestions of appropriate activity. Example resources provide a specific example of how the activity can be achieved. Reflection resources provide an explanation of how the particular tactic can benefit the child's learning.

As can be observed from Tables 3.3 and 3.4 277 resources have been developed. 24 domain independent reflection resources were developed to assist the parent in developing home tutoring best practice. 127 content resources were developed for Suzuki violin while 126 content resources were developed for mathematics. In terms of the Suzuki violin resources, these comprised 60 explanation resources and 67 example resources. For mathematics, the 126 resources comprised 63 explanation resources and 63 example resources.

Table 3.3 Suzuki Violin Resources

	Explanation	Example	Reflection
Expert Demonstration	1	12	3
Mastery Learning	6	6	4
Motivational Game	17	17	5
Positive Reinforcement	16	16	4
Repetition	2	3	4
Review	12	8	5
Tutoring Variation	6	6	3

The number of Suzuki violin explanation resources for each tutoring tactic can be observed from Table 3.3. A large proportion of the resources were created for the motivational game, positive reinforcement and review tactics as it was important to have a diverse selection to maintain engagement. There was only need for one explanation resource for expert demonstration, a text fragment suggesting that the parent press play on an embedded multimedia object to listen to the child's current piece (reader is directed to Figure 3.11). Similarly, with the example resources a higher proportion of resources were created for the positive reinforcement and motivational game tactics in an endeavour to engage the child.

Table 3.4 Mathematics Resources

	Explanation	Example	Reflection
Expert Demonstration	1	1	3
Mastery Learning	3	3	4
Motivational Game	12	12	5
Positive Reinforcement	16	16	4
Review	27	27	5
Tutoring Variation	4	4	3

The number of mathematics explanation resources for each tactic can be observed from Table 3.4. As with Suzuki violin a large proportion of the explanation resources were created for the motivational game, positive reinforcement and review tactics in an endeavour to engage the child. The particularly high proportion of review explanation and example resources is to accommodate presenting the child with three mathematics problems for review. There is a need for a large selection of resources so the child will not continuously encounter the same mathematics problems. This is achieved through the development of a number of varying review activities for each learning strand. There was only need for one explanation resource for the expert demonstration tactics, which comprised a text fragment suggesting that the parent show the child how to do the first sum (reader is directed to Figure 3.24). In terms of the example resources a higher proportion of example resources were created for the motivational game, positive reinforcement and review tactics for reasons outlined previously. However, with mathematics there was a need for fewer mastery learning and motivational game explanation and example resources than for Suzuki violin as the repetition tactic and therefore repetition phase was not included for mathematics due to the nature of the domain. The validation process is described in Chapter 5

3.4 User Models

Within adaptive educational systems, this research provides a novel contribution insofar as a user model in constructed for both users, tutor (parent) and tutee (child). The user models provide the source of information from which the system can provide personalised support for both users. During interaction with the system, all information is recorded and used to provide a complete description of the learner's knowledge, characteristics and preferences.

The parent user model in P.A.C.T. has the following characteristics

- It records and updates parental self-efficacy as they proceed through the system. A self-efficacy value, which is some value between 1 and 7, is maintained for each of the tutoring tactics. 1 indicates a low level of self-efficacy while 7 indicate a high level of self-efficacy. All values are logged which allows for the provision of a history of parents' self-efficacy in using each of the tutoring tactics.
- It represents the navigation history, a record of the navigation path the parent has taken through the educational material.
- It maintains a record of the tutoring tactics suggested to the parent, the level of support received for each tactic on each occasion and time spent on each learning activity.
- It maintains a record of the parent's name.
- It represents a value indicating if the parents should receive full or adaptive support. Full support indicates that the parent always receives full support for each tutoring tactic (i.e. they are provided with an example, explanation and reflection resource). Adaptive support signifies that a parent receives a level of support corresponding to their self-efficacy value for that tactic (reader is directed to section 4.2.3 for a more detailed description).
- It is dynamically updated during interaction to reflect the learner's current state.

The child's user model in P.A.C.T. has the following characteristics

- All affective states experienced by the child are logged, this allows for the provision of a history of the child's affective experiences.
- It also maintains a record of the child's current affective state and previous affective state.

- It maintains a record of the child's name.
- With the Suzuki violin domain, it maintains a record of the child's current goal in order to provide review suggestions tailored to the child's needs. This is not necessary for mathematics, as progression through the syllabus is not linear.
- It is dynamically updated during interaction to reflect the learner's current state.

The user models outlined for both parent and child are non-traditional in so far as they do not model user knowledge. The reason for this is two-fold. Firstly, it was important that parents perceived P.A.C.T. to be a supportive environment and therefore it would not be appropriate to quiz parents in order to identify knowledge level in terms of each of the tutoring tactics. Secondly, it was decided to model the child's affective state as research indicates that positive affective states can have a positive effect on learning. Therefore modelling the child's user knowledge was outside the scope of this research however, this may form the basis of future research.

3.5 Presentation Model

The presentation model is based on an abbreviated version of Gagné's model (Gagné, 1985). It comprises three key instructional events, as illustrated in Figure 3.29.

- Engage: the purpose of this is to attract the users' attention.
- Activate: the purpose of this stage is to allow the user to practice some newly acquired skill.
- Reinforce: the purpose of this stage is reinforce the key message through reflection.

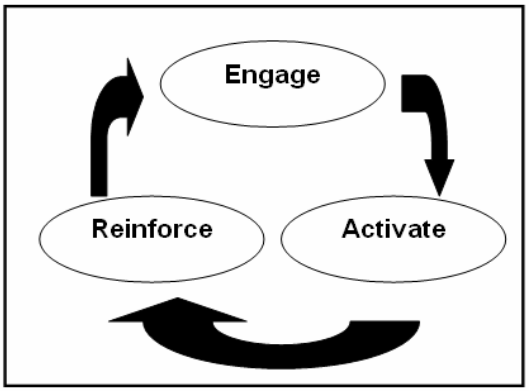

Figure 3.29 Presentation Model Events

Figure 3.30 illustrates the engage state where the user is asked to enter the child's current affective state. It tries to stimulate interest through the colourful emoticons and bring both parent and child into the learning space. With each submission of the child's affective state P.A.C.T. automatically builds a model of the child's emotional experience. This in turn allows P.A.C.T. to provide a personalised learning path.

The activity stage provides an activity for parent and child based on input from the user models. These activities are domain dependent and based on the syllabi for Suzuki violin and mathematics. The parent is provided with suggested activities to carry out with their child. Each activity comprises and explanation and example as described previously.

The reinforce stage, coaches the parent in domain independent tutoring skills by providing a mechanism for reflection. More specifically, this stage provides an opportunity to reinforce the purpose of the tutoring tactic just encountered. This is illustrated in Figure 3.31 where the parent is given an opportunity to reflect on the benefit of the review tactic. The statement *Review provides the building blocks for all learning* may reinforce the benefits of review. Figure 3.31 also illustrates the mechanism by which parents can provide feedback on their confidence at using particular tactics. The parent is asked to select a value 1-7, which best represents how confident they feel in using the particular tutoring tactic (the reader is directed to section 4.2.3 for a more detailed discussion). Research suggests that seeking feedback from the parent encourages deep reflection, thus reinforcing the learning (Espinoza et al., 2006).

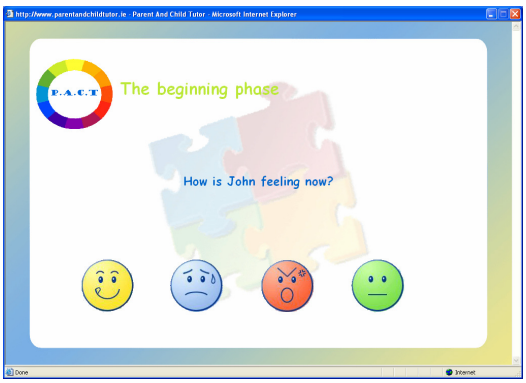

Figure 3.30 Events in Presentation Model

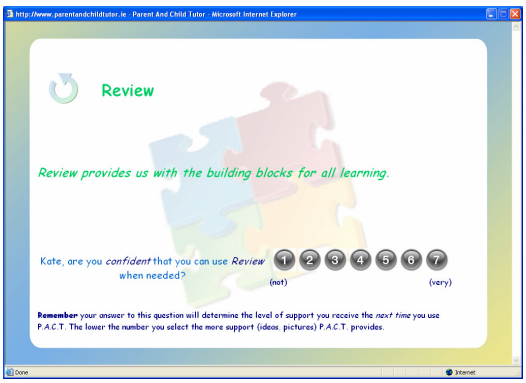

Figure 3.31 Events in Presentation Model

3.6 Pedagogical Model

P.A.C.T.'s design allows for flexibility in the use of different pedagogical strategies. Such strategies involve providing users with a broad set of resources and providing users with a restricted set of resources. These strategies are implemented by dynamically tailoring the environment using information from the user models and output from the adaptive engine. Adaptivity is implemented using two adaptation technologies: adaptive presentation and adaptive sequencing (Weber & Brusilovsky, 2001). These technologies are incorporated in such a way to support both parent and child.

A number of adaptive presentation techniques are incorporated including text and multimedia fragment insertion and removal, explanation variants and altering fragments. Text and multimedia fragments are inserted and removed as a result of changes in the parent's user model, in particular, their self-efficacy value. Higher self-efficacy values equates to removal of content, which in turn leads to parents receiving less support. Lower levels of self-efficacy leads to insertion of content, thus the parent receives more support. In addition, multiple variations of the same content afford the possibility of providing the parent with various explanation of each tutoring tactic, in terms of explanation, example and reflection.

Text and multimedia fragments are altered in an endeavour to provide personalised support for the child based on their knowledge level. Content is altered based on input from the child's user model.

Finally, adaptive sequencing is used to simultaneously support both the parent and the child. Adaptive sequencing techniques determine the appropriate tutoring tactic to suggest to the parent at each stage, thus guiding them through the tutoring process. However, the tactic, which is suggested to the parent, depends largely on the emotional state of the child, which is maintained in the child's user model.

At the core of the pedagogical model is a set of pedagogical rules comprising tutoring rules, content rules and efficacy rules. These pedagogical rules, in particular the tutoring rules are a unique contribution and are discussed in detail in Chapter 4.

In summary, P.A.C.T.'s novel dual user architecture comprises dual domain models, which allows P.A.C.T. to support dual users in different domains. P.A.C.T. supports the parent in developing home tutoring best practice and the child in developing Suzuki violin or mathematics skills. In addition, P.A.C.T. contains dual user models, which allow P.A.C.T. to provide simultaneous support for users with different needs. The pedagogical model has at its core a set of pedagogical rules and uses a number of adaptive

technologies to provide adaptive support for both users. The presentation model handles the flow of interaction between P.A.C.T. the tutor (parent) and tutee (child).

3.7 Technical Implementation

P.A.C.T. is implemented as a web based adaptive educational system using Java servlets and Java Server Pages technology. The domain model is stored in multimedia format. Individualised user models are stored dynamically and persistently within a MySQL database. The adaptive engine has been developed using Java and comprises a Rule Engine (Bigus & Bigus, 2001). The pedagogical manager is implemented in Java. It is responsible for analysing feedback from the user, updating the user models, retrieving information from the user model, communicating with the adaptive engine and making decisions about which instructional strategy to use. The presentation model receives input from the pedagogical manager and manages the presentation of information through the use of cascading style sheets. It observes monitors and handles all feedback from the user in the form of links activated, buttons pressed and text entered.

The architectural design of P.A.C.T is based on the mediator design pattern, which can be described as a behavioural design pattern that provides a central hub to control the interactions between many objects (Gamma et al., 2004). In relation to Java servlets it is often referred to as servlet-centric design. The control and application logic is encapsulated in a central servlet or group of servlets with Java Server Pages only used for presentation purposes. In this approach, requests are indirectly routed to the Java Server Pages via a servlet. This approach promotes loose coupling by avoiding explicit references among Java Server Pages. This provides the possibility to vary their interaction independently. This is illustrated in Figure 3.32.

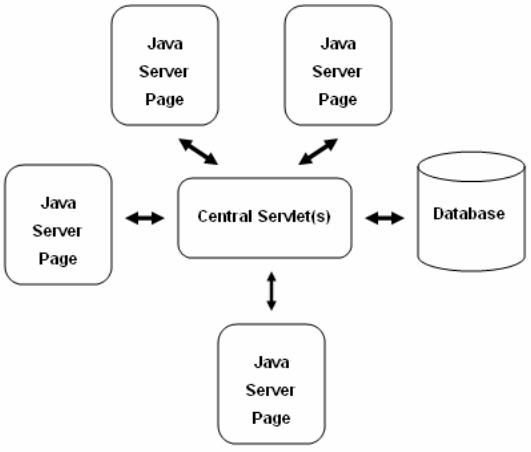

Figure 3.32 Mediator Behavioural Design Pattern

A further description of the implementation of P.A.C.T is detailed in the Appendix. This includes implementation details for the, presentation model, pedagogical model and its adaptive engine. Example code fragments are also provided.

3.8 Summary

The chapter has described the architecture, design and implementation of P.A.C.T.. It describes P.A.C.T.'s novel dual user architecture and its different components comprising dual domain models (parent and child), dual user models (parent and child), presentation model and pedagogical model. The architecture is based on the mediator behavioural design pattern. The next chapter will describe in detail the architecture and implementation of the adaptive engine.

4 Adaptive Engine

4.1 Introduction

The adaptive engine, using Artificial Intelligence techniques dynamically determines the next step in the tutoring process. Additionally, it identifies the level of support required for this step and informs the pedagogical strategy on what content to present.

This chapter describes the architecture and implementation of the adaptive engine. Firstly, it outlines the overall architecture of the adaptive engine. Next, it describes the novel set of pedagogical rules, which informed by Talent Education philosophy define tutoring best practice. The validation of such rules is presented in Chapter 5. Therefore, together Chapter 4 and 5 describe how Talent Education philosophy is an appropriate educational theory from which to elicit a set of rules that define tutoring best practice.

4.2 Engine Architecture

The adaptive engine lies at the core of P.A.C.T.'s dual user architecture. It is informed by both user models and informs P.A.C.T.'s pedagogical strategy. The engine is implemented using a forward chaining algorithm, which determines how different pedagogical rules are fired. The pedagogical rules comprise three categories as illustrated in Figure 4.1 tutoring rules, content rules and efficacy rules. The tutoring rules determine the next step in the tutoring process. The content rules determine the particular skill to present to both parent and child. The efficacy rules determine the level of support provided by PA.C.T. for the parent. Together the rules allow for a personalised learning path throughout P.A.C.T.

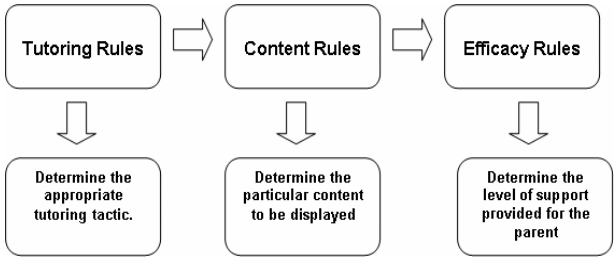

Figure 4.1 Adaptive Engine - Pedagogical Rules

4.2.1 Tutoring Rules

Lahart et al. (2008a) have derived a set of 40 domain independent tutoring rules, which identify the conditions under which particular tutoring tactics should be used. Each rule comprises two antecedents; the child's emotional state (happy, sad, angry or fearful (Kort et al., 2001)) and the current phase in the tutoring process (beginning, review, new material, repetition (Lahart et al., 2007c)) and one consequent, the suggested tutoring tactic (expert demonstration, mastery learning, motivational game, positive reinforcement, repetition, review or tutoring variation (Lahart et al., 2006, 2007c). This is illustrated in Figure 4.2 where the antecedent values are; angry (emotional state) and beginning of lesson (phase in the tutoring process) and the consequent is positive reinforcement (tutoring tactic).

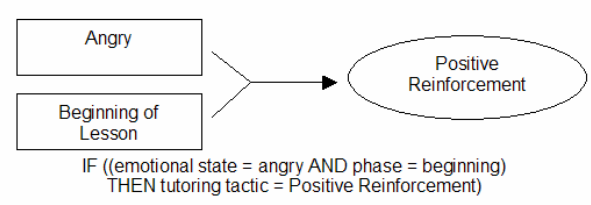

Figure 4.2 Inferred Rule

4.2.1.1 Elicitation of Tutoring Rules

Developing a set of rules is a non-trivial task therefore involving a significant amount of design and a number of validation phases. The instrument used in elicitation of this set of tutoring rules was a questionnaire. The design of the questionnaire was important, as it was necessary to glean a set of tutoring rules rich enough to adequately support parents in their role as home tutor. The questionnaire comprised a number of scenarios. The scenarios were based on the four basic emotions (anger, fear, happiness, sadness) and the key phases in a Suzuki lesson (beginning, review, new material and repetition). Each of the four emotions was combined with each of the four phases in a Suzuki lesson to produce 16 scenarios. Participants were asked to choose as many tutoring tactics as deemed necessary. The order in which they choose them was important. To denote order, participants were asked to label the tutoring tactic they would use first as 1, second as 2 and so on. Participants were asked to explain their choice and give an example. Figure 4.3 illustrates a sample of a completed scenario. The scenario is based on the beginning phase with the emotional state as angry.

Scenario	Expert Demonstration	Mastery Learning	Motivational Game	Positive Reinforcement	Repetition	Review	Tutoring Variations
At the beginning of the lesson and the child is angry			1	2			
Explain: 1. I would start the lesson with an upbeat game to focus the child on the lesson and distract them from what's bothering them. 2. To proceed I would work on an area the child enjoys							
Example: 1. I would do listen & copy games where I clap a rhythm and the child claps it back to me. 2. If the child really loved playing a particular piece I would ask them to play it to increase their confidence and enjoyment							

Figure 4.3 Sample Scenario

Fourteen Suzuki Teachers volunteered to complete the questionnaire. A face-to-face meeting took place where participants were given instructions on how to fill out the questionnaire. Participants were then given time to complete the questionnaire. However, all participants requested to take the questionnaire away with them and fill it out in their own time stating that they expected it to be a very difficult task. Eleven questionnaires were returned. On analysis, the three non-respondents had valid reasons for non-completion of the questionnaire. These reasons comprised time constraints and self-believed lack of experience of the Suzuki method. Out of the eleven who responded, two of the questionnaires could not be used, as the particular participants found it too difficult to complete – which perhaps illustrates the complexity associated with identifying tutoring rules.

If (phase = repetition AND emotional state = angry)							
	A	B	C	D	E	F	G
Expert Demonstration				1			
Mastery Learning	1	2					
Motivational Game	4	1					
Positive Reinforcement			1				
Repetition							
Review							
Tutoring Variations	3	1					

Figure 4.4 Rule Elicitation

The nine completed questionnaires were analysed and collated by the author. The questionnaires were collated through a coding scheme, which captured (a) the number of participants, which selected a particular tutoring tactic, and (b) the order in which they were selected. This is illustrated in Figure 4.4 where the scenario is the repetition phase and the emotional state is angry. The motivational game tactic received 4 first preference votes and 1 second preference vote, the tutoring variation tactic received 3 first

preference votes and 1 second preference vote and the mastery learning tactic received 1 first preference vote and 2 second preference votes. This example results in the formation of three rules, which are listed in Table 4.1.

This data was also refined, in that, any instances where only one participant chose a particular tutoring tactic were removed from the data set. These were removed on the basis that if the tutoring tactic was deemed important enough in that scenario more than one participant would have selected it. This resulted in the elicitation of 51 tutoring rules. However, with any set of rules there is a need for a stringent validation process. Subsequently there were three phases of validation, phase one was carried out by the author, phase two involved 20 Suzuki practitioners and a more focused third phase involved two expert Suzuki practitioners. This resulted in a refinement of the previous set of rules to a rule base comprising 40 rules. The validation phases are described in detail in Chapter 5.

Table 4.1 Rule Elicitation – Resulting Rules

	Rule Definition
1	If (phase = repetition AND emotional state=angry THEN tactic = Motivational Game)
2	If (phase = repetition AND emotional state=angry AND Motivational Game = true THEN tactic = Tutoring Variations)
3	If (phase = repetition AND emotional state=angry AND Motivational Game = true AND Tutoring Variations = true THEN tactic = Mastery Learning)

4.2.1.2 Description of Tutoring Rules

The complete set of tutoring rules is listed in Table 4.2, where 1 denotes the tutoring tactic, which is first suggested by P.A.C.T, 2, denotes the tutoring tactic, which is then suggested if the same situation persists and so on. For example, if it is at the beginning phase and the child is angry, P.A.C.T. suggests some positive reinforcement. If the child remains angry, and still at the beginning phase, P.A.C.T. suggests a motivational game.

Each tutoring process begins at the beginning phase. P.A.C.T automatically maintains and updates the phase variable throughout the tutoring process. The phase variable is updated each time a link tutoring tactic is suggested. The purpose of link tactics is to progress the tutoring process through the various phases. The values associated with the link variable are based around the four key phases of a Suzuki lesson. The link tactics comprise mastery learning, review and repetition. More specifically, in the beginning phase the *link* tutoring tactics are mastery learning, repetition and review. When the

mastery learning tactic is suggested, the phase variable is automatically updated to the new material phase. When the repetition tactic is suggested, the phase variable is automatically updated to the repetition phase and when the review tactic is suggested, the phase variable is automatically updated to the review phase. Similarly, in the review phase, the *link* tactics are new material and repetition and in the new material phase, there is just one *link* tactic that is repetition. In the repetition phase, there are no link tactics as the repetition phase is the final phase in the tutoring process.

Table 4.2 Tutoring Rules

	Beginning				Review				New Material				Repetition			
	Angry	Fearful	Happy	Sad	Angry	Fearful	Happy	Sad	Angry	Fearful	Happy	Sad	Angry	Fearful	Happy	Sad
Expert Demonstration									3	2						
Mastery Learning							1						3	2		
Motivational Game	2			1				2				1	1	3		1
Positive Reinforcement	1	1		2	1	1		1	1	1		2				
Repetition						2				3	1					
Review		2	1													
Tutoring Variations									2			3	2	1		
Finish	3			3	2			3	4			4	4	4	1	2

4.2.2 Content Rules

In addition to suggesting an appropriate tutoring tactic, it is also necessary to identify the skill to present to the child. This is achieved though the content rules. The content rules work by means of a two-pronged process. Firstly, the skill to be presented to the child is selected and secondly the learning content used to present that skill is selected. Multiple variations of the same content exist and it is the content rules that determine which text and multimedia fragments are presented. The content rules are used to support both the parent and the child and are informed by the current tutoring phase and the child's domain model.

4.2.2.1 Phase Specific Content Rules

The content rules determine phase specific text and multimedia fragments to present to the user. For each tutoring tactic selected P.A.C.T's content rules provide an explanation of the tutoring tactic, an example of how the tutoring tactic can be implemented and a reflection on the importance of the tutoring tactic. For example, Figures 4.5 and 4.6 illustrate a presentation of the positive reinforcement tactic, where the tactic is explained ("Observe your child praise something they are doing well"), exemplified ("For example, you are very good at standing in rest position") and its benefits are described ("Positive

Figure 4.5 Phase Specific Content Rules (Explanation & Example)

Figure 4.6 Phase Specific Content Rules (Reflection)

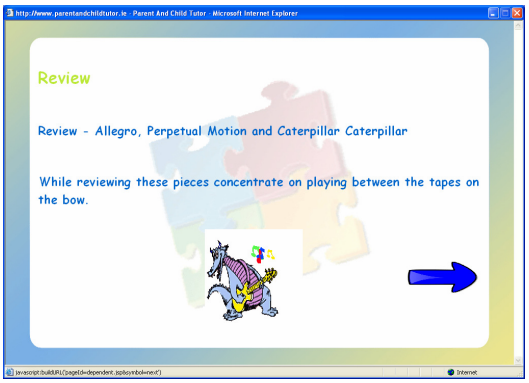

Figure 4.7 Domain Specific Content Rules (Review)

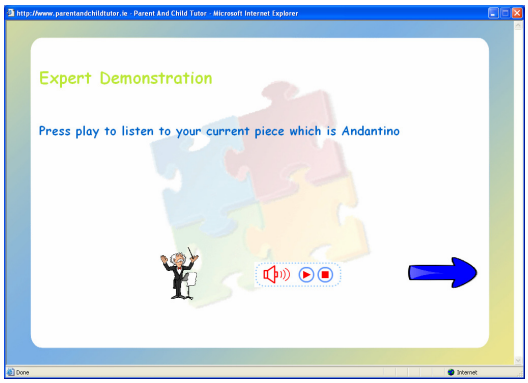

Figure 4.8 Domain Specific Content Rules (Expert Demonstration)

Reinforcement aids in building your child's confidence"). The multimedia object corresponds to the example, it is a 'jack-in-the-box', which pops out and praises the child.

The content rules ensure that the parent is supported with phase (beginning, review, new material and repetition) specific content. For example, in Figure 4.5, the parent is at the beginning phase of the tutoring process. P.A.C.T. suggests that the parent praises the child's rest position posture, a posture that is specific to the beginning phase in the tutoring process. Similarly, parents are also presented with phase specific support at each of the other three phases.

Once a phase specific set of text and multimedia content has been identified, the particular fragments for presentation are selected through a randomised selection process. The reason for this is two fold. Firstly, it is necessary to vary the content presented to the

user. Secondly, this type of selection process could potentially reduce bias in terms of the parental self-efficacy. This will be discussed in detail in section 4.2.3.

4.2.2.2 Domain Specific Content Rules

Previously, we have discussed how the set of content rules provide phase specific support to both parent and child. In addition, the content rules provide domain specific support to reflect the child's knowledge-level. More specifically, if particular tutoring tactics are suggested as a result of firing the set of tutoring rules, the content presented to the user will be informed by the knowledge-level value maintained in the child's user model.

Figure 4.7 provides an example whereby the suggested tutoring tactic is review. P.A.C.T. suggests that the child reviews three pieces ("Allegro", "Perpetual Motion" and "Caterpillar"). These pieces are selected based on the child's current piece, which can be ascertained from the child's user model. Figure 4.8 demonstrates an instantiation of the expert demonstration tactic. Here the text is altered and the multimedia object selected to reflect the child's current piece, in this case, "Andantino". These domain specific content rules only pertain to Suzuki violin. With mathematics, there is not a need to fire such rules for a number of reasons. Firstly, the mathematic syllabus is not taught linearly instead, teachers move from topic to topic where appropriate. Therefore, a hierarchical skill set which exists with Suzuki violin does not exist with mathematics. Secondly, due to the nature of the Junior Infants mathematics syllabus it is not necessary for children to have covered a topic in class for them to carry out review at home. The focus of the Junior Infants syllabus is everyday mathematics therefore students will have a lot of previous experience. Finally, due to the simple level of Junior Infants mathematics it is possible for the parent to assume the role of expert demonstrator.

4.2.3 Efficacy Rules

The purpose of the efficacy rules is to provide the necessary level of support for the parent during the tutoring process. The level of support the parent receives is self-determined and based on their submitted self-efficacy values. As self-efficacy refers to one's belief in one's ability to succeed at certain tasks, self-efficacy is scored per tutoring tactic. That is, the parent specifies a separate self-efficacy value for each of the seven tutoring tactics. These self-efficacy values determine the level of support the parent receives for each tactic suggested by P.A.C.T.. The instrument for collecting parents' self-efficacy is illustrated in Figure 4.9. Here the parent is asked to rate themselves (1-7)

on how confident they are in using positive reinforcement when needed. Once a parent submits a value, the parent user model is updated. Initially, all values are initialised to 1, which means parents receive full support on their first interaction with each tutoring tactic.

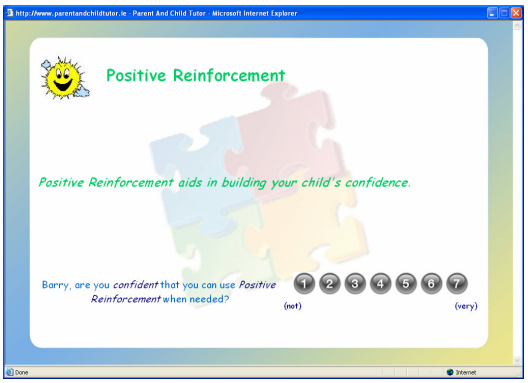

Figure 4.9 Self-Efficacy Collection Instrument

When the parent specifies their self-efficacy value for a particular tutoring tactic it corresponds to the level of support, they receive on their next interaction with that tactic. The efficacy rules are detailed in Figure 4.10. These efficacy rules define that a self-efficacy value of one or two ensures full support as illustrated in Figure 4.11. Full support comprises suggestion of the appropriate tutoring tactic, explanation, example and reflection. An explanation comprises an explanation of the tutoring tactic and/or suggestions of appropriate activity. An example provides a specific example of how the activity can be achieved. An efficacy value of three or four ensures a parent is presented with all support except the reflection fragment. This is illustrated in Figure 4.12. Figure 4.13 illustrates the level of support received with an efficacy value of five or six. Such an efficacy value suggests a level of confidence in using that tutoring tactic and so this level of support comprises the suggested tutoring tactic and an explanation of it. Finally, an efficacy value of seven suggests a high level of confidence in using that tutoring tactic and so the level of support only comprises the identification of the appropriate tutoring tactic. This is illustrated in Figure 4.14.

The efficacy rules are based on the premise that one's mastery experiences are the most influential source of self-efficacy (Bandura, 1986). More specifically, success raises self-efficacy and failure lowers it. To this end, an appropriate tutoring tactic is always suggested to the parent, irrespective of their self-efficacy value. In addition, unless the parents perceive themselves to be very confident (self-efficacy value of 7) in using the

particular tutoring tactic they are also presented with an explanation and/or example of the tutoring tactic. It is important to note that parents are asked for their sense of efficacy in using the tactic (e.g. Motivational Game) as opposed to the specific instantiation of the tactic (e.g. the Statues games). For this reason the text and multimedia with which each tactic is instantiated is selected through a randomised selection process.

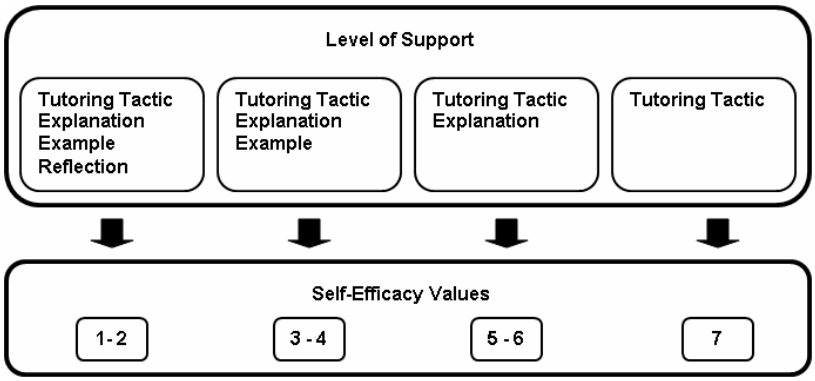

Figure 4.10 Self-Efficacy Rules

In addition, efficacy rules are informed by Bloom's taxonomy (Bloom, 1956) in so far as intellectual abilities and skills can be categorised in terms of degrees of difficulty. Bloom identifies six categories knowledge, comprehension, application, analysis, synthesis and evaluation where each must be mastered in turn. In this research, explanation resources can be mapped to the knowledge and comprehension categories, example resources to the application category and reflection resources can be mapped to the analysis, synthesis and evaluation categories. It is for this reason that support is provided in the order of tutoring tactic, explanation, example and reflection.

Figure 4.11 Self-Efficacy Value 1 – 2

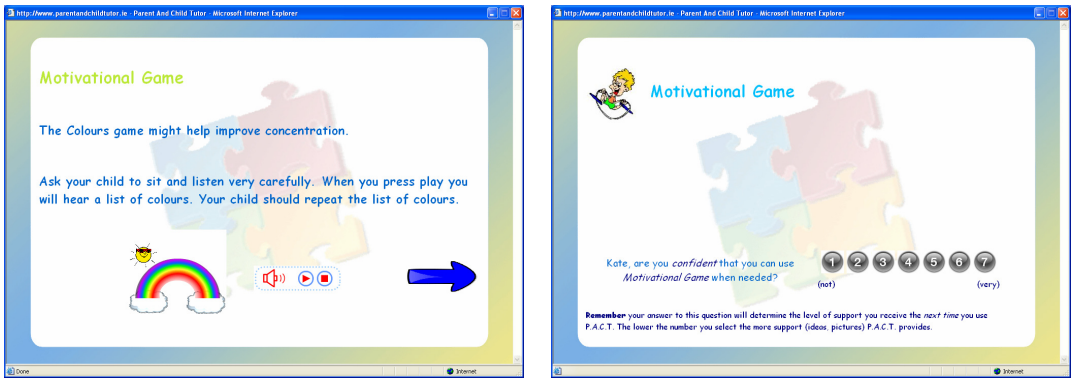

Figure 4.12 Self-Efficacy Value 3 – 4

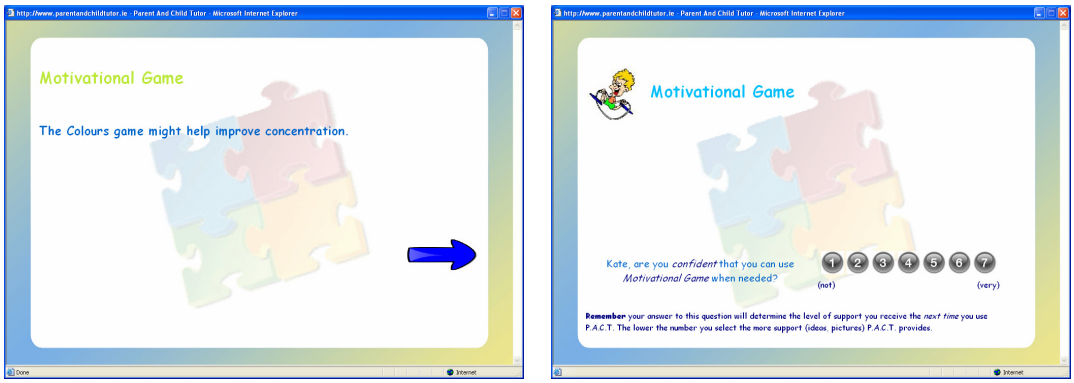

Figure 4.13 Self-Efficacy Value 5 – 6

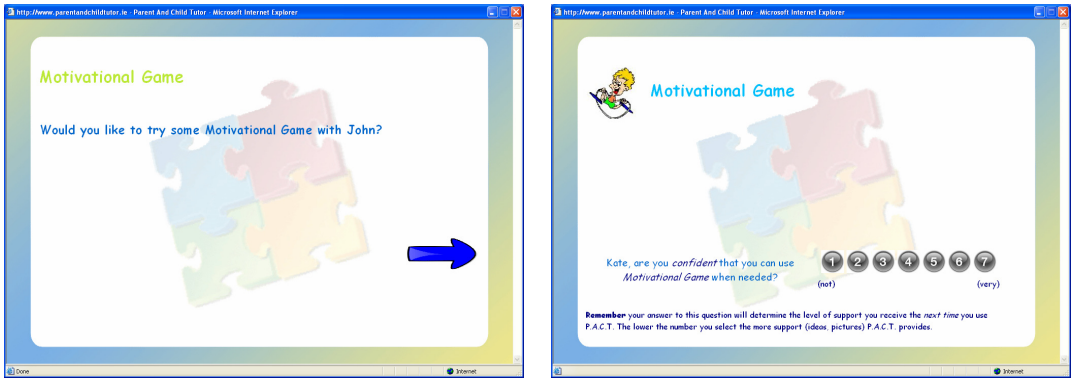

Figure 4.14 Self-Efficacy Value 7

4.3 The Dual-User Approach

It is through the combined use of the adaptive engine, parent domain model, child domain model, parent user model and child user model that P.A.C.T. provides personalised support for both parent and child. It is this inter-dependency among the aforementioned models that forms the basis of this dual approach. An example of this inter-dependency is provided in order to illustrate the necessity of this dual user approach.

Assume the parent and child are undertaking mathematics homework, the child is happy and they are at the beginning of the tutoring process. The parent and child dyad interact with P.A.C.T. through the presentation interface. The dyad enters the affective state of the child and the child user model is updated. The adaptive engine retrieves the child's affective state from the child user model and using the tutoring rules determines the appropriate tutoring tactic. In this example, the resultant tutoring tactic is review. The adaptive engine through the content rules communicates with the child user model in order to identify a particular skill to review, for example, matching pairs. Once the skill to be reviewed is selected, the associated learning content is retrieved. Subsequently, the adaptive engine communicates with the parent domain model in order to identify the skills necessary for using the review tactic when tutoring. Finally, the adaptive engine retrieves the parent's self-efficacy value for review from the parent user model and using the efficacy rules determines the appropriate level of support for the parent. The presentation model is then updated to reflect the suggested tutoring tactic and supporting learning content.

The interdependency between the adaptive engine, user models and domain models in the example presented illustrates why this dual approach cannot be implemented as two separate courses running on a single adaptive engine or as a single course on a multi-modal based adaptive engine. The combined use of the four models through the adaptive engine is key to the provision of personalised support for both parent and child.

4.4 Implementation of Engine Architecture

The adaptive engine is a rule-based system, which reasons intelligently using the set of pedagogical rules in order to infer the next step in the tutoring process. The rule system is implemented using a set of rules and an inference engine, which determines which rules to fire. The inference engine using a forward chaining (Luger and Stuberfield, 1998) algorithm searches the pedagogical rules in order to conclude or infer a valid consequent.

A forward-chaining algorithm can be used for data driven searching where the problem-solver begins with the facts of the given problem and a set of rules for changing state. The search proceeds by applying rules to facts to produce new facts, which are in turn used by the rules in order to generate additional facts. P.A.C.T.'s, rule-based system comprises three categories of rules, tutoring rules, content rules and efficacy rules. The forward chaining algorithm, chains through each set of rules in order to reach a goal state.

Figure 4.15 provides an example of how the forward chaining algorithm operates. In this example, the initial facts are {affective state = happy} and {phase = beginning}. The forward chaining algorithm chains through the rules and infers a new fact based on the initial facts, that is {tutoring tactic = review}. The forward chaining algorithm once again chains through the set of rules, this time with three facts (affective state, phase and tutoring tactic) and infers three suitable review pieces ("Lightly Row", "May Song" and "Allegro"). Again, the forward chaining algorithm traverses the rule base, where this time the appropriate level of support is identified. Finally, the forward chaining algorithm traverse the rule base, no new facts are inferred and therefore the process is complete. The adaptive engine returns the inferred facts through the pedagogical model to the presentation model for presentation.

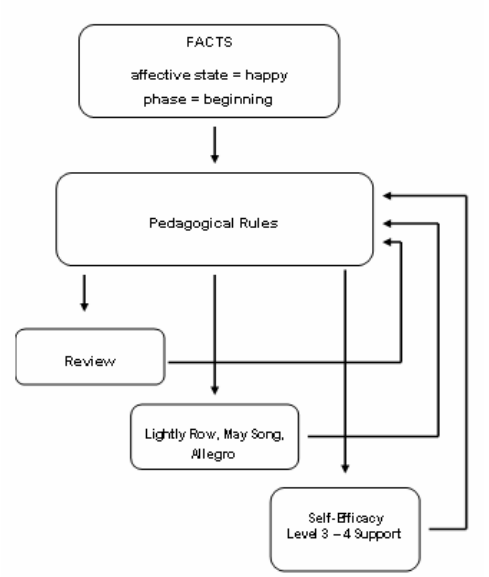

Figure 4.15 Forward Chaining Algorithm

Additionally, once a tutoring tactics is inferred, the rule variable corresponding to that tactic is updated so that the inference engine will know that it has been previously suggested. The adaptive engine automatically updates the phase variable once a link tactic

has been inferred (reader is directed to 4.2.1.2). This allows the tutoring process to progress. The inference engine and rule base are implemented in Java (Bigus & Bigus, 2001).

4.5 Summary

The chapter described the architecture and implementation of the adaptive engine. The central component of the engine comprises a set of pedagogical rules. It has also illustrated the three categories of rules and how these work together to provide a personalised level of support for both parent and child. The following Chapter 5 describes empirical studies conducted to validate the rule base component of the engine.

5 Rule Elicitation and Validation

5.1 Introduction

The previous two chapters have described the development of P.A.C.T. Chapter 3 has described P.A.C.T.'s novel dual user architecture and how the principles of Talent Education philosophy can be used to influence its teaching model. Chapter 4 has described the development of the adaptive engine and how its pedagogical rules allow the flexibility to dynamically adapt to the needs of its users. In an endeavour to investigate if Talent Education philosophy is an appropriate theory from which to elicit a set of tutoring rules a number of validation studies were conducted. Each rule comprises two antecedents, the emotional state of the child and the current phase in the tutoring process and one consequent, the appropriate tutoring tactic. It was necessary to ascertain the validity of the set of tutoring tactics, the key phases in the Suzuki lesson and the tutoring rules themselves. It was not necessary to validate the four basic emotions as their inclusion was based on results of previous research (Kort et al., 2001).

The first study comprised validation of the set of seven tutoring tactics. This study comprised a focus group of ten Suzuki practitioners. The second validation study involved validation of the key phases in a Suzuki lesson, this involved interviewing three Suzuki experts. Finally, the third validation study conducted in order to validate the set of tutoring rules involved three phases. Phase 1 was carried out by the author. Phase 2, which involved role-plays involved twenty Suzuki practitioners. Phase 3 involved a more focused approach with two expert Suzuki practitioners completing a questionnaire.

5.2 Rule Elicitation

Seven tutoring tactics have been identified which provide a mechanism for the incorporation of Talent Education philosophy within the home tutoring context. A focus group, comprising Suzuki practitioners was conducted in order to determine how accurately they reflect Suzuki principles.

5.2.1 Validating Tutoring Tactics – Methodology

The focus group comprised ten participants. The sample was opportunistic given that the only criterion for inclusion was that participants were currently teaching using

Suzuki's philosophy. The participants had not seen the list of tutoring tactics derived by Lahart et al. (2006). The focus group was one hour in duration and was facilitated by the author. The facilitator commenced discussion by posing the question "What are the teaching strategies that a lesson would have to include in order to be called a Suzuki lesson?" The facilitator remained silent for the duration except when it was necessary to seek clarification around a contribution. Discussions were recorded and analysed by the author.

5.2.2 Validating Suzuki Tutoring Tactics – Results

All participant responses were analysed and labelled using one of the seven tutoring tactics identified by Lahart et al. (2006) (for a detailed discussion on how there tutoring tactics were derived reader is directed to section 3.3.1). Those responses, which did not refer to any of the seven tutoring tactics, were labelled as extra. These were analysed separately to identify common themes but none emerged. However, what did emerge were responses corresponding to each of the previously defined tutoring tactics (Lahart et al., 2006). Table 5.1 illustrates an example of some of the labelled responses. In Table 5.1, expert demonstration is referred to by learning from sound. It is important to remember that participants in the focus group were Suzuki practitioners and therefore some examples are based in the music domain. This example may be thought of more generically as learning from example.

Table 5.1 Tutoring Tactics Validation

Tutoring Tactic	Reference
Expert Demonstration	*Learning from sound*
Mastery Learning	*Tiny steps. . we must break the task down*
Motivational Games	*Make it fun, play little games, so that the environment is happy*
Positive Reinforcement	*You have to be positive at all times*
Repetition	*Repetition*
Review	*Constantly reviewing what you have already learnt*
Tutoring Variation	*Present the same thing five different ways*

In summary, the focus group validated the set of seven tutoring tactics with no additional tactics emerging.

5.3 Tutoring Phases Validation

The second validation study comprised validation of the four phase of the tutoring process, which are based on the key phases in a Suzuki lesson. This study involved individual interviews with three Suzuki experts, who were experts in so far as they each had in excess of ten years experience of Talent Education philosophy.

5.3.1 Validation Key Phases in a Suzuki Lesson

Research literature implies four key phases in a Suzuki lesson (Suzuki 1981) comprising beginning, review, new material and repetition as illustrated in Table 5.2. The beginning phase occurs before teaching begins. In the review phase, the teacher reviews previously learnt material. The new material phase refers to the phase where the teacher introduces something new. The repetition phase is when the student repeats whatever has been introduced in the previous phase. It is necessary to identify these phases, as the phase will influence the suggested tutoring tactics.

Individual interviews were conducted with three expert Suzuki practitioners (who were expert in so far as they had in excess of ten years experience of Talent Education philosophy and were recognised experts in the area). Experts were provided with a copy of Table 5.2 and asked how accurately they reflected the structure of a Suzuki lesson. All experts agreed that these phases were an accurate reflection of the structure of a Suzuki lesson and were defined correctly.

Table 5.2 Tutoring Phases Validation

Phase	Definition
Beginning	Warm-up period before practice begins
Review	Encompasses review of previously acquired concepts/skills
New Material	The aspect of the lesson where new material is covered
Repetition	Repetition of new concepts/skills so they become internalised

In summary, the experts validated all four phases and concurred with the definitions of each phase with no additional phases or definitions emerging.

5.4 Tutoring Rules Validation

The final validation study comprised validation of the set of tutoring rules. This study comprised three phases Phase one was carried out by the author. Phase two involved twenty Suzuki teachers conducting role-plays. Finally, phase three involved interviews with two Suzuki experts, who were expert in so far as they had in excess of ten years experience of Talent Education philosophy and were recognised experts in the area.

5.4.1 Tutoring Rules Validation – Phase 1

As mentioned the elicitation of tutoring rules resulted in a set of 51 rules as is illustrated in Table 5.3. Phase 1 of the validation process was carried out by the author and involved refinement of the rules using a number of criteria:

1. Simplifying over complex rule structures.
2. Allowing for transition from phase to phase of the learning process using link tactics.
3. Including *Finish* criteria to avoid tutoring paths with no end state.

This process resulted in a refinement of the original set of rules resulting in a set of 42 tutoring rules; a description of the refinement process follows.

Table 5.3 Tutoring Rules (51 rules)

	Beginning				Review				New Material				Repetition			
	Angry	Fearful	Happy	Sad	Angry	Fearful	Happy	Sad	Angry	Fearful	Happy	Sad	Angry	Fearful	Happy	Sad
Expert Demonstration					2				4	3	1					
Mastery Learning			1				2		1	2	4	4	3	2	4	
Motivational Game	2			1	3			2				1	1	3	3	1
Positive Reinforcement	1	1	2	2	1	2	3	1	2	1	5	2			5	
Repetition						3				5	3				1	
Review		2			4	1	1			4						
Tutoring Variations					5				3		2	3	2	1	2	

In the beginning phase two refinements occurred. Based on feedback from experts during the phase validation study (reader is directed to section 5.3). It is known that after the beginning phase the child should progress to the review phase. Therefore, rule 1 was substituted with rule 2, where the rules are listed in Table 5.4. Subsequently, rule 3 became invalid. As *review* is a link tactic, rule 3 would never fire because rule 2 would involve changing the phase variable from *beginning* to *review*. Therefore, as rule 3 was

now redundant it was also removed. Rule 4 and 5 were included in an endeavour to avoid tutoring paths with no end state.

Table 5.4 Rule Refinements – Beginning Phase

Rule No.	Rule Definition
1	If (phase = beginning AND emotional state = happy THEN tutoring tactic = Mastery Learning)
2	If (phase = beginning AND emotional state = happy THEN tutoring tactic = Review)
3	If (phase = beginning AND emotional state = happy AND Mastery Learning = true THEN tutoring tactic = Positive Reinforcement)
4	If (phase = beginning AND emotional state = angry AND positive reinforcement = true and Motivational Game = true) THEN tutoring tactic = Finish)
5	If (emotional state = sad AND Motivational Game = true AND Positive Reinforcement = true THEN tutoring tactic = Finish)

Table 5.5 lists the refined rules for the review phase. Rule 1 and 2 were discarded, as they were redundant. The reason for this is if the tutoring process is at the review phase it means the review tactic has been suggested by P.A.C.T and the phase variable has been updated to review. Therefore, rule 1, 2 and 3 are not necessary. Rule 4 was discarded, as *mastery learning* is a link tactic to the *new material* phase rule 4 becomes redundant, as it would never fire. Rules 5-8 were discarded in a belief that the unnecessarily complicated the tutoring process. The reason being if a child remained angry at that stage of the tutoring process it was believed it might be best to end practice for now and return to practice when the child assumed a positive affective state. In addition, rule 9 was discarded for the same reason. Rule 10 and 11 were included to avoid tutoring paths with no end state.

Table 5.5 Rule Refinements – Review Phase

Rule No.	Rule Definition
1	If (phase = review AND emotional state = happy THEN tutoring tactic = Review)
2	If (phase = review AND emotional state = fearful THEN tutoring tactic = Review)
3	If (phase = review AND emotional state = angry AND Positive Reinforcement = true AND Expert Demonstration = true AND Motivational Game = true THEN tutoring tactic = Review)
4	If (phase = review AND emotional state = happy AND Mastery Learning = true THEN tutoring tactic = Positive Reinforcement)
5	If (phase = review AND emotional state = angry AND Positive Reinforcement = true THEN tutoring tactic = Expert Demonstration)
6	If (phase = review AND emotional state = angry AND Positive Reinforcement = true AND Expert Demonstration = true THEN tutoring tactic = Motivational Game)
7	If (phase = review AND emotional state = angry AND Positive Reinforcement = true AND Expert Demonstration = true AND Motivational Game = true THEN tutoring tactic = Review)
8	If (phase = review AND emotional state = angry AND Positive Reinforcement = true AND Expert Demonstration = true AND Motivational Game = true AND Review =true THEN tutoring tactic = Tutoring Variation)
9	If (phase = review AND emotional state = angry AND Positive Reinforcement = true AND Expert Demonstration = true AND Motivational Game = true AND Review = true THEN tutoring tactic =Tutoring Variation)
10	If (phase = review AND emotional state = angry AND Positive Reinforcement = true AND Expert Demonstration = true AND Motivational Game = true THEN tutoring tactic = Finish)
11	If (phase = review AND emotional state = sad AND Positive Reinforcement = true AND Motivational Game = true THEN tutoring tactic = Finish)

The refined rules at the new material phase are listed in Table 5.6. Rule 1 and 2 were discarded, as their inclusion would duplicate the tutoring process because, if P.A.C.T. enters the new material phase it means the *mastery learning* tactic has been suggested. Similarly, it would not be intelligent to loop back to the *review* phase and so rule 3 was discarded. Rules 4–8 were replaced by rule 9. The reason for this was, based on input

from Suzuki practitioners it was decided from the outset that if the child was happy they would move directly through the four phases of learning.

Table 5.6 Rule Refinements – New Material Phase

Rule No.	Rule Definition
1	If (phase = new material AND emotional state = sad AND Motivational Game = true AND Positive Reinforcement = true AND Tutoring Variation = true THEN tutoring tactic = Mastery Learning)
2	If (phase = new material AND emotional state = fearful AND Positive Reinforcement = true THEN tutoring tactic = Mastery Learning)
3	If (phase = new material AND emotional state = fearful AND Positive Reinforcement = true AND Mastery Learning = true AND Expert Demonstration = true THEN tutoring tactic = Review)
4	If (phase = new material AND emotional state = happy THEN tutoring tactic = Expert Demonstration)
5	If (phase = new material AND emotional state = happy AND Expert Demonstration = true THEN tutoring tactic = Tutoring Variation)
6	If (phase = new material AND emotional state = happy AND Expert Demonstration = true AND Tutoring Variation = true THEN tutoring tactic = Repetition)
7	If (phase = new material AND emotional state = happy AND Expert Demonstration = true AND Tutoring Variation = true AND Repetition = true THEN tutoring tactic = Mastery Learning)
8	If (phase = new material AND emotional state = happy AND Expert Demonstration = true AND Tutoring Variation = true AND Repetition = true AND Mastery Learning = true THEN tutoring tactic = Positive Reinforcement)
9	If (phase = new material AND emotional state = happy THEN tutoring tactic = Repetition)
10	If (phase = new material AND emotional state = sad AND Motivational Game = true AND Positive Reinforcement = true AND Tutoring Variation = true THEN tutoring tactic = Finish)
11	If (phase = new material AND emotional state = angry AND Positive Reinforcement = true AND Tutoring Variation = true AND Expert Demonstration = true THEN tutoring tactic = Finish)

Otherwise, appropriate tutoring tactics would be suggested in an endeavour to positively affect the child's affective state. Rule 10 and 11 were included to avoid tutoring paths with no end state.

The repetition phase proffered one set of rule refinements. As mentioned previously it was decided that a happy affective state would allow direct progress through the phases therefore rules 1–5 were replaced by rule 6. Rules 7-9 were added to avoid hanging tutoring paths. The rules are listed in Table 5.7.

Table 5.7 Rule Refinements – Repetition Phase

Rule No.	Rule Definition
1	If (phase = repetition AND emotional state = happy THEN tutoring tactic = Repetition)
2	If (phase = repetition AND emotional state = happy AND Repetition = true THEN tutoring tactic = Tutoring Variation)
3	If (phase = repetition AND emotional state = happy AND Repetition = true AND Tutoring Variation = true THEN tutoring tactic = Motivational Game)
4	If (phase = repetition AND emotional state = happy AND Repetition = true AND Tutoring Variation = true AND Motivational Game = true THEN tutoring tactic = Mastery Learning)
5	If (phase = repetition AND emotional state = happy AND Repetition = true AND Tutoring Variation = true AND Motivational Game = true AND Mastery Learning = true THEN tutoring tactic = Positive Reinforcement)
6	If (phase = repetition AND emotional state = happy THEN tutoring tactic = Finish)
7	If (phase = repetition AND emotional state = sad AND Motivational Game = true THEN tutoring tactic = Finish)
8	If (phase = repetition AND emotional state = angry AND Motivational Game = true AND Tutoring Variation = true AND Mastery Learning = true THEN tutoring tactic = Finish)
9	If (phase = repetition AND emotional state = fearful AND Tutoring Variation = true AND Mastery Learning = true AND Motivational Game = true THEN tutoring tactic = Finish)

Therefore, phase one of the tutoring rules validation process resulted in a refinement of the set of 51 rules by the author resulting in a set of 42 tutoring rules. These are listed in Table 5.8.

Table 5.8 Tutoring Rules (42 rules)

	Beginning				Review				New Material				Repetition			
	Angry	Fearful	Happy	Sad	Angry	Fearful	Happy	Sad	Angry	Fearful	Happy	Sad	Angry	Fearful	Happy	Sad
Expert Demonstration					2				3	2						
Mastery Learning							1						3	2		
Motivational Game	2			1	3			2				1	1	3		1
Positive Reinforcement	1	1		2	1	1		1	1	1		2				
Repetition						2				3	1					
Review		2	1													
Tutoring Variations									2			3	2	1		
Finish	3			3	4			3	4			4	4	4	1	2

5.4.2 Tutoring Rules Validation – Phase 2

In order to truly assess the validity of the tutoring rules, it was necessary to gain feedback from experts. As this set of tutoring rules is grounded in Talent Education philosophy, the expert group comprised Suzuki teachers. In an endeavour to collect rich feedback, it was decided that the validation study would involve Suzuki teachers role-playing home practice with P.A.C.T., where one teacher would assume the role of the parent and the other the role of the child. P.A.C.T. was modified for the purpose of the study in order to gain feedback on the appropriateness of specific domain independent tutoring rules.

5.4.2.1 Validation Tutoring Rules Phase 2 - Instrument Development

The parent and child dyads navigated through the system as per usual. However, when presented with each tutoring tactic, they were asked to provide feedback (1 – 4) on that tutoring tactic. This is illustrated in Figure 5.1, where it states “Grace was sad I suggested Motivational Game. Was this a good thing to try at this time?” Notice the use of the tutoring tactic term (Motivational Game) as opposed to domain specific game (for

example the Colours game). The reason for this was that the purpose of the study was to validate the tutoring rules not the content rules. In Figure 5.3, we can see how this text provides a mechanism for collecting feedback on specific tutoring rules. Figure 5.3 illustrates how the feedback captured corresponds to a specific tutoring rule, where the emotional state is sad, let us presume that we are at the beginning phase and the tutoring tactic is motivational game. As P.A.C.T. maintains the value for the phase, the parent is not required to know it. Input validation would ensure that feedback, in terms of a rating from one to four, was received before progressing.

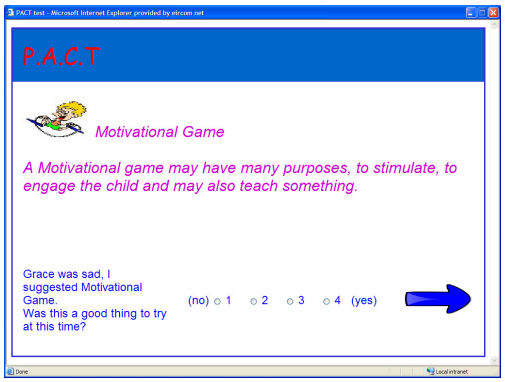

Figure 5.1 Rule Validation

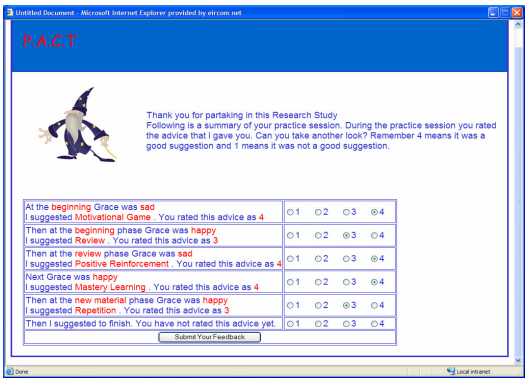

Figure 5.2 Rule Validation Reflection

In addition, to providing a mechanism for collecting feedback throughout the tutoring process, it was also decided to provide an opportunity for reflection on this feedback at the end of the tutoring process before final submission. The primary reason for this was that the Suzuki teacher who assumed the role of the child might not have been involved in the feedback process throughout the practice session. Figure 5.2 illustrates this end of session reflection, where a summary of the feedback given throughout the practice is displayed.

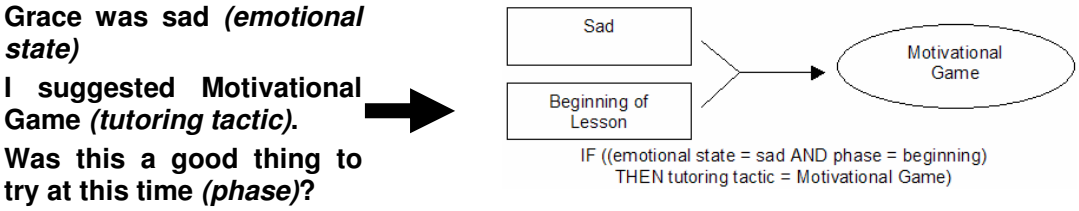

Figure 5.3 Capturing Feedback on Specific Tutoring Rules

5.4.2.2 Validation Tutoring Rules Phase 2 - The Study

The purpose of the study was to validate the set of tutoring rules used within P.A.C.T.. Twenty Suzuki teachers volunteered to take part in the validation study. A face-to-face meeting took place where participants were given instructions, resources and a very short demonstration of the system. Suzuki teachers were asked to divide into pairs; within the pair, one would assume the role of the parent while the other assumed the role of the child. For the remainder of this section we will refer to the Suzuki teachers by their role – parent or child.

To help with the role-play each child received a role-play card. This contained their current piece, a description of their emotional ground on entering the home practice and an emotional map, which loosely outlined their emotions throughout the practice sessions. The children were informed that this role-play card was an aid without need to stick rigidly to it. Another reason for giving the emotional map was to encourage participants to take varying paths through the system thus increasing the possibility of receiving feedback on a greater number of rules, as depending on the input received by PA.C.T.'s Adaptive Engine different rules are fired. The role-play card is illustrated in Figure 5.4.

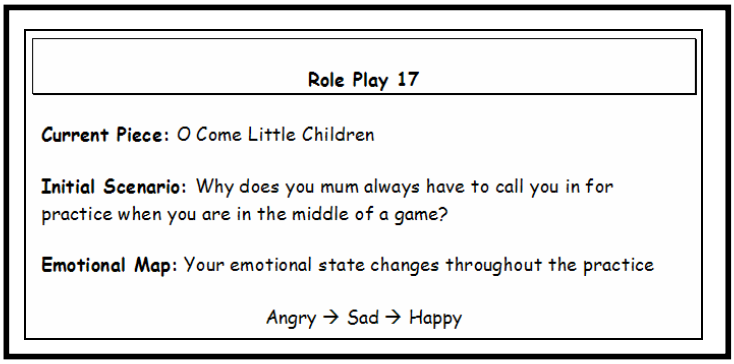

Figure 5.4 Role-Play Card

The parents were informed that the purpose was not to investigate whether they could assess the emotional child but to provide feedback on P.A.C.T.'s tutoring suggestions in response to the given emotional state of the child. To this end, they could see the emotional map given to the child. In addition, they were given an emotional chart, which contained the basic emotion and a list of synonyms. It was necessary to categorise the child's affective state in terms of one of the four basic emotions. In addition, it was stressed that parents were not providing feedback on the content rule (that is the particular

motivational game that was presented) but on the tutoring rule itself (i.e. was a motivational game a good thing to try at this time?) as the question states in Figure 5.1.

Each parent and child dyad had a computer. On average, most dyads took approximately fifteen minutes to complete a role-play. Most dyads carried out two role-plays, some more, some less. At the end of each role-play, once the Practice Session Reflection screen (Figure 5.2) was reached both the parent and child could drop their roles and reflect on P.A.C.T.'s advice as Suzuki teachers. On reflection, the teachers could modify their feedback if desired. Feedback submitted during the practice session and feedback from the reflections was logged.

5.4.2.3 Validation Tutoring Rules Phase 2 - The Results

The log files were collated and analysed by the author. Altogether, the log files comprised 134 entries. Feedback was received on 74% of the forty-three domain independent rules. This was a high proportion of rules given the fact that due to the adaptive nature of P.A.C.T. and the nature of the validation study it was not possible in advance to identify the range of rules, which would be fired.

Rules where the feedback had preponderance towards the higher end of the scale (1-4) were deemed valid. Rules, where the feedback had preponderance towards the lower end, were deemed invalid. For those rules where the feedback did not have preponderance in either direction the mean was calculated. Rules with a mean greater than 2.5 were deemed valid, less than 2.5 were deemed invalid. Preliminary results indicate that of the thirty-two rules on which feedback was received, 81% were deemed valid while 19% were deemed invalid. This is illustrated in Table 5.9, where validated rules are indicated by a V. Rules deemed invalid are indicated using an I and rules, which did not receive feedback are indicated using an X.

Table 5.9 Validation Study Phase 2 – Results

	Beginning				Review				New Material				Repetition			
	Angry	Fearful	Happy	Sad	Angry	Fearful	Happy	Sad	Angry	Fearful	Happy	Sad	Angry	Fearful	Happy	Sad
Expert Demonstration					X				V	V						
Mastery Learning							V						X	I		
Motivational Game	X			V	X			V				V	I	V		V
Positive Reinforcement	V	V		V	I	V		V	V	V		V				
Repetition						I				V	V					
Review		I	V													
Tutoring Variations									X			V	V	I		
Finish	V			V	X			X	X			X	X	V	V	X

As can be seen from Table 5.9 a number of the rules where the suggestion is to finish were not validated. Dyads were only asked for feedback on this on the reflection page. However, many failed to select an option. This is as a result of a design flaw, which could have easily been overcome with input validation

At the beginning phase, only one rule was deemed invalid, this rule was only encountered by two dyads, where one dyad gave it a rating of 1, while the other dyad gave it a rating of 3. There were only two rules in the review phase, which were deemed inappropriate; both had only one associated rating. All encountered rules in the new material phase were deemed valid. In the repetition phase, there were three rules deemed invalid. Of these three rules, the rules suggesting mastery learning and tutoring variation were only rated by one dyad. Interestingly, this was the same dyad in each case. Finally, the rule suggesting using a motivational game was encountered by five dyads. Interestingly two dyads gave it a rating of 4 while three dyads gave it a rating of 1. Informal feedback from participants indicates that unfortunately, in this scenario participants may have provided feedback on the content rule (i.e. they did not like the specific game) as opposed to the tutoring rule (the idea of playing a game). In an endeavour to validate those rules, which were not encountered and seek further clarification around those which were deemed invalid a third phase of validation was necessary.

5.4.3 Validation Tutoring Rules – Phase 3

Phase three of the validation process involved validating the 40% of rules, which were not validated in phase 2. Of this set, 65% had not been evaluated (due to the nature of the study as previously outlined) while the remaining 35% were evaluated and deemed invalid. Therefore, phase three of the validation process comprised gaining feedback on those rules, which had not been evaluated, and to carry out analysis on the rules, which were deemed invalid. This task was carried out by two experts.

The experts were given a questionnaire, which listed the set of 17 rules (those marked with an I or X in Table 5.9). They were asked to specify whether each rule was valid or invalid. The experts worked individually and did not communicate around the questionnaire. Interestingly, both experts answered the questionnaire identically. 15 rules were deemed valid, while 2 rules were deemed invalid. The rules, which were deemed invalid were of the same hierarchical group (at review phase and the child is angry). The reason for deeming these rules invalid was reasonable in so far as the experts believed

that it would be a good idea to positively reinforce the child in this situation but if the child remained angry, it would be best to finish practice for now. Therefore, the final validated set of tutoring rules comprises.40 rules as illustrated in Table 5.10.

Table 5.10 Tutoring Rules (40 rules)

	Beginning				Review				New Material				Repetition			
	Angry	Fearful	Happy	Sad	Angry	Fearful	Happy	Sad	Angry	Fearful	Happy	Sad	Angry	Fearful	Happy	Sad
Expert Demonstration									3	2						
Mastery Learning							1						3	2		
Motivational Game	2			1				2				1	1	3		1
Positive Reinforcement	1	1		2	1	1		1	1	1		2				
Repetition						2				3	1					
Review		2	1													
Tutoring Variations									2			3	2	1		
Finish	3			3	2			3	4			4	4	4	1	2

5.5 Summary

This chapter has described two studies conducted to validate the tutoring rules within P.A.C.T.'s adaptive engine. The phase validation study confirmed that the suggested phases were appropriate in representing the Suzuki process. The second validation study comprised three phases. Phase 1, carried out by the author involved rule refinement. Phase 2 and 3 comprised rule validation, which also resulted in refinement of particular rules. The studies indicate that P.A.C.T. has the ability to provide personalised learning paths in line with Talent Education philosophy. Together, these studies provide empirical grounding for experimental studies that evaluate the effectiveness of P.A.C.T. during the home tutoring process.

6 Experimental Design

6.1 Introduction

P.A.C.T. informed by Talent Education philosophy contains a model of home tutoring best practice. Its adaptive engine, through the set of pedagogical rules, provides the potential to reason intelligently on the level of support required by both users' parent and child. However, the question remains, what is an appropriate basis for adapting to the needs of the tutor and tutee?

In order to address this question a number of empirical studies were conducted to investigate:

- What is the effect of using P.A.C.T. on parents' (1) self-efficacy (2) knowledge and (3) perception of their role as home tutor?
- What is the effect of adapting to the affective needs of the child throughout the home tutoring process?

P.A.C.T. provides personalised support for the parent by altering the level of support based on their self-efficacy. Low levels of self-efficacy receive high levels of support. High levels of self-efficacy receive low levels of support. In addition, P.A.C.T. provides personalised support for the child by adapting to the child's affective state.

This chapter presents the experimental design, experimental procedure, data collection and participants in the research studies conducted.

6.2 Experimental Design

With any adaptive system, there is always a need for experimentation in order to identify the effect of providing adaptive support. Where an adaptive engine provides two levels of adaptivity, there is a need to identify the effect of both levels. Therefore, there was a need for an experimental design comprising two phases. Phase 1 was concerned with identifying the effect of P.A.C.T. on parents' self-efficacy, knowledge and their perception of their role as home tutor. Phase 2 was concerned with identifying the effect on the home tutoring environment when adapting to the affective needs of the child. It was also necessary to identify the role of P.A.C.T throughout the home tutoring process.

6.2.1 Experimental Design – Phase 1

As previously stated, phase 1 of the experimental design comprised investigating the effect of P.A.C.T. on parents' self-efficacy, knowledge and their perception of their role as home tutor. For this purpose, three dependent variables were defined; self-efficacy, knowledge-level, and role as home tutor.

Self-efficacy can be defined as parents' sense of efficacy in their ability to use particular tutoring tactic when appropriate. Self-efficacy is measured as a value from one to seven. As self-efficacy is best measured as a task-specific value, the dependent variable self-efficacy comprises seven values, a self-efficacy value for each of the seven tutoring tactic. Therefore, self-efficacy is measured as a quantitative value.

Knowledge-level can be defined as parents' knowledge of each of the seven tutoring tactics namely expert demonstration, mastery learning, motivational game, positive reinforcement, repetition, review and tutoring variation. The dependent variable knowledge-level comprises two values what and when. It is necessary for parents' to understand what each tutoring tactic comprises and when it should be used. Knowledge-level is measured in terms of quantitative data as a value from one to seven.

Role as home tutor can be defined as parents' perception of their role as home tutor and P.A.C.T.'s effect on this. This dependent variable is measured in terms of qualitative data.

Finally, the independent variable mode comprises two values full support and adaptive support:

- Full Support – parents receive full support regardless of their self-efficacy value for that tutoring tactic.
- Adaptive Support – parents receive full support on their first occurrence with each of the tutoring tactics subsequently the level of support was determined by their self-efficacy value for that tactic. High self-efficacy values results in less support, lower self-efficacy values results in greater support.

Experiments were designed in such a manner to investigate the effect of altering this independent variable on the dependent variable parental self-efficacy.

6.2.2 Experimental Design – Phase 2

Phase 2 of the experimental design was concerned with identifying the effect on the home tutoring environment when adapting to the affective needs of the child. For this

purpose, two dependent variables were defined affective experience and home tutoring environment.

The affective experience can be defined as the affective states experienced by the child throughout the home tutoring process. This dependent variable comprises a log of these affective states, which can be measured in terms of happy, sad, angry or fearful.

In terms of the dependent variable home tutoring environment it can be defined as the effect of P.A.C.T. on the parent-child dynamic. In particular, this will involve identifying the strategies used for elicitation of effect and the effect on the home tutoring process of adapting to child's affective needs.

Finally, in terms of evaluating the role of P.A.C.T. throughout the home tutoring process this can be ascertained through qualitative data.

6.3 Experimental Procedure

For each dyad, the experiment comprises four stages as illustrated in Figure 6.1. The process begins with an induction, which explains the purpose of the study and the terminology used within P.A.C.T.. It also provides a short demonstration of P.A.C.T.. For some the induction is face-to-face while for others it is delivered through a movie distributed via C.D. (the reader is directed to the Appendix). The content of both are identical.

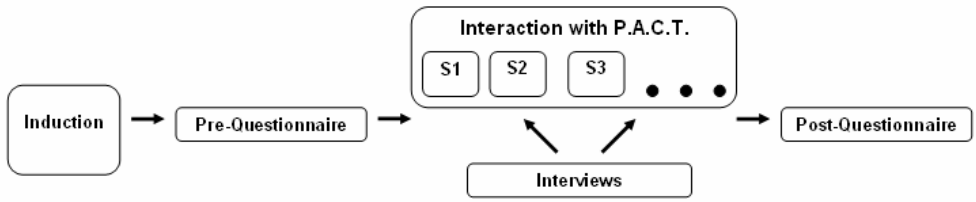

Figure 6.1 Experimental Procedure

The second stage of the process involves the parent completing a pre-questionnaire. The completion of the questionnaire can be carried out via a computer or on paper depending on the technical ability of the parent. The pre-questionnaire contains closed questions to measure parents' knowledge and self-efficacy and open questions to measure parents' perceptions of the home tutoring process. An excerpt of a questionnaire is illustrated in Figure 6.2.

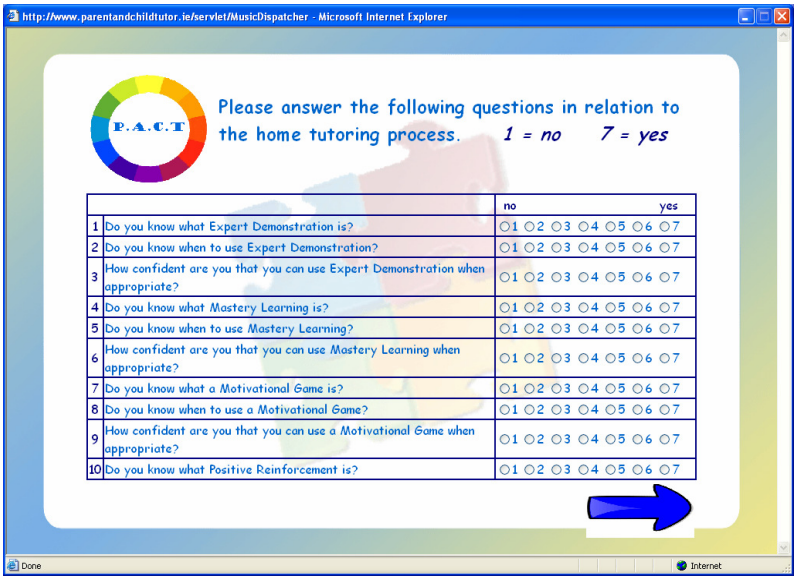

Figure 6.2 Excerpt form Pre-Questionnaire

Stage three involves participants using P.A.C.T. during the home tutoring context. For some, this takes place at home, for others it involves using P.A.C.T. in the school's computer lab at specific times. All dyads were asked to commit to using P.A.C.T. a minimum of three times. Those using P.A.C.T. at home could use it as often, and, whenever they choose. Those using P.A.C.T. in school could use it twice a week for four weeks at specific times agreed in advance of the study. Parents were interviewed during the period when using P.A.C.T.. The interview process allowed for the collection of qualitative data.

Finally, stage four of the process involved parents completing a post-questionnaire. Again, parents could complete a paper-based or computer-based version of the questionnaire depending on their technical ability. The questions in both modes were identical. Post-questionnaire questions were almost identical to those asked in the pre-questionnaire.

Participants were randomly assigned to one of two groups defined by the type of support provided by P.A.C.T.. All dyads received adaptive support in terms of P.A.C.T. adapting to the affective needs of the child. Parents assigned to Group A (full support) received non-personalised support. That is parents received full support regardless of their self-efficacy. Parents assigned to Group B (adaptive support) received adaptive support in terms of their self-efficacy. In addition, two studies were conducted, where

Study 1 involved the domain of Suzuki violin and Study 2 involved the domain of Mathematics.

6.4 Data Collection

Upon interaction with P.A.C.T., data is collected on both users (parent and child). This section describes how this data is analysed in order to identify indicative traits of both parent and child. More specifically, it describes the elicitation of parental self-efficacy and the child's affective state. Other data collected includes navigation path, time spent at each stage of the tutoring process and tutoring tactics encountered.

6.4.1 Self-Efficacy

Each time P.A.C.T. suggests a tutoring tactic the parent must specify their self-efficacy in using that tactic as illustrated in Figure 6.3. For those parents in the adaptive group, parental self-efficacy is used to determine the level of support they receive throughout the tutoring process. P.A.C.T. maintains four categories of self-efficacy and thus four levels of support. The levels of support are level 1-2 (self-efficacy values of 1 or 2), level 3 -4 (values of 3 or 4), level 5-6 (values of 5 or 6) and level 7 (a value of 7). Initially, the level of support is set to level 1-2, which ensures the parents receive full support on their first encounter with each of the tutoring tactics.

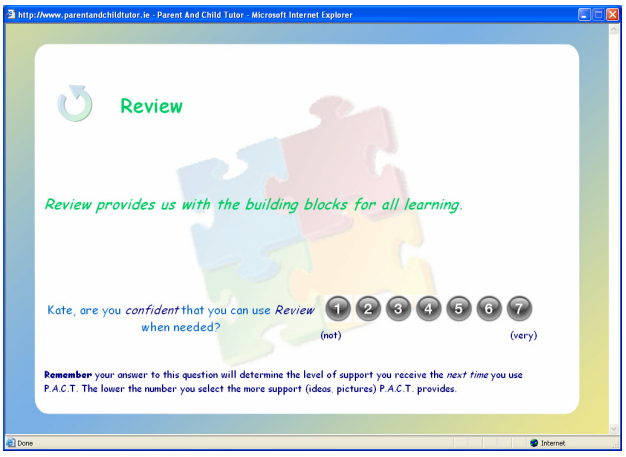

Figure 6.3 Eliciting Self-Efficacy

6.4.2 Affective State

The child's affective state is elicited prior to each learning activity using the instrument illustrated in Figure 6.4. The instrument contains four emoticons each representing one of the four basic emotions, happy sad, angry and fearful. The emoticon which best represents the child's current affective state is selected. Once the emoticon is selected, the associated affective state is derived and logged.

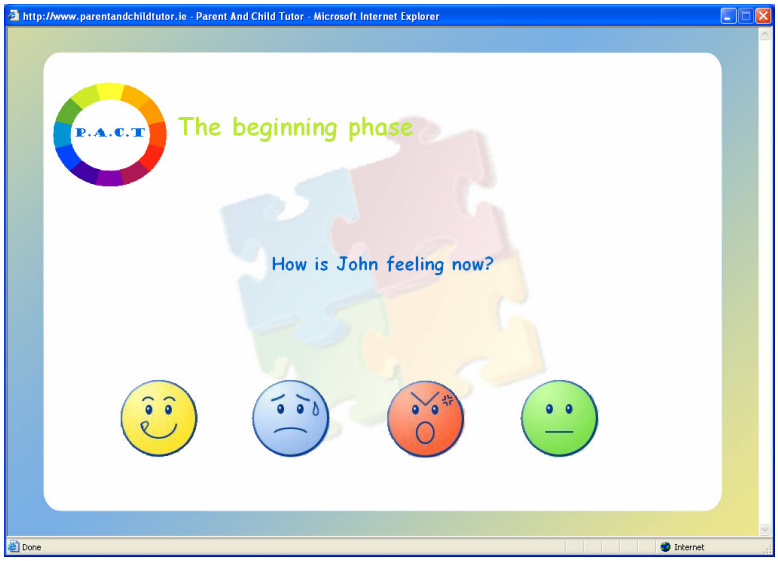

Figure 6.4 Eliciting Emotion

Additionally, P.A.C.T. logs data on parents' navigation through the system and time spent on each learning activity. It also maintains a log of the tutoring tactics suggested by P.A.C.T..

6.5 Participants

Two studies were conducted with P.A.C.T. in order to identify the best way to adapt the learning environment for both parent and child. Study 1 used a version of P.A.C.T. developed for Suzuki violin. Study 2 used a version of P.A.C.T. developed for Junior Infants (4 -5 years of age) mathematics.

In Study 1, thirteen parent and child dyads (12 female parents and 1 male parent, children comprised 7 girls and 6 boys) participated. The children's ages ranged from 4 to 8 with an average age of 5. All participants volunteered to take part in the study, no

reward incentives were provided. Participants were currently taking Suzuki violin classes and were students of a variety of teachers. All children were beginning Suzuki students. Participating parents had varying degrees of previous experience. The study itself was conducted in parents' homes by using P.A.C.T. through the medium of the Internet.

Thirty-six parent and child dyads participated in Study 2. The children involved in this study attended one of three schools, where all three schools were designated disadvantaged. This is determined by the numbers of students in the school from families with socioeconomic- characteristics that have been found to be associated with low levels of educational achievement (e.g., unemployment, medical cardholders etc.) (Archer 2005). Participants from the first two schools used P.A.C.T. during school time in the school's computer laboratory. Participants from the third school used P.A.C.T. at home through the medium of the Internet. All participants volunteered to take part in the study, no reward incentives were provided.

6.6 Summary

Two studies were conducted using P.A.C.T. to investigate its effect on the home tutoring process. Study 1 was conducted in the domain of Suzuki violin. Study 2 was conducted in the domain of mathematics. Participants used P.A.C.T. in one of two modes either (a) at home or (b) in the computer laboratory at school. For each participant P.A.C.T. logged data on parental self-efficacy, the child's affective states, time spent on each learning activity, navigation path through the system and tutoring tactics encountered.

These studies allowed for the investigation of the effect of P.A.C.T. on parents' self-efficacy, knowledge and perception of their role as home tutor. In addition, the studies allow for an exploration into the effect of adapting to the affective needs of the child throughout the home-tutoring process on the parent-child dynamic. The results of these studies will be discussed in Chapter 7.

7 Results

7.1 Introduction

This chapter describes the results of two empirical studies, which were conducted using P.A.C.T. in order to investigate if self-efficacy and affect are an appropriate basis for adapting to the needs of the tutor and tutee.

In order to answer this question quantitative and qualitative data was collected to investigate:

- What is the effect of using P.A.C.T. on parents' (1) self-efficacy (2) knowledge and (3) perception of their role as home tutor?
- What is the effect of adapting to the affective needs of the child throughout the home tutoring process?

In addition, data was collected to determine the role of P.A.C.T. during the home tutoring process.

The goal of the qualitative and quantitative analysis was to evaluate the hypotheses that providing support for parents throughout the home tutoring would have a positive impact on their (1) self-efficacy (2) knowledge and (3) their perception of their role as home tutor. In parallel, it was necessary to determine if the provision of affective support for the child would promote a positive learning environment.

Table 7.1 provides a description of the type of data collected in order to address the aforementioned research question, the mechanism used to collect it and analyse it and the sample size involved. 13 participants were involved in Study 1, which resulted in approximately 19 hours of interaction logged data and approximately six hours of recorded interview data. The 19 hours of interaction-logged data consisted of approximately 2000 interactions. 36 participants were involved in Study 2 that resulted in excess of 16 hours interaction-logged data and approximately three hours of interview data. The 16 hours of interaction-logged data comprised in excess of 2800 interactions. Based on usage statistics a more detailed analysis was performed on the data of 11 of the 13 participants in Study 1 and 20 of the 36 participants in Study 2. A threshold representing the minimum number of uses of P.A.C.T. necessary to identify its effect was defined and dyads falling below this threshold were discarded from the data set. This resulted in the analysis of 18 hours of interaction-logged data and the 6 hours of recorded

interviews for Study 1 and 12 hours of interaction-logged data and approximately three hours of interviews for Study 2.

Table 7.1 Data Collection and Analysis Techniques

Analysis	Data Collection Mechanism	Type of Data	Analysis	Sample Size	
				Study 1	Study 2
Self-Efficacy (Pre & Post Test Scores)	Questionnaire	Quantitative	Statistical (paired sample t-test)	11	20
Efficacy Path	Interaction Logs	Quantitative	Pattern analysis Group A vs. Group B	Group A- 6 Group B- 5	Group A- 9 Group B- 11
Knowledge (Pre & Post Test Scores)	Questionnaire	Quantitative	Statistical (paired sample t-test)	11	20
Role as Home Tutor	Questionnaire & Interviews	Qualitative	Coding Strategies	11	20
Affective Experience	Interaction Logs	Quantitative	Statistical (percentage)	11	20
Strategies for Eliciting Affect	Questionnaire & Interviews	Qualitative	Coding Strategies	11	20
Effect of providing Affective Support	Questionnaire & Interviews	Qualitative	Coding Strategies	11	20
Role of Technology	Questionnaire & Interviews	Qualitative	Coding Strategies	11	20

The reader is reminded that group A (full support) and group B (adaptive support) as referred to in Table 7.1, refer to those who received full support and adaptive support. Where:

- Full Support - parents receive full support regardless of their self-efficacy value for that tutoring tactic.

- Adaptive Support – parents receive full support on their first occurrence with each of the tutoring tactics subsequently the level of support was determined by their self-efficacy value for that tactic.

The results from the analysis confirmed the hypotheses that providing support for parents throughout the home tutoring has a positive impact on their (1) self-efficacy (2) knowledge and (3) their perception of their role as home tutor and that provision of affective support for the child promotes a positive learning environment. Some additional interesting results were also revealed. More specifically, results indicate the possible dichotomy between parental self-efficacy and desired level of support, suggesting the need for the development of subtle self-efficacy collection instruments. In addition, results suggest the need for intelligent design when adapting to the affective needs of the child due to the possible risk of gaming. The following sections will present and discuss these results. Section 7.2 presents the results of a study carried out in the domain of Suzuki violin. Section 7.3 describes the results of an empirical study, which supports these findings in the domain of mathematics. Finally, section 7.4 discusses the two studies together and concludes with recommendations on how adaptive educational systems can support the home tutoring process.

7.2 Study 1: Evaluating the effect of an AES to support the home tutoring process in the domain of music

Study 1 comprised 13 parent and child dyads (12 female parents and 1 male parent, children comprised 7 girls and 6 boys). The children's ages ranged from 4 to 8 with an average age of 5. All participants volunteered to take part in the study, no reward incentives were provided. Participants were currently engaging in Suzuki Violin classes with a variety of teachers. All children were beginning Suzuki students; however, parents had varying degrees of previous experience. The study was conducted in participants' homes over the Internet. Participants were randomly assigned to one of the two versions, full support and adaptive support. 7 (all female parents, children comprised 3 girls and 4 boys) participants were assigned to the full support version, while 6 (1 male 5 female parents, children comprised 4 girls and 2 boys) participants were assigned to the adaptive support version. The resultant data set comprised approximately 18 hours of interaction-logged data and approximately six hours of recorded interview data. Based on usage statistics a more detailed analysis was performed on the data of 11 out of the 13 participating data. The selection criterion was based on a requirement that participants

have used P.A.C.T. for a minimum of three sessions, as a level of interaction with P.A.C.T. is necessary in order to ascertain with any degree of certainty its effect.

7.2.1 Investigating the effect of P.A.C.T. on Parents

This section will provide analysis of the data in an endeavour to identify if providing support throughout the home tutoring process through the use of an adaptive educational system may have a positive effect on parents' (1) self-efficacy (2) knowledge and (3) their perception of their role as home tutor. Firstly, an analysis of the results pertaining to self-efficacy will be presented. Subsequently the effect of P.A.C.T. on parents' knowledge will be investigated and finally the effect of P.A.C.T. on parents' perception of their role as home tutor will be explored.

7.2.1.1 Self-Efficacy

The results were analysed in order to identify the effect on parents' self-efficacy of providing support throughout the home tutoring process. As self-efficacy is best measured when task specific it was expected that there would be an increase in self-efficacy across those tutoring tactics encountered by the parent throughout the study. It is important to note that due to the adaptive nature of P.A.C.T. and the dynamic nature of the home tutoring process a parent may not encounter all seven tutoring tactics and will encounter some more frequently than others.

Parents' self-efficacy was analysed at two levels:

- Pre and Post tests – which were conducted prior to commencing the study and after their last interaction with P.A.C.T.
- Self-efficacy path – self-efficacy values, which were collected during participants interactions with P.A.C.T.

An excerpt from the instrument used to collect pre and post test scores is illustrated in Figure 7.1. The instrument comprised seven question where parents were asked to rate their confidence in using each of the seven tutoring tactic where appropriate. Parents were asked to rate their confidence using a likert scale comprising seven values, 1 being not confident and 7 being very confident. Analysis of the pre and post test scores allows for an understanding of how P.A.C.T. may influence parents' self-efficacy in the area of home tutoring. The self-efficacy path, which comprises a log of parents' self-efficacy scores for each tutoring tactic throughout the tutoring process, provides more precise insights into parents' self-efficacy. All self-efficacy scores were logged directly after the

parent completed each activity. The instrument used for collecting the self-efficacy path values is illustrated in Figure 7.2. This, similar to the instrument used during the pre and post test involved parents selecting the self-efficacy value that best represents their confidence in using a particular tutoring tactic (the tutoring tactic, which P.A.C.T. has just suggested). In order to navigate to the next screen parents must select one of the buttons 1-7, 1 being not confident, 7 being very confident.

How confident are you that you can use Expert Demonstration when appropriate?	(not) 1 2 3 4 5 6 7 (very)

How confident are you that you can use Mastery Learning when appropriate?	(not) 1 2 3 4 5 6 7 (very)

Figure 7.1 Pre-Questionnaire Excerpt – Self-Efficacy

Figure 7.2 Self-Efficacy Data Collection Instrument

7.2.1.1.1 Self-Efficacy Pre and Post Test Scores

An increase in mean values across all seven tutoring tactics can be observed from pre to post test scores. This is illustrated in Table 7.2. A paired sample t-test was conducted, which showed a statistically significant increase at the $p<0.05$ level across mastery learning ($p=.02$), motivational game ($p=.005$) and repetition ($p=.02$). Additionally, positive reinforcement ($p=.07$) is approaching statistical significance.

Table 7.2 Pre and Post Test Mean Values (Self-Efficacy)

Tutoring Tactic	Pre-Test	Post-Test	P-value
Expert Demonstration	M 3.81 SD 2.13	M 5.27 SD 1.84	
Mastery Learning	M 3.54 SD 2.20	M 5.45 SD 1.12	P 0.02
Motivational Game	M 4.27 SD 1.90	M 6.45 SD 1.21	P 0.005
Positive Reinforcement	M 5.63 SD 1.85	M 6.72 SD .90	P 0.07
Repetition	M 5.18 SD 1.83	M 6.54 SD .82	P 0.02
Review	M 5.18 SD 2.13	M 6.36 SD .33	
Tutoring Variation	M 3.45 SD 2.38	M 4.63 SD 2.20	

Expert demonstration, review and tutoring variation showed no statistical significant increase between pre and post tests scores. The lack of a significant increase in parents' self-efficacy across expert demonstration and tutoring variation is not altogether surprising considering the limited number of times these tutoring tactics were encountered. Figure 7.3 demonstrates the frequency with which P.A.C.T. suggested each of the tutoring tactics. Of the 506 tutoring tactic suggestions P.A.C.T. made .2% of these suggestions involved suggesting expert demonstration, while 2% of the suggestions involved suggesting tutoring variation. This indicates that parents gained little experience in using these tactics, which may explain the lack of a statistically significant increase in their self-efficacy. The review tactic was suggested 21% of the time throughout the course of the study. This suggests that parents had the opportunity to gain significant experience in using the review tactic. Albeit that there was an increase in parents' self-efficacy between pre and post test scores for review this increase was not statistically significant. Perhaps the reason for this may be that on using P.A.C.T. parents gained a deeper understanding of the intricacies of the review tactic and therefore remained somewhat cautious in using it.

Additionally, the decrease of variance between users at post-test is of interest as it indicates an increase in uniformity across results. Post test scores indicate an increase in mean values. Therefore, this suggests that there may be a more dramatic increase in post-test self-efficacy scores for participants with lower pre-test scores than for participants with higher pre-test scores.

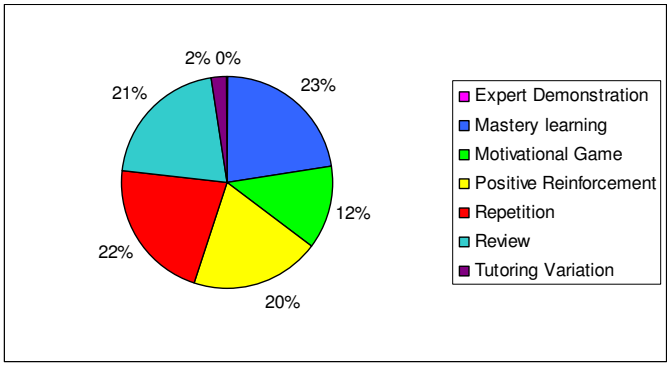

Figure 7.3 Tutoring Tactic Occurrences

In summary, P.A.C.T. had a positive effect on parents' self-efficacy values as measured from pre and post test scores. For some tutoring tactics, namely mastery learning, repetition, positive reinforcement and motivational game this increase was statistically significant.

7.2.1.1.2 Self -Efficacy Paths

Since each parent submits a self-efficacy value after using each tutoring tactic it is possible to determine a self-efficacy path (or dynamic self-efficacy measure) for each parent across each tactic. This may be of benefit in understanding the effect on self-efficacy when supporting the home tutoring process through the use of an adaptive educational system. As previously, outlined participants were randomly assigned to one of two groups. The first group received full support this means regardless of the self-efficacy value entered they received full support. The second group received adaptive support, where the level of support they received was determined by their self-efficacy value for that tactic. Due to the adaptive nature of P.A.C.T. and the dynamic nature of the learning environment each of the seven tutoring tactics were encountered with varying frequency (reader is directed to Figure 7.3). As a result of this, it was decided to perform a deep analysis of those tutoring tactics, which were most frequently encountered. These comprised mastery learning (23%), repetition (22%) and review (21%). Due to the nature of the data logged by the system, it is possible to plot individual self-efficacy paths. However, some interesting observations arise when self-efficacy paths are averaged across all participants. For the purpose of this study, the self-efficacy paths of participants receiving full support will first be analysed and subsequently the self-efficacy paths of

those who received adaptive support will be analysed. This will provide insights into the effect of providing full versus adaptive support on parents' self-efficacy.

Figure 7.4 illustrates the self-efficacy path for the review tutoring tactic for participants who were provided with full-support when using P.A.C.T. The x-axis corresponds to the number of interactions with that tutoring tactic. The y-axis corresponds to parental self-efficacy and is measured using a value from 1 to 7. Each self-efficacy value illustrated in Figure 7.4 is calculated based on the average self-efficacy value of all participants who received full support for that interaction, where all values are rounded to the nearest whole number. More specifically, the first value illustrated on the graph corresponds to the average submitted self-efficacy value of parents' first interaction with that tutoring tactic. The second value corresponds to the average submitted self-efficacy value of parents' second interaction with the tactic and so on. As P.A.C.T. suggests tutoring tactics based on the affective needs of the child each parent may have interacted with each tutoring tactic a varying number of times. In order to overcome bias a threshold was identified whereby averages were only included that comprised the self-efficacy values of a minimum of three participants.

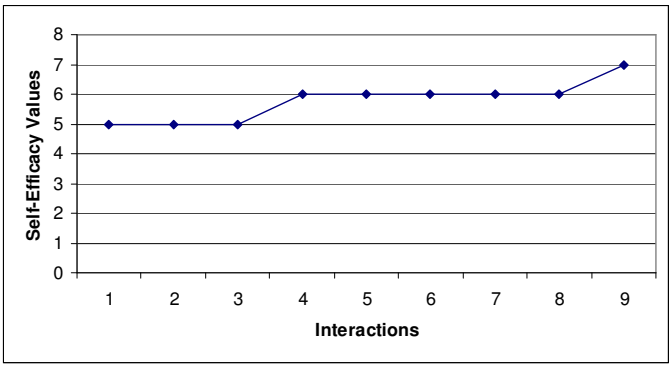

Figure 7.4 Mastery Learning Self-Efficacy Values – Full Support

Table 7.3 illustrates the percentage of the population (number of participants) included in calculating each of the averages in Figure 7.4. As can be seen from Table 7.3 all values listed in Figure 7.4 are calculated based on the submitted self-efficacy values of more than 50% of participants who received full support.

Table 7.3 Calculating Self-Efficacy Values – Mastery Learning Full Support

Interaction	Self-Efficacy Value	% Population Included
1	5	100
2	5	100
3	5	83
4	6	67
5	6	67
6	6	67
7	6	67
8	6	67
9	7	50

Figure 7.4 illustrates that on average the self-efficacy values for mastery learning of participants receiving full support increased from 5 on the first interaction to 7 on the ninth interaction. This is a steady increase, which suggests that P.A.C.T. had a positive effect on parental self-efficacy.

Figure 7.5 illustrates the self-efficacy of participants receiving full support path for the repetition tutoring tactic. It shows no increase in self-efficacy from the first interaction with the tactic to the last interaction. All values lie in the range 5-6. This suggests that in this instance P.A.C.T. had no effect on the parents' self-efficacy.

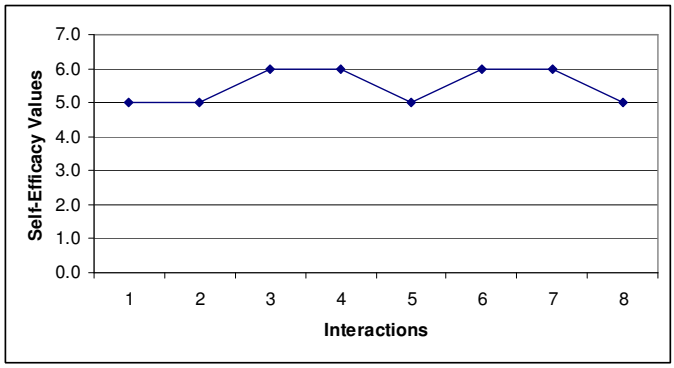

Figure 7.5 Repetition Self-Efficacy Values – Full Support

The percentage of the population included in calculating the averages in Figure 7.5 is listed in Table 7.4. It can be observed that all values listed in Figure 7.5 are based on data of over 60% of participants. This suggests that the self-efficacy path illustrated in Figure 7.5 is representative of the population.

Table 7.4 Calculating Self-Efficacy Values – Repetition Full Support

Interaction	Self-Efficacy Value	% Population Included
1	5	100
2	5	100
3	6	67
4	6	67
5	5	67
6	6	67
7	6	67
8	5	67

The self-efficacy path for the review tutoring tactic for those receiving full support is illustrated in Figure 7.6. All values except for one lie in the self-efficacy range of 5-6. The self-efficacy path peaks on the 7th interaction with a self-efficacy value of 7. It can be observed from Table 7.5 that this value was calculated using data from 67% of participants. It is difficult to determine the reason for this sudden peak. However, qualitative data collected during interviews may provide further insight into these results.

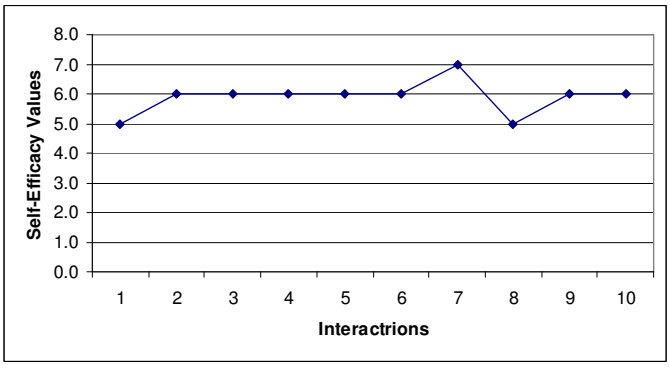

Figure 7.6 Review Self-Efficacy Values – Full Support

Table 7.5 Calculating Self-Efficacy Values – Review Full Support

Interaction	Self-Efficacy Value	% Population Included
1	5	100
2	6	100
3	6	100
4	6	83
5	6	83
6	6	67
7	7	67
8	5	67
9	6	50
10	6	50

Table 7.6 provides a sample of the type of data pertaining to self-efficacy, which was collected during interviews with participants. Parents were asked how they felt about being asked to enter a self-efficacy value after using each of the tutoring tactics. Results are reported using pseudonyms in an endeavour to protect participants' identity. Maebh and Sarah's response is representative of the type of responses received. They have indicated that the submitted self-efficacy value maybe as a result of a suggestion by their child as opposed to a reflection of how confident they were feeling at that time. Maebh describes how her daughter wanted her to enter the highest self-efficacy value possible (7) as her daughter believes that it is important to enter the "best" number. This suggests an implication that the self-efficacy scale is graded, where seven is best. Sarah reports that she does not see any personal benefit in submitting her self-efficacy value and therefore has developed somewhat of an ad hoc approach to it. The most important thing for Sarah is keeping her son happy, if this entails him choosing the value she is happy for that to happen. This is understandable as because these participants received full support the level of support remains the same regardless of the submitted value.

Table 7.6 Qualitative Data - Self-Efficacy Path Full Support

Maebh - She was saying to me put in a 7. She thinks you have to put in the best one the whole time. She wants to be a part of the whole packet. Sarah - I wouldn't personally see any benefit and I don't do it with any thought there sometimes he wants to take over the mouse and he wants to click on the number he likes and my attitude is along as it is keeping him happy and it is keeping him involved and it is keeping him positive about the whole thing that's the biggest benefit for me.

In summary, few patterns have emerged from the self-efficacy paths of those parents who received full support from P.A.C.T. There was an a slight increase in parents self-efficacy when using review and a more significant increase in parents self-efficacy when using mastery learning. Interestingly all values (apart from the peak in mastery learning and review) across all paths lay in 5-6 efficacy level. However, conclusions may only be tentative as qualitative data suggests a somewhat ad hoc approach in submitting self-efficacy values due to a perception of its lack of relevance.

Figure 7.7 illustrates the self-efficacy path for the mastery learning tutoring tactic of those participants receiving adaptive support. As can be observed the path is quite erratic with no clear increases. The path peaks at interaction 5 with a self-efficacy value of 6. The values are distributed between the upper self-efficacy level of 5-6 and lower self-efficacy level of 3-4. Support at the 5-6 self-efficacy level comprises the suggested tactic and an explanation of how it can be used. Support at the self-efficacy level of 3-4 comprises the suggested tutoring tactic, an explanation and an example of its use.

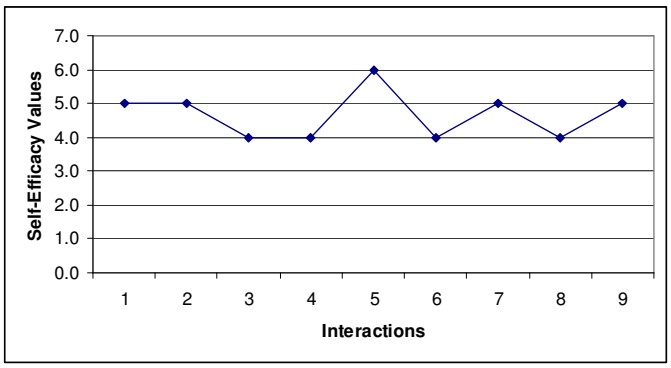

Figure 7.7 Mastery Learning Self-Efficacy Values – Adaptive Support

From Table 7.7 it can be observed that 75% of the values plotted in Figure 7.7 are based on the data of 100% of participants who received adaptive support. This suggests that the graph is a good representation of parental self-efficacy in using the mastery learning tutoring tactic.

Table 7.7 Calculating Self-Efficacy Values – Mastery Learning Adaptive Support

Interaction	Self-Efficacy Value	% Population Included
1	5	100
2	5	100
3	4	100
4	4	100
5	6	100
6	4	100
7	5	80
8	4	80
9	5	80

The self-efficacy path for repetition of those participants receiving adaptive support is plotted in Figure 7.8. Similarly, to Figure 7.7 this graph is quire erratic, with self-efficacy dropping marginally from 6.0 in the 1st interaction to 5.0 in the 12th interaction. The highest self-efficacy value was recorded during the 1st and 2nd interaction, while the lowest self-efficacy value was recorded in interaction 11.

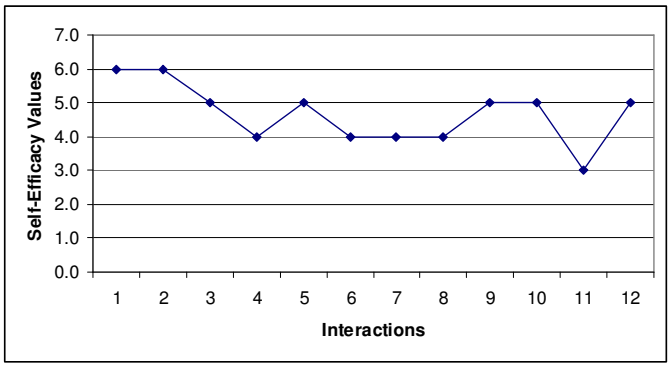

Figure 7.8 Repetition Self-Efficacy Values – Adaptive Support

Table 7.8 Calculating Self-Efficacy Values – Repetition Adaptive Support

Interaction	Self-Efficacy Value	% Population Included
1	6	100
2	6	100
3	5	100
4	4	100
5	5	100
6	4	80
7	4	80
8	4	80
9	5	80
10	5	60
11	3	60
12	5	60

Table 7.8 illustrates that all values plotted on the graph are based on data from over 60% of participants, which indicates that the path can be taken as an accurate representation of the group as opposed to a representation of the minority.

The self-efficacy path for the review tutoring tactic of those who received adaptive support is plotted in Figure 7.9. This shows an overall increase in self-efficacy from 4 to 6. Again the graph is erratic, the lowest value 3 was recorded on the 10th interaction while the highest value 6 was recorded on the 13th interaction. All values lie between 3 and 6.

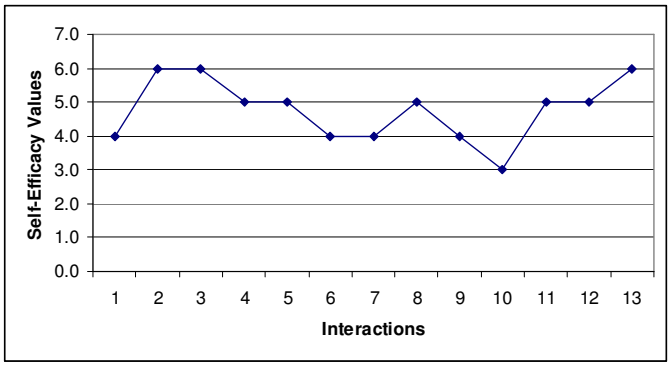

Figure 7.9 Review Self-Efficacy Values – Adaptive

Support

From Table 7.9 it can be observed that all values plotted in Figure 7.9 are based on the data of at least 60% of the participants. Therefore, the erratic nature of the graph is not a result of a minority bias but a representation of participants' self-efficacy levels. Qualitative data from interviews held throughout the study provides some insight.

Table 7.10 lists some examples of the qualitative data collected based on how participants felt about being asked to enter a self-efficacy value after using each of the tutoring tactics. The examples provided in Table 7.10 can be seen as representative of the type of data collected.

Table 7.9 Calculating Self-Efficacy Values – Review Adaptive Support

Interaction	Self-Efficacy Value	% Population Included
1	4	100
2	6	100
3	6	100
4	5	100
5	5	100
6	4	100
7	4	100
8	5	80
9	4	80
10	3	60
11	5	60
12	5	60
13	6	60

Interestingly, Ciara, Niamh, Isabelle and Chloe all report some level of experimentation with P.A.C.T. in an endeavour to receive the desired level of support. Qualitative data suggests that participants submitted self-efficacy values lower than desired in order to receive the desired level of support. To this end, the submitted value may be a representation of the level of support they desired as opposed to their perceived level of self-efficacy. For example, Ciara reports of easing back in order to receive more

"jobs" (more activity suggestions) from PA.C.T, while Niamh's strategy is pretending that she "hadn't a clue". Chloe frames it as tricking the system into working for their benefit by submitting 1's, this is clearly illustrated in Figure 7.10 where Chloe's self-efficacy values across mastery learning, repetition and review quickly plummet. Certainly, it appears that there is a dichotomy between their perceived level self-efficacy and the desired level of support, in so far as parents are entering high levels of self-efficacy but still desire high levels of support.

Table 7.10 Qualitative Data - Self-Efficacy Path Adaptive Support

Ciara - In the beginning I wasn't sure . . . I was going one away from the top mark at one stage, when everything was a seven you wouldn't get much to do so on a couple of occasions I'd ease back and instead of doing all the 7's thinking I'm great we will come back and get our jobs to do.
Niamh - That took me a while to manage because at the beginning I was saying I was very confident and I wasn't getting as much feedback as I did when I said I was less confident or that I hadn't a clue it seemed to work best when you said you hadn't an idea and look for suggestions rather than saying I'm very confident at doing this I'm very confident at doing the other . . . where as if you suggested that you weren't as confident it gave you a few extra ideas.
Isobelle - getting on better because . . . going lower in scores gives you more help.
Chloe - We had to trick it into working for us, had to enter 1 to get it to give suggestions.

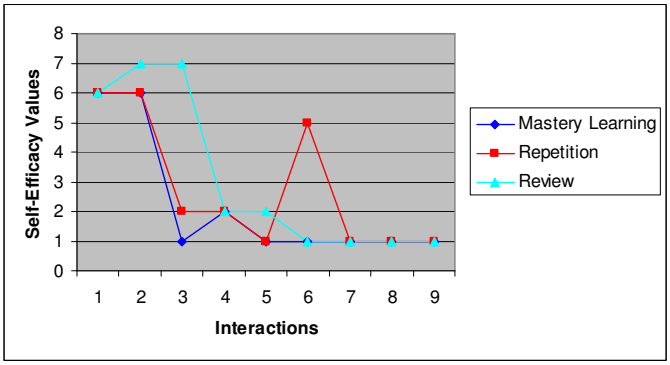

Figure 7.10 Chloe's Self-Efficacy Values

A comparison of self-efficacy paths of those participants who received full support and those participants who received adaptive support highlights the lack of emergent patterns. However, qualitative data indicates that the reason for this may vary between groups. Participants receiving full support indicated that there might have been a somewhat ad hoc approach to submitting self-efficacy values. On the other hand, participants receiving adaptive support indicated a need to submit self-efficacy values lower than desired in order to receive the desired level of support.

In summary, post test scores indicate an increase in parental self-efficacy values across all seven tutoring tactics. The increase was statistically significant at the $p<0.05$ level in mastery learning, motivational game and repetition and was approaching statistical significance with positive reinforcement. This suggests that P.A.C.T. may be of benefit in increasing parental self-efficacy in the domain of home tutoring. However, on closer inspection, based on parents' self-efficacy paths it may be that these values are not as true a reflection as initially expected. Parents receiving full support report that on occasion they allowed their child to select the value to submit. Parents receiving adaptive support identify the need to submit a value lower than their perceived self-efficacy value in order to receive the desired level of support. These results provide important insights in so far as they indicate dichotomy between parents' perceived self-efficacy and desired level of support. Secondly, it is clear that there is a need for a more subtle instrument for eliciting self-efficacy if it is to be used within adaptive educational systems.

7.2.1.2 Parents' Knowledge

Results were analysed to identify the result of P.A.C.T. on parents' knowledge. For the purpose of this research, knowledge was defined as (1) knowledge of what each of the tutoring tactics comprised, (2) knowledge of when to use each of the tutoring tactics. A

paired-samples t-test was conducted to compare the pre and post test for each category of knowledge. Figure 7.11 provides an example of the data collection instrument used in both pre and post tests.

Do you know what Expert Demonstration is?	(no) 1 2 3 4 5 6 7 (yes)
Do you know when to use Expert Demonstration?	(no) 1 2 3 4 5 6 7 (yes)

Do you know what Mastery Learning is?	(no) 1 2 3 4 5 6 7 (yes)
Do you know when to use Mastery Learning?	(no) 1 2 3 4 5 6 7 (yes)

Figure 7.11 Pre-Questionnaire Excerpt – Knowledge

In terms of parents' knowledge of what each tutoring tactic comprises, results indicated a statistically significant increase for both the mastery learning (p=.024) and motivational game (p=.034) tutoring tactics. Results for the review (p=.062) tutoring tactic are approaching statistical significance. For all other tutoring tactics there was an increase in the mean values between pre and post test scores however, these increases were not statistically different, this is illustrated in Table 7.11.

Table 7.11 Pre and Post Test Mean Values (Knowledge What)

Tutoring Tactic	**Pre-Test**		**Post-Test**		**P-value**
Expert Demonstration	M 4.45	SD 2.76	M 5.63	SD 1.80	
Mastery Learning	M 4.09	SD 2.58	M 6.09	SD 0.83	P 0.024
Motivational Game	M4.81	SD 2.22	M 6.54	SD 0.82	P 0.034
Positive Reinforcement	M 5.85	SD 2.19	M 6.85	SD 0.37	
Repetition	M 6.09	SD 1.75	M 6.90	SD 0.30	
Review	M 5.54	SD 2.11	M 6.90	SD 0.30	P 0.062
Tutoring Variation	M4.18	SD 2.75	M 4.72	SD 2.14	

In terms of parents' knowledge of when to use each tutoring tactic, results indicate a statistically significant difference for mastery learning (p=.004) and motivational game (p=.015) at the p<.05 level and results for expert demonstration (p=.085), positive

reinforcement (p=.07) and review (p=.058) are approaching statistical significance. For all other tutoring tactics there was an increase in mean values between pre and post test scores however these increases were not statistically significant. This is illustrated in Table 7.12.

Interestingly, the mastery learning and motivational game tactics show the most profound statistical significant difference across both categories of knowledge. The significant increase in parents' knowledge of mastery learning is not altogether surprising as it was the tutoring tactic suggested most frequently by P.A.C.T (23% of the time, reader is directed to Figure 7.3) throughout the study. In contrast, the motivational game tactic was only suggested 12% of the time (reader is directed to Figure 7.3). As data suggests that P.A.C.T. may have a positive effect on the home-tutoring environment (this will be discussed in 7.2.2), it may be that P.A.C.T. itself had an implicit effect on parents' knowledge in this area.

The decrease of variance between users at post-test as illustrated in table 7.11 and 7.12 is of interest as it indicates an increase in uniformity across results. As post test scores indicate an increase in mean values this suggests a more dramatic increase in post-test scores of participants with lower pre-test scores than of participants with higher pre-test scores. This suggests that in this instance the provision of adaptive support had a more significant effect on participants who indicated less knowledge at pre test than those who indicated greater knowledge.

Table 7.12 Pre and Post Test Mean Values (Knowledge When)

Tutoring Tactic	Pre-Test		Post-Test		P-value
Expert Demonstration	M 3.72	SD 2.41	M 5.36	SD 1.80	P 0.085
Mastery Learning	M 3.63	SD 2.24	M 6.00	SD 1.00	P 0.004
Motivational Game	M 4.54	SD 2.11	M 6.45	SD 1.03	P 0.015
Positive Reinforcement	M 5.63	SD 1.85	M 6.72	SD 0.90	P 0.07
Repetition	M 5.54	SD 1.91	M 6.54	SD 0.82	
Review	M 5.27	SD 2.19	M 6.63	SD 0.80	P 0.058
Tutoring Variation	M 3.54	SD 2.42	M 4.63	SD 2.20	

Qualitative data provides greater insights into parents' increase in knowledge, which is illustrated in Table 7.13. Ciara indicates an increase in knowledge of the motivational game tactic by suggesting the need to make more of a game out of home practice. Maebh demonstrates knowledge of the positive reinforcement tactic when she explains how she now phrases feedback in a positive manner. Niamh provides a clear explanation of the importance of review and its benefits, which demonstrates a deep level of understanding of the tactic. Sarah also reports on her increased knowledge of the need for review. Finally, Valerie provides a description of one of the pitfalls many parents can fall into when practicing with their child where they continuously say to their child "just play it one more time", she acknowledges that this strategy does not promote learning and identifies the importance of learning in small manageable chunks.

In summary, results indicate that P.A.C.T. may be of benefit in increasing parents' knowledge of home tutoring best practice. In particular, results indicate statistically significant increase in mastery learning and motivational game tactics.

Table 7.13 Qualitative Data – Knowledge

Ciara - Make more of a game out of it *(Motivational Game)*
Maebh - Instead of saying "that was fine but you didn't . . . . . I'm more inclined to say could we get it as good as . . . *(Positive Reinforcement)*
Niamh - More emphasis on repeating what has gone on before hand . . . as a mother because they are progressing at school and everything else you kind of have a tendency to get them to do what they have to do and move on to the next thing rather than looking back to see I should have learnt this from piece A., this from piece C and this from piece B and it is important to look at all these piece before you even look at your new piece *(Review)*
Sarah - Definitely learnt the importance of the revision pieces *(Review*)
Valerie - I suppose I'm quite intense which I suppose most parents who do this are. . So like if there is something we need to review instead of maybe reviewing it just twice and accepting that it's not going to be perfected I might kind of go on and say come on just do it one more time and maybe one more time you almost had it that time where's then they start to feel like oh just blow off will you so the thing is that with the computer I found that it's taught me just to like really do just a little bit all the time and not get sucked into this you're almost there just do it one more time *(Repetition)*

7.2.1.3 Role of Home Tutor

Data was collected on parents' perception of their role as home tutor using the post-questionnaires and interviews conducted throughout the study. Results indicate that P.A.C.T. had an effect on parents' perception of their role as home tutor, in so far as there was now an acknowledgement of the need to:

- Provide more structure.
- Give more attention.
- Be more positive/fun.
- Be more aware of their child's emotional needs.

7.2.1.3.1 Providing Structure

Parents reported an ability to provide more structure and consistency during home practice as a result of using P.A.C.T.. This may not be altogether surprising due to the structured nature of P.A.C.T. Table 7.14 provides an example of the qualitative data collected and is representative of the entire data set. Chloe, Elizabeth and Niamh's indicate that P.A.C.T. reminded them that it necessary to structure practice as opposed to allowing an ad hoc approach. In addition, Chloe reports that without P.A.C.T. it was difficult not to revert to habitual tendencies and omit some of the key elements of the practice. This suggests the needs for ongoing support.

Table 7.14 Qualitative Data – Role of Home Tutor (Structure)

Anna – Practice is now more structured and each evening there is an obvious progress with both review and new pieces . . . organisation of lessons, adhering to a proper structure.
Chloe – it reminds you, it makes you a little bit more consistent because when we don't use it we are going straight to her newest piece and we are probably not doing all the stuff we should be doing.
Elizabeth – Small steps need to be taken and reviewing pieces should always be part of daily practice. Definitely has changed perception in terms of review and structure
Niamh – it encourages you to do all the review and repetition rather than just doing the little bit she had to do for this week and if they follow this particular format, do this do that do the next it will get them into good practice technique that will probably stay with them.
Valerie – I help keep their practice regular.

7.2.1.3.2 Giving Full Attention

Table 7.15 provides example of qualitative data collected during the study, which indicates the benefit of P.A.C.T. in reminding parents of the need to give full attention during home practice. Isobelle reports that P.A.C.T. provides an opportunity to give single pointed attention as opposed to carrying out practice while multi-tasking with other house keeping activities. The fact that the computer is located in a different room ensures that once a decision is made to practice all other tasks are let go and full attention is given to the practice. Ciara shares a similar experience, stating that previously she may have

been listening to the practice but doing something else, however, now practice time is spent together. Niamh's report indicates that P.A.C.T. may have been of benefit in encouraging full attention as now endeavours are made to carry out home practice when there are fewer distractions. As these parents have become involved in the Suzuki method, it is clear that there is some belief in the benefit of parental involvement in their child's learning, however, results indicate an idea among parents that this involvement does not require full attention. Therefore, results indicate that P.A.C.T may be of benefit in encouraging parents to become fully engaged in their child's learning.

Table 7.15 Qualitative Data – Role of Home Tutor (Attention)

Ciara – More one-to-one, would be listening but might be doing something else. Now we spend time together which is good.
Isobelle – I'd actually be more relaxed going in doing it because I know that I have to have the time to go through the whole package rather than before I'd just sit her maybe you know on the high stool so the little one wouldn't be getting at her and I'd be doing the dinner and all where as now it's one to one and that's it . . . . you see it is less stressful then because I am not trying to do three or four things together I just go down in to the room put on the computer, close the door and it is just me and her and the computer. My role has changed a great deal I now realise that a lesson needs my full attention to achieve a better result.
Niamh – there is four in the house and there is three older than her so I kind of wait until they are gone out doing something or when they have something on and I have the house maybe that bit quieter because I don't want them distracting her either and of course they are interested in this package on the computer as well.

7.2.1.3.3 Be more Fun/Positive

There was an expectation that P.A.C.T. may be of benefit in providing a more positive learning environment for the child. However, participants suggest that P.A.C.T. may also facilitate a more positive attitude in parents towards home practice. Table 7.16 provides qualitative data that is representative of the data collected. Anna recognises that she needs to enjoy practice, Nina states that she now has a more positive attitude to practice and Valerie identifies that there is never any reason to get serious or cross and that one should always keep it light and happy. Maebh frames it as she now sees her role as to encourage as opposed to instructing.

Nina makes an interesting observation that in order to engage her child she needs to make it fun and avoid "going on" at him. Chloe takes this a step further saying that she now sees her role as motivating her child to do practice. Elizabeth informs us that after using P.A.C.T. she now knows how to make practice more enjoyable.

Table 7.16 Qualitative Data – Role of Home Tutor (Creating a Positive Learning Environment)

Anna – It has taught me to vary out exercises regularly . . I need to be innovative with exercise and enjoy the practice also.
Chloe – Role is to motivate Cathy into practice mostly.
Maebh – To facilitate practice to encourage rather that me instructing Kate
Elizabeth – I now know how to make practice enjoyable and Colm sees the importance of reviewing pieces. One needs to be patient and encouraging.
Nina – It has changed. Initially I would have approached tutorship as a taskmaster but P.A.C.T. made practice more interesting and fun. I think both Joe and I have a more positive attitude to practice . . . . . even to cajole Joe to do a little bit more I would use similar methodology to PACT I would try and inject a bit of randomness or fun. I realise now that going on to Joe about posture you have to do it in a fun way because you are not going to engage him otherwise.
Valerie – A little bit at a time and there is never any reason to get serious and cross always keep it light and happy.

7.2.1.3.4 Awareness of Child's Affective State

Results indicate that P.A.C.T. may also be of benefit in encouraging parents to be more aware of their child's affective state. This is not surprising as P.A.C.T. adapts to the affective needs of the child. For Maebh, P.A.C.T. has reminded her to be aware of Kate's affective state prior to practice and adapt the practice accordingly. Elizabeth also alludes to the need to adapt the practice based on the child's emotional needs. Valerie identifies that P.A.C.T. may be of great benefit in a relationship where the child may resist the

parents endeavours as P.A.C.T. may provide the necessary space for negative emotions to dissolve. These examples are illustrated in Table 7.17.

Table 7.17 Qualitative Data – Role of Home Tutor

(Awareness of Child's Affective State)

Maebh – Using the programme has prompted me to focus on how Kate feels in general before we practice and to adapt accordingly
Elizabeth – one should gauge the format of the practice depending on the form of the student
Valerie - It has really helped him and you know our relationship because he tends to dig his heels in and if you push him it's even more resistance so this has been particularly useful in a relationship like that.

7.2.1.3.5 Role of Home Tutor Summary

Results suggests that P.A.C.T. was of most benefit in reminding parents to provide more structure during practice time, to pay full attention during practice, to encourage a positive attitude and be more aware of their child's affective state. In terms of the effect of P.A.C.T. on parents' knowledge, results indicate that P.A.C.T. had most significant effect in term of mastery learning, motivational game and review.

7.2.1.4 The Effect of P.A.C.T. on Parents Summary

Results indicate that overall P.A.C.T. had a positive effect on parental self-efficacy, home tutoring knowledge and their perception of their role as home tutor. Post test scores indicate an increase in parental self-efficacy across all tutoring tactics with a statistically significant increase across mastery learning, motivational game and repetition. Data indicates that for collection of self-efficacy throughout the tutoring process a subtle instrument is required as there may be a dichotomy between parents' perceived self-efficacy and their desired level of support. Data also suggests increases in parents' knowledge most notably in mastery learning and motivational game tactics. On parents' perception of their role as home tutor, P.A.C.T. may be of benefit in reminding parents to provide more structure during practice time, to pay full attention during practice, to encourage a positive attitude and be more aware of their child's affective state.

7.2.2 The provision of Affective Support

This section provides insights into the effect of providing affective support for the child throughout the home tutoring process. Firstly, results pertaining to the child's affective experience are presented. This indicates the breakdown of affective reports across the four basic emotions. This may be of benefit in identifying the effect of P.A.C.T. on the child's affective state. Secondly, results pertaining to the strategies used in eliciting affect will be presented. Finally, data indicating the effect of P.A.C.T. on the home tutoring process will be outlined. As P.A.C.T. adapted to the affective needs of the child for all participants a comparison of parents receiving full versus adaptive support (based on self-efficacy) is irrelevant and therefore will not be presented.

7.2.2.1 Affective Experiences

As a result of elicitation of the child's emotional state prior to each learning activity, it is possible to identify the breakdown of affective experiences throughout the course of the study. Of the 639 occasions where P.A.C.T. elicited emotion, children reported being happy 71% of the time and an even distribution across the other three emotions sad (10%), angry (9%) and fearful (11%). This is illustrated in Figure 7.12. Albeit, that based on this result alone it is not possible to hypothesis that P.A.C.T. had a positive effect on home tutoring. However, when combined with the qualitative data, which will be presented later in this chapter (Table 7.22 and Table 7.29), it appears that P.A.C.T. may be of benefit in encouraging positive affective states throughout the home tutoring process.

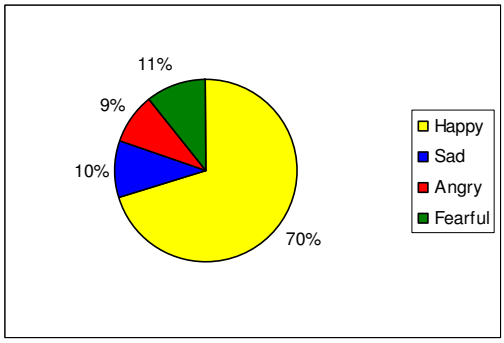

Figure 7.12 Affective Experiences

7.2.2.2 Strategies for Eliciting Affect

Research data suggests a number of strategies were employed by participants when eliciting affect. These strategies can be broadly categorised in terms of (1) self-report (2) collaborative–report and (3) observed-report. Self-report involves the child solely deciding on which emoticon best represents their affective state. The collaborative-report strategy involves a discussion around how the child is feeling from which a decision arises. Finally, the observed-report strategy involves the parent selecting an emoticon, which they perceive best represents the child's affective state. Qualitative data suggests that many participants used a variety of the aforementioned strategies as opposed to using a single strategy throughout the entire study. Table 7.18 provides examples of each of the strategies. These examples are representative of the data collected and are given from the parents' perspective.

Table 7.18 Strategies for Eliciting Affect

Chloe – She loved clicking herself on how she was feeling but that's when I kind of lost a little bit of faith in it was when she started clicking on sad face and I said you're not sad and she said well I want to see what it says. *(Self-Report)*
Valerie - He is usually happy to go onto the computer so most of the faces that he clicks on are the happy faces . . . . . so how we have worked it is he gets to do all the clicking on the computer . . . if he does it too much then it tells you to come again later then we have to go and log in again and all that and then I get a bit annoyed. *(Self-Report)*
Ciara – She says "*What face have I on me mammy?" (Collaborative-Report)*
Isobelle - When the little happy face and sad face and all them come up you know I do kind of get her involved in it and ask her which one is she now. *(Collaborative-Report)*
Sarah - He does not like me pressing sad, he doesn't like it being recorded that he is in bad form . . . wondering what other people might think. *(Observed-Report)*

Chloe and Valerie provide examples of the self-report strategy where the child decides how they are feeling and selects the appropriate emoticon. In this instance, Ciara and Isobelle have used the collaborative–report strategy. As Ciara reports, the child initiates the collaborative discussion. However, with Isobelle it is the parent who initiates the

discussion, by asking her child which emoticon best represents her current affective state. Sarah gives an insight into the observed-report strategy, where she decides on which emoticon best represents the child's affective state without his involvement.

It is interesting to note the potential negative effect of the self-report and observed-report strategies. Negativity may occur if either party perceives the other to have made an invalid judgement of the child's affective state. In terms of self-report Chloe reports of "loosing faith" in P.A.C.T. when her child submits an emotion, which she perceives to be invalid. In the same instance, Valerie reports of getting annoyed. In terms of observed-report, Sarah reports of her son not liking it when she selects an emoticon, which he deems invalid. This suggests that there may be benefit in encouraging a collaborative approach between self-reporter and observer when eliciting affect. A collaborative approach may encourage a more positive learning environment not least through maintaining a positive dynamic between parent and child.

7.2.2.3 Adapting based on Affect

As previously stated, results indicates that on 70% (reader is directed to Figure 7.12) of occasions that affect was elicited children indicated they were happy. Albeit, that it is difficult to determine the reason for such a result qualitative data (Table 7.22) suggests that P.A.C.T. may be a contributing factor. In addition, Table 7.19 provides data, which supports this finding, as Valerie reports on the effectiveness of P.A.C.T. in dissolving frustration or anger through the suggestion of appropriate tutoring tactics.

Table 7.19 The Effect of Adapting Based of Affect

Valerie – If he really does feel, if we do get a bit tense and he really is feeling a bit frustrated or cross or I got a bit cross about something and it got a bit tense or whatever and if he really puts in well then I find that after whatever comes up, whatever the praising him or a motivational game or whatever that after that he is usually ok and we are back on track so it actually kind of works, it actually kind of work.

However, an interesting observation by all parents is the curiosity among children in expressing affective states other than that which they are currently experiencing. It appears that depending on the nature of the child and perhaps the parent-child dynamic there may be a risk of the child attempting to game the system (Baker et al, 2006). These activities vary in severity and for the purpose of this study can be defined as experimentation, trickery and definite gaming. Experimentation can be described as the

selection of an emoticon other than that which best represents the current emotional state based on a curiosity of what would happen. Trickery involves pretending that one is experiencing a different emotion than ones actual affective state. Gaming the system involves using the system rules against itself for the child's own benefit. It is important to note that these instances are reported from parents' perspectives. Examples of each type of activity are illustrated in Table 7.20.

In terms of experimentation with P.A.C.T. Valerie and Maebh, describe how their children choose alternative emoticons in an endeavour to see what will happen. There is a curiosity to see which activity will be suggested. Valerie and her child have agreed on a strategy for managing this experimentation whereby once during each session her son can select an emoticon, which does not represent the current affective state.

Chloe and Sarah report instances of trickery. Chloe reports that her child liked clicking on the sad face when she was happy. Sarah reports that her son said he was angry or sad when he was not.

Table 7.20 Effect of Adapting Based on Affect

Maebh – Oh she is watching for that her self and to be honest with you she plays a little bit with it in that one day she put in fearful and she wasn't a bit . . . . but she wanted to see herself because she said oh I've done happy every day let's see what happens if I do this. *(Experimentation)*
Valerie – most of the faces that he clicks on are the happy faces but he wants to click on the other ones so how we have worked it is he gets to do all the clicking on the computer and then he can choose one of his times anyone of the times when he gets to choose how he is feeling he can pick one of the other faces even though he's not but just to see what they bring up. *(Experimentation)*
Chloe – she'd trick it by clicking the sad face when she was feeling happy. *(Trickery)*
Sarah – Loved the idea of being able to decide what mood he is in but it has nothing to do, it is no reflection at all on the mood he is actually in. He thinks it is funny saying he is angry or he's sad even when he is not. *(Trickery)*
Nina – Always said happy because he thought if he said happy he would get out of it quicker . . . all about getting it over with so he can get on to the Nintendo. *(Gaming)*

Finally, Nina has experienced an instance where her child has attempted to game the system, where her child continuously selected the happy emoticon in order to complete the practice as quickly a possible. However, when the affective state of a child is one of happiness the child is directed through the core elements of any practice, review, practice of homework and repetitions. Therefore, albeit that it is difficult to determine the level of learning, which will take place if the child has a desire to be somewhere else they are not effectively gaming the system as they are completing all required elements of a practice. Interestingly, if a child wished to truly game the system it would involve selecting the angry or sad emoticon a number of times in a row, P.A.C.T. would then suggest that now may not be a good time for practice and maybe they should try again later. Chloe and Valerie report instances of this occurring. However, in these cases it was clearly unintentional. This data is illustrated in Table 7.21

Table 7.21 Gaming the System

Chloe – she was feeling happy but she clicked on the sad face, she clicked on the sad face too much . . . the program ended . . . we had to start again
Valerie – it's just it gets annoying, we have found if he does it too much then it tells you to come again later then we have to go and log in again and all that and then I get a bit annoyed

As a result of the design of P.A.C.T., attempts to game the system may not necessary result in lack of learning. This is because all paths through P.A.C.T. promote learning and fundamentally encourage review, completion of homework and a number of repetitions of the new concept/skill. Of course, this is different to other intelligent tutoring systems where gaming can limit learning gain as students may arrive at an answer without working through the required learning process (Beck, 2005; Murray & vanLehn, 2005; Johns & Woolf, 2006; Walonoski & Heffernan, 2006).

7.2.2.4 Affective Support Summary

Results indicate that P.A.C.T. may be of benefit in maintaining positive affective states. The instrument used for emotion elicitation in this study provides interesting insights into the self-reporter observed-reporter dynamic and how this can affect the learning environment. It is not uncommon for there to be discrepancies between observed reports and self-reports of affective states (Alsmeyer et al., 2007). The study suggests that their may be benefit in encouraging collaboration between parties when eliciting

emotions and perhaps their may be benefit in using a more elaborative tool, which would encourage more collaborative discussion, particularly if the aim was to develop emotional intelligence and awareness. Furthermore, the findings of this study may be of interest to designers of affectively intelligent systems as far as designers need to take into consideration that learners may attempt to game the system. However, if the design of the system is robust gaming the system may not necessarily lead to reduced learning as all learning paths through the system could promote learning.

7.2.3 Role of P.A.C.T.

Analysis of the qualitative data collected from interviews suggests that P.A.C.T. may be of benefit during home practice in:

- Creating a positive environment.
- Acting as the mediator.

7.2.3.1 Creating a Positive Environment

The data provides strong indications that P.A.C.T. may be of benefit in creating a positive environment for learning in the home. Results indicate that children are happier to practice with P.A.C.T. a sample of the type of data collected is illustrated in Table 7.22. Ciara reports that practicing with P.A.C.T. is a "treat" and Maebh reports that the child asks to practice now. When asked why children may be happier when practicing with P.A.C.T. a number of suggestions arise (1) children's enthusiasm for technology (Nina and Edith), (2) personalisation aspect of P.A.C.T. (Isobelle and Sarah) (3) the game aspect (Valarie).

Table 7.22 Creating a Positive Learning Environment with P.A.C.T.

Isobelle - Always happier doing it with P.A.C.T. She likes when her name comes up. She thinks there is someone listening in.
Ciara - Doing it on the computer makes it a treat for her.
Nina - Even introducing the whole concept of the computer changed my attitude to the whole thing because I wasn't groping and start. Great excitement going to the computer, he asks to do it with the computer.
Chloe - Really enjoyed it made her want to do Violin practice
Maebh - She comes looking for practice now
Edith - More interested in practice as children are so interested in computers
Valerie - I don't get moans if we do it with the computer. .you know it's just this extra element that makes it a bit more fun. Makes it more playful for him it is not all about me and him and all the seriousness of an instrument
Sarah - The computer has allowed it to be more positive. We are going into the whole thing with much more enthusiasm and excitement than we would be if it wasn't there. When I say let's go up and do It with the computer he is much more enthusiastic and the practices also last a lot longer because it is much more interactive. He loves the way his name comes up. He gets very excited he feels like someone has listened to him

7.2.3.2 Acting as Mediator

Interestingly, data suggests that many parents found P.A.C.T. beneficial in acting as mediator throughout home practice. Table 7.23 provides example of the data collected. Isobelle reports of fewer rows during home practice when practicing with P.A.C.T.. As her daughter Andrea was happier practicing with the computer and happy to go along with its suggestions. Nina indicates that she liked the mediation aspect of P.A.C.T. as it meant that Michael was receiving instruction other than from her. Sarah reports that this has also worked well during their practice. Valerie provides insights into why children may be happier to take instruction from P.A.C.T. She suggests that it may be that

P.A.C.T. never adds negative energy to the environment and it does not react regardless of the child's behaviour therefore the child does not wish to displease P.A.C.T.

Table 7.23 P.A.C.T. as Mediator

Isobelle - Easier to teach her when we aren't rowing so much.
Nina - I liked the fact that it was solid he was getting the instruction from something else other than me.
Sarah - The think that I find I am able to do is to teach him the notes from a song but for me to teach him technique is much more difficult because normally he wouldn't allow me to correct his hand position or correct his finger position the way he would in a lesson because he would get angry with me. It is very hard to do that in a positive way, I mean I know I need to learn more skills on how to do that better when we start off a practice in the past without the computer there it was always starting off with a negative thing like "I don't want to do it" so you are at a disadvantage from the beginning. . it is the computer saying it instead of me and that has worked very well for us. It is not like it is me telling him this it is like it's an outsider
Valerie - Adds a different dimension to practice gives them space to work in. He is happy to do what computer says because the computer doesn't get cross or short so you are not going to displease it where's me I have times where I'm short or my annoyance isn't hidden it has nothing to do with the way he is playing it's his attitude and I know, I mean I'm an adult I know it isn't helping but he knows the computer doesn't get that way he just goes on to the next thing.

However, data suggests one key problem with using technology during home practice. This is a lack of resources. Firstly, parents without broadband found that initial set-up time often resulted in them not using P.A.C.T. as often as desired. Secondly, for those participants who did not have a laptop, it was found that if the computer was in a room, which was not conducive to practice there might be a reluctance to use it. This suggests that although Ireland has become technologically enriched over the past number of years there is more to be done before the benefits of technology can be truly exploited during learning activities in the home. This is illustrated in Table 7.24.

Table 7.24 Challenges of using P.A.C.T.

Nina - The place of the computer in the house physically would be very important because sometimes they didn't want to do it in the room where the computer was so if one had a laptop it would be much easier.
Isobelle - Finding it hard to get in front of the computer, we have dial up so it's a bit slow.
Edith - Not using it as much as we should, this is due to my own organisation and setting it up in the office we haven't got broadband.

7.2.3.3 Role of P.A.C.T. Summary

Results indicate that technology is best place within the home tutoring process in providing a fun element to home practice. Parents suggest that the personalisation and randomness easily provided by computer-based technology is appealing to the young child. Additionally, there is a belief that computer-based technology can be of benefit in mediating the home practice. Results suggest that children are happier to take instruction from the computer other than their own parents, which maybe due to the non-reactive nature of the technology. However, there is a gap between emergent adaptive educational systems and the technological resources, which may impact negatively on the use of technology in home-tutoring.

7.2.4 Study 1 Summary

Results of Study 1 provide great insights into the effect of supporting the home tutoring process of Suzuki violin through the use of an adaptive educational system. Overall, results indicate that P.A.C.T. had a positive effect on parents' self-efficacy, knowledge and their perception of their role as home tutor. Most interestingly, results indicate the complexity associated with collecting parents' self-efficacy values throughout the tutoring process. Firstly, unless parents understand its relevance and value, data may be submitted in an ad hoc manner. Secondly, data suggests a dichotomy between parental self-efficacy and desired level of support. In terms of the effect of providing affective support, results highlight the benefit in adapting to the child's affective state and the potential benefit in promoting collaborative strategies for eliciting affect. Interestingly, results indicate that P.A.C.T. may be of benefit in encouraging attentive parental involvement and may play a role in developing affective awareness.

7.3 Study 2: Evaluating the effect of using an adaptive educational system to support mathematics homework.

Study 1 was concerned with investigating the effect of using P.A.C.T. to support home tutoring of Suzuki violin. The purpose of study 2 was to investigate the effect of using such a system to support the home tutoring of mathematics (the population of P.A.C.T. with mathematics content is described in Chapter 3 section 3.3.2.2). This study comprised 36 parent and child dyads (32 female parents, 4 male parents, 18 male and 18 female children). All participants volunteered to partake in the study and no reward incentives were given. All children were at the Junior Infants level (aged 4-5 year olds). The study itself was conducted across three schools where all three schools are designated disadvantaged in terms of the number of students in the school from families with socioeconomic characteristics that have been found to be associated with low levels of educational achievement (e.g. unemployment, medical card holders etc) (Archer, 2005). In the first and second school, the study was conducted during school time in the school's computer laboratory. The reason for this is that these families did not have access to a computer at home. Participants from the first school had the opportunity to use P.A.C.T. for eight sessions while participants from the second school had the opportunity to use P.A.C.T. for four sessions. Participants from the third school used P.A.C.T. at home and therefore could use it as often as desired.

Study 1 revealed a possible dichotomy between parental self-efficacy and desired level of support in so far as parents with high levels of self-efficacy still desired high-levels of support. This is surprising as research suggests that highly efficacious students seek challenging learning experiences (Sewell & St George, 2000), which suggests that low levels of support would be adequate. According to Bandura (1986), the most functional efficacy judgments tend to exceed what one can actually accomplish and he suggests that this overestimation serves to increase effort and persistence. However, it remains to be answered to what degree participants may benefit from high perceptions of capability in the face of low knowledge of tutoring tactics. Clearly, efforts to decrease parental self-efficacy, in order to receive better levels of support, should be avoided. This suggests the need for subtle modification in the way P.A.C.T. adapts based on parental self-efficacy.

Therefore, Study 2 involved a slightly modified version of P.A.C.T. where P.A.C.T. continued to provide support based on the efficacy rules (described in Chapter 4 section

4.2.3), however, users were simultaneously provided with the option of receiving the next level of support. For example, Figure 7.13 illustrates the level of support provided by P.A.C.T. for a user with a self-efficacy value of 7 for the review tutoring tactic. The user is only provided with the suggested tutoring tactic. However, they are also provided with the option to select '*more help*'. If selected P.A.C.T. provides the next level of support (this level of support equates to a self-efficacy value of 5-6) where they are also provided with an explanation of the tutoring tactic. Figure 7.14 illustrates how the user is again presented with the option to select '*more help*'. If selected they are provided with an example (this equates to a self-efficacy value of 3-4) as illustrated in Figure 7.15. Therefore, even a user with a self-efficacy value of 7 for a particular tactic now has the possibility of receiving an explanation and example by selecting '*more help*' at each stage. The users submitted self-efficacy value and the self-efficacy value pertaining to their desired level of support are both logged by the system.

Figure 7.13 Self-Efficacy Value of 7

Figure 7.14 Self-Efficacy Value of 5-6

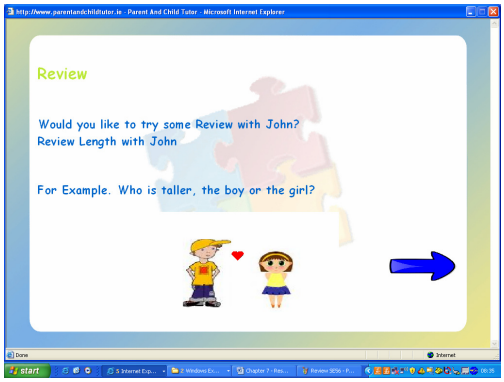

Figure 7.15 Self-Efficacy Value of 3-4

Participants were randomly assigned to one of two versions of P.A.C.T., full-support or adaptive-support (where adaptive-support refers to the modified version described previously). Based on usage statistics a more detailed analysis was performed on the data from 20 of the participating dyads. The selection criterion, as with Study 1, was based on a requirement that participants have used P.A.C.T. for a minimum of three sessions. In terms of the 20 participants, 9 (8 female and 1 male parent, 5 female and 4 male children) were assigned to the group who received full support while 11(9 female and 2 male parents, 4 female and 7 male children) were assigned to the group who received adaptive support.

7.3.1 Investigating the effect of P.A.C.T. on Parents

This section will provide analysis of the data in an endeavour to identify if providing support throughout the home tutoring process through the use of an adaptive educational system may have a positive effect on parents' (1) self-efficacy (2) knowledge and (3) their perception of their role as home tutor. Firstly, we will analyse the results pertaining to self-efficacy. Subsequently we will investigate the effect on parents' knowledge and finally we will investigate the effect on their perception of their role as home tutor.

7.3.1.1 Self-Efficacy

Similarly, to Study 1 results were analysed in an endeavour to identify the effect, if any, of supporting the home tutoring process with an adaptive educational system. In particular, the focus for this study was in supporting the mathematics homework process. Due to the complexity of self-efficacy and in order to gain a clearer insight, self-efficacy will be analysed at two levels.

- Pre and post tests
- Self-efficacy path

Similarly, to Study 1 pre and post tests involved parents rating their self-efficacy on a scale of 1-7 in using each of the six tutoring tactics. The self-efficacy path involves parents submitting a self-efficacy value for each tutoring tactic suggested by P.A.C.T. and such values being stored in the parent's user model

With Study 2, firstly we will analyse pre and post tests for the group as a whole. Secondly, we will investigate trends in parents' self-efficacy paths by (a) identifying the effect of providing full versus adaptive support on parents' self-efficacy paths through a pattern analysis of three of the most frequently used tutoring tactics and (c) investigating

the dichotomy between parents' submitted self-efficacy values and their desired level of support.

7.3.1.1.1 Self-Efficacy Pre and Post Test Scores

Table 7.25 shows an increase in mean across all of the six tutoring tactics from pre to post test scores for all participants. This suggests an increase in parent self-efficacy values on using the adaptive educational system to support the process around mathematics homework. In addition, a paired sample t-test was conducted, which identified a statistically significant increase at the $p<0.05$ level in the positive reinforcement ($p=.04$) and review ($p=.02$) tactics. Additionally, results of the motivational game ($p=.06$) tactic are approaching statistical significance.

Table 7.25 Pre and Post Test Scores of all Participants

Tutoring Tactic	**Pre-Test**	**Post-Test**	**P- value**
Expert Demonstration	M 3.25 SD 2.49	M 3.75 SD 2.76	
Mastery Learning	M 3.37 SD 2.32	M 4.75 SD 2.65	
Motivational Game	M 4.25 SD 2.49	M 5.75 SD 2.37	P 0.06
Positive Reinforcement	M 3.22 SD 2.22	M 5.55 SD 2.60	P 0.04
Review	M 4.22 SD 2.48	M 6.00 SD 2.00	P 0.02
Tutoring Variation	M 3.12 SD 2.10	M 3.50 SD 2.97	

7.3.1.1.2 Self-Efficacy Paths

As described previously due to P.A.C.T.'s design it was possible to record parental self-efficacy for each tutoring tactic suggested by P.A.C.T. throughout the learning process. This allowed for pattern analysis of the self-efficacy values. Section 7.3.1.1.1 has described how self-efficacy has increased across all tutoring tactics between pre and post test. Therefore, is it possible to identify similar patterns in parents' self-efficacy paths?

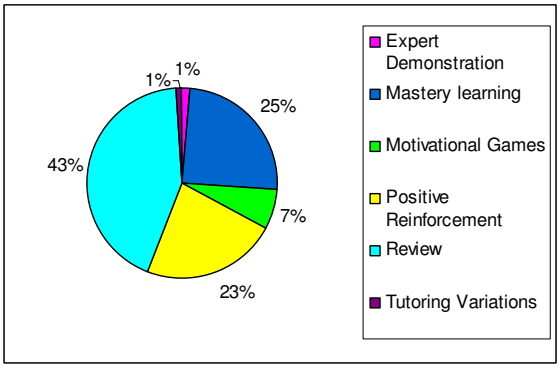

Figure 7.16 Tutoring Tactic Occurrences

As P.A.C.T. adapts the tutoring process based on the affective needs of the child participants used each of the tutoring tactics a varying number of times. Figure 7.16 demonstrates the frequency with which P.A.C.T. suggested each of the tutoring tactics. For the purpose of this study, P.A.C.T. had been modified in order to omit the repetition tutoring tactic from its tutoring model. The reason for this was that its inclusion would create duplication in the tutoring process. When a mathematics teacher prescribes homework for her students, she implicitly includes the repetition tactic. It is usual for a mathematics teacher to prescribe a number of mathematics problems on the same concept in order for the learning to be internalised through repetition. This may not be the case with Suzuki violin homework where the teacher prescribes a set of notes but may not suggest the number of required repetitions.

It can be observed from Figure 7.16 that of the 441 tactic suggestions that P.A.C.T. made the review tutoring tactic was suggested most frequently (43%) followed by mastery learning (25%) and positive reinforcement (23%). Motivational Game (7%) tutoring variation (1%) and expert demonstration (1%) were suggested less often. Therefore, when analysing parents' self-efficacy paths we will concentrate on those tactics suggested more frequently namely review, mastery learning and positive reinforcement. Firstly, we will look at the self-efficacy paths of those receiving full support, subsequently we will look at the self-efficacy path of those receiving adaptive support and finally we will provide some comparison.

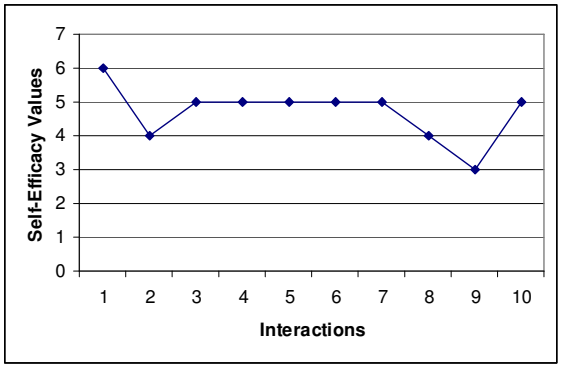

Figure 7.17 Review Self-Efficacy Values – Full Support

Figure 7.17 illustrates the self-efficacy path for the review tutoring tactic for participants who were provided with full-support when using P.A.C.T.. Similarly, to Study 1 the reader is reminded that the x-axis corresponds to the number of interactions with the tutoring tactic the number of interactions may vary for each tactic. The y-axis corresponds to self-efficacy and is measured using a value from 1 to 7. Each self-efficacy value illustrated in Figure 7.17 is calculated based on the average self-efficacy values of all participants who received full support, where all values are rounded to the nearest whole number. More specifically, the first value illustrated on the graph corresponds to the average submitted self-efficacy value of parents' first interaction with that tutoring tactic. The second value corresponds to the average submitted self-efficacy value of parents' second interaction with the tactic and so on. As P.A.C.T. suggests tutoring tactics based on the affective needs of the child each parent may have interacted with each tutoring tactic a varying number of times. As with Study 1, in order to overcome bias a threshold was identified whereby only values were included where they comprised the average of a minimum of three submitted self-efficacy values across all participants in that group. Table 7.26 illustrates the percentage of the population (number of participants) included in calculating each of the averages in Figure 7.17 and as can be seen from Table 7.26 the majority are calculated based on the submitted self-efficacy values of more than 50% of all participants.

Table 7.26 Calculating Self-Efficacy Values – Review Full Support

Interaction	Self-Efficacy Value	% Population Included
1	6	100
2	4	100
3	5	100
4	5	89
5	5	78
6	5	56
7	5	56
8	4	33
9	3	33
10	5	33

The self-efficacy path is erratic across interactions. However, it does show a steadiness in self-efficacy in so far as all but three values lie in the same self-efficacy level (efficacy values of 5-6), with values outside this range lying in the 3-4 self-efficacy level.

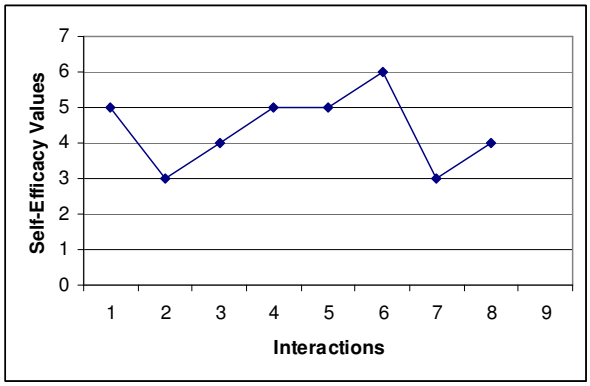

Figure 7.18 Mastery Learning Self-Efficacy Values – Full Support

Figure 7.18 illustrates the self-efficacy path for the mastery learning tutoring tactic of those receiving full support. After the initial drop, a steady increase in self-efficacy values

can be observed, save the last two values. Interestingly, similar to the review efficacy path all values lie in one of two efficacy levels, the 5-6 efficacy level or 3-4 efficacy level. Table 7.27 illustrates the percentage of the population included in calculating each of the averages in Figure 7.18.

Table 7.27 Calculating Self-Efficacy Values – Mastery Learning Full Support

Interaction	Self-Efficacy Value	% Population Included
1	5	89
2	3	78
3	4	78
4	5	67
5	5	56
6	6	33
7	3	33
8	4	33

Figure 7.19 illustrates the self-efficacy path for the positive reinforcement tutoring tactic. Again all values lie in the 3-4 or 5-6 efficacy level. This graph appears a little more erratic than the previous two graphs. It may not be coincidental that the percentage population used in calculating 66% of the averages is less than 50%. This is illustrated in Table 7.28 where 3 of the 9 values are calculated using 56% or more participants while the other 6 values are calculated using 44% or fewer participants.

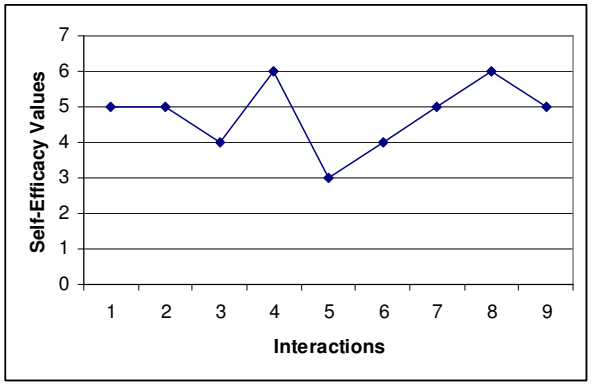

Figure 7.19 Positive Reinforcement Self-Efficacy Values – Full Support

Table 7.28 Calculating Self-Efficacy Values – Positive Reinforcement Full Support

Interaction	Self-Efficacy Value	% Population Included
1	5	100
2	5	78
3	4	56
4	6	44
5	3	44
6	4	33
7	5	33
8	6	33
9	5	33

In summary, few patterns have emerged from the self-efficacy paths of those parents who received full support from P.A.C.T. However, interestingly all values across all paths lay in one of two efficacy levels, level 3-4 or level 5-6. The unstructured order of the efficacy paths may not be altogether surprising when one remembers that self-efficacy is task specific. Albeit that every endeavour was made to encourage participants to submit a self-efficacy value corresponding to their confidence in using the tutoring tactic, this may not have occurred. Instead, it may be that participants submitted values based on their reaction to specific activities suggested by P.A.C.T. as opposed to their confidence in using the particular tactic.

Figure 7.20 illustrates the self-efficacy path for the review tutoring tactic of those participants receiving adaptive support. This graph illustrates a steady increase in self-efficacy from 4 to 6 across the 9 interactions. This signifies an increase in self-efficacy from the 3-4 level to the 5-6 level. As can be viewed in Table 7.27 all but two averages were calculated based on self-efficacy values of over 50% of the population

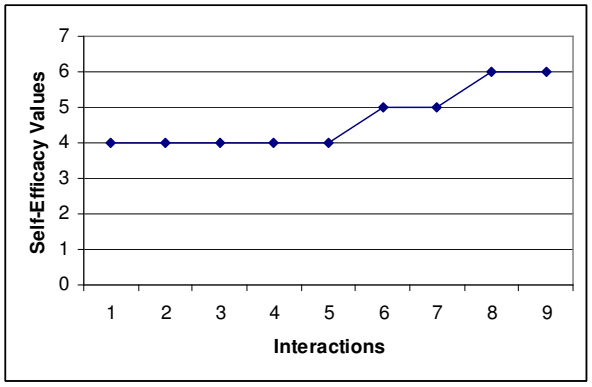

Figure 7.20 Review Self-Efficacy Values – Adaptive Support

Table 7.29 Calculating Self-Efficacy Values – Review Adaptive Support

Interaction	Self-Efficacy Value	% Population Included
1	4	100
2	4	100
3	4	91
4	4	91
5	4	91
6	5	73
7	5	64
8	6	36
9	6	27

Figure 7.21 illustrates the self-efficacy path for the mastery learning tutoring tactic for those receiving adaptive support. The graph illustrates an overall steady increase in self-

efficacy. There is one drop in self-efficacy, where at interaction 3 self-efficacy decreases from 5 to 4. At interaction 4, self-efficacy is on the increase once more with its value increasing from 4 to 5 for interaction 5.

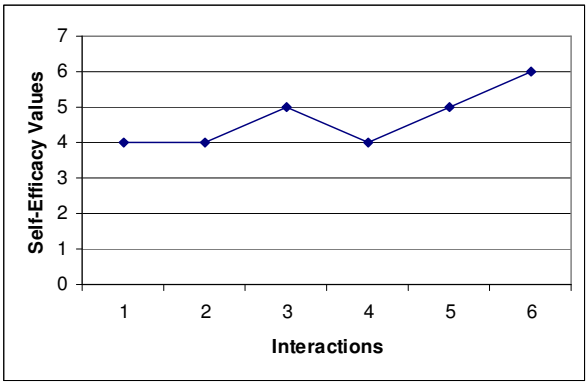

Figure 7.21 Mastery Learning Self-Efficacy Values – Adaptive Support

Table 7.30 illustrates that the plotted self-efficacy values are based on the average self-efficacy values of a high proportion of the population (64 – 100%) and therefore may be taken as representative.

Table 7.30 Calculating Self-Efficacy Values – Mastery Learning Adaptive

Interaction	Self-Efficacy Value	% Population Included
1	4	100
2	4	100
3	5	82
4	4	82
5	5	73
6	6	64

The self-efficacy path plotted in Figure 7.22 represents the self-efficacy values for the positive reinforcement tutoring tactic. Similarly, to the mastery learning tactic with positive reinforcement an overall increase in self-efficacy is illustrated. There is one drop

in self-efficacy at the fifth interaction where self-efficacy decreases from 5 to 4. However, at interaction 6 self-efficacy increase once again with its value increasing from 4 to 5. Self-efficacy remains at a value of 5 for the reminder of the path.

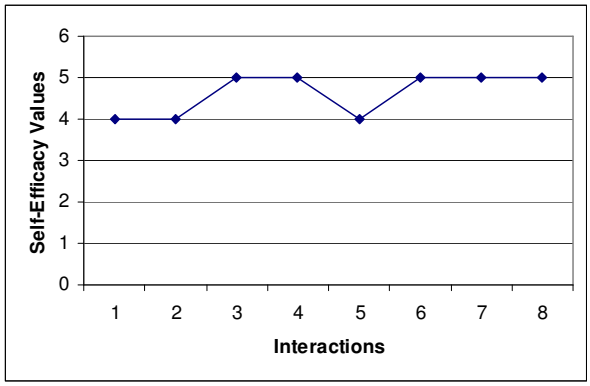

Figure 7.22 Positive Reinforcement Self-Efficacy Values – Adaptive Support

Table 7.31 illustrates that the first half of self-efficacy path illustrated in Figure 7.22 comprises values based on 64-91% of the population while the remaining values are based on 36-45% of the population.

Table 7.31 Calculating Self-Efficacy Values – Positive Reinforcement Adaptive

Interaction	Self-Efficacy Value	% Population Included
1	4	91
2	4	82
3	5	64
4	5	64
5	4	45
6	5	36
7	5	36
8	5	36

Results indicate that overall there was an increase in self-efficacy across the review, positive reinforcement and mastery learning tutoring tactics for those participants who received adaptive support.

As described previously P.A.C.T. adapts the level of support provided based on the self-efficacy value submitted by the parent for that tutoring tactic. However, in Study 2 P.A.C.T. also provided parents with an opportunity to request the next level of support. Interestingly, 63% of participants receiving adaptive support requested additional support from P.A.C.T. at some point throughout the study. This indicates that on average participants did not receive the desired level of support, which suggests a dichotomy between parental self-efficacy and desired level of support.

A number of patterns emerged from the data surrounding requests for additional support. Interestingly, further support was requested for four of the six tutoring tactics namely, mastery learning, motivational game, positive reinforcement and review. Based on all requests for additional support, request for further support with review comprised 82% followed by mastery learning 9%, positive reinforcement 8% and motivational game 1% as illustrated in Figure 7.23. This may not be altogether surprising as these were also the order for most frequently suggested tutoring tactics (reader is directed to Figure 7.16). However, perhaps more interestingly, upon further inspection results indicate that 56% of the time that the review tutoring tactic was suggested participants asked for further support. 24% of the time that mastery learning was suggested participants asked for further support. 23% of the time that positive reinforcement was suggested participants asked for further support and finally 8% of the time that motivational game was suggested participants asked for further support. This is illustrated in Figure 7.24. This suggests a difference between parents perceived level of self-efficacy and desired level of support.

For example with the review tactic participants submitted a self-efficacy value, which did not equate to their desired level of support more than half of the time. Furthermore, based on all requests for additional support 27% of requests involved parents requesting an explanation of the tutoring tactic (self-efficacy level 5-6) while 73% of requests involved parents requesting an example of the tutoring tactic (self-efficacy level 3-4). As participants can only request further support at the 3-4 self-efficacy level if they have previously received support at the 5-6 self-efficacy level this suggests that participants may require an example in order to perform the task. Additionally, there may be a tendency to submit a self-efficacy value of 5-6 even if the level of support desired equates to a self-efficacy value of 3-4.

In terms of strategies used for requesting additional support 31% of requests involved requesting further support at the 5-6 self-efficacy level and immediately requesting further support at the 3-4 self-efficacy level. This equates to asking P.A.C.T. for an explanation of the tutoring tactic and immediately asking for an example. 6% of request involved only asking for further support at the 5-6 level, this corresponds to only asking for an explanation and not requiring an example.

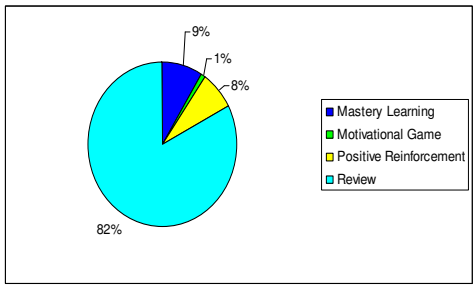

Figure 7.23 Breakdown of Requests for Additional Support by Tutoring Tactic

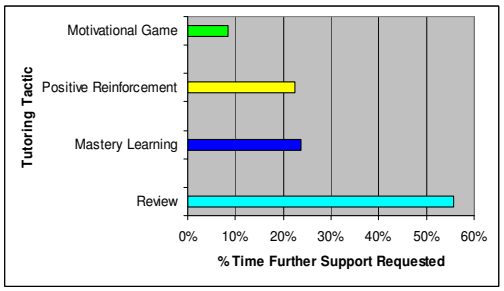

Figure 7.24 % Time Further Support Required by Tutoring Tactic

Finally, 63% of requests involved asking for further support at the 3-4 self-efficacy level, this equates to P.A.C.T. suggesting an appropriate tutoring tactic and providing an explanation and the participant asking for an example. This suggests a dichotomy between parents perceived level of self-efficacy and desired level of support because as illustrated in Table 7.32, 31% of requests involved participants submitting a self-efficacy value of 7 but desiring a level of support corresponding to a self-efficacy value of 3-4, this is a substantial difference.

Table 7.32 Requests for Further Support

% Requests for Further Support	Submitted Self-Efficacy Value	Desired Level of Support
31%	7	Level 3-4
6%	7	Level 5-6
63%	5-6	Level 3-4

In summary, results indicate an overall increase in self-efficacy between pre and post test. Self-efficacy paths of participants receiving adaptive support show an increase in self-efficacy, the same cannot be said for participants who did not receive adaptive support. On participants receiving adaptive support, results indicate a dichotomy between parents perceived level of self-efficacy and desired level of support. More specifically patterns have emerged which indicate that parents are entering efficacy values, which are too high for their desired level of support. 31% of requests for further support were as a result of parents submitting a self-efficacy value of 7 but desiring a level of support corresponding to a self-efficacy value of 3-4. This may indicate a lack in understanding of the link between self-efficacy and ability, or indeed an eagerness to appear confident in their ability, which may lead to unwillingness to ask for assistance. Therefore, there is a need for future research into the design of a more subtle instrument for collecting self-efficacy values.

7.3.1.2 Parents' Knowledge

The data was analysed in order to identify the effect of P.A.C.T. on parents' knowledge. Similarly to Study 1 knowledge was analysed from two aspects (1) did parents gain an understanding of what was meant by each of the tutoring tactic (2) did parents gain an understanding of when to use each tutoring tactic.

Do you know what Expert Demonstration is?	☐ Yes ☐ No
Do you know when to use Expert Demonstration?	☐ Yes ☐ No

Figure 7.25 Pre and Post Questionnaire Example

The primary instrument for data collection for this purpose was a pre and post questionnaire. An extract from the questionnaire is shown in Figure 7.25 where the participant is asked (1) do they know what is meant by expert demonstration and (2) do they know when to use it. Participants can answer yes or no. The yes/no option was selected above a likert scale in Study 2 in order to avoid over complicating the process. Both pre and post questionnaires comprise similar questions for all six tutoring tactics. Additional data was collected through a short questionnaire (reader is directed to Appendix). Participants using P.A.C.T. in the school's computer lab completed this short questionnaire at the end of each session. Participants using P.A.C.T. at home completed the short questionnaire during a group meeting and during one-to-one interviews where

the short questionnaire formed the basis of the interview. For the remainder of this chapter we will refer to all three data collection activities as questionnaires. Despite attempts to use simple straightforward data collection instruments, completion rates were low as parents found it difficult to complete the questionnaire.

Results indicate an increase, between pre and post tests, in the number of parents who indicated understanding of what each tutoring tactic comprised. This is illustrated in Table 7.33. Most notable are the increases in mastery learning (increase of 42%) and positive reinforcement (increase of 26%). Interestingly, in the post test all participants indicated an understanding of what the review tactic comprises. It is unsurprising that expert demonstration showed little increase from pre to post test as it was suggested so infrequently (1%) by P.A.C.T. (reader is directed to Figure 7.16). However, despite the infrequency with which P.A.C.T. suggested tutoring variation (1%) there was an increase in understanding from 29% to 50% between pre and post test, this is difficult to explain.

Table 7.33 Knowledge (What) Pre and Post Test Scores

	Pre-Test		**Post-Test**	
	Yes	**No**	**Yes**	**No**
Expert Demonstration	44%	56%	50%	50%
Mastery Learning	31%	69%	73%	27%
Motivational Game	60%	40%	82%	18%
Positive Reinforcement	47%	53%	73%	27%
Review	75%	25%	100%	
Tutoring Variation	29%	71%	50%	50%

Table 7.34 illustrates the pre and post test results based on parents' knowledge of when to use particular tutoring tactics. It is interesting to note that a comparison of pre test scores of parents' knowledge of when to use particular tutoring tactics and parents' knowledge of what each tutoring tactic comprises, indicates that prior to using P.A.C.T., a higher percentage of parents understood what each tutoring tactic comprised than of when each tactic should be used. Analysis of data pertaining to parents' knowledge of when to use particular tutoring tactics indicates an overall increase in the percentage of parents who know when to use particular tutoring tactics from pre to post test. In this instance,

motivational game was the tutoring tactic, which showed the highest increase (52%). This is followed by review (44%) and mastery learning (42%).

Additional data collected from participants based on their experiences indicated that a high proportion of parents had great difficulty in using the computer (not even in using P.A.C.T.). Table 7.35 lists some of the challenges encountered by participants. Results are reported using pseudonyms in an endeavour to protect participants' identity. Holly learnt how to switch on the computer, Andrea states she learnt hoe to use the computer. Niamh, Mary and Tina report that they have learnt how to log-in. Logging in involved putting in a username and password.

Table 7.34 Knowledge (When) Pre and Post Test Scores

	Pre-Test		Post-Test	
	Yes	**No**	**Yes**	**No**
Expert Demonstration	27%	74%	42%	58%
Mastery Learning	25%	75%	67%	33%
Motivational Game	38%	63%	90%	10%
Positive Reinforcement	36%	64%	73%	27%
Review	56%	44%	100%	
Tutoring Variation	21%	79%	50%	50%

The username and password were written on a card and placed beside each person's computer desk. The username was the parent's first name and the password was alphanumeric. In terms of data supporting an increase in their knowledge of tutoring tactics, the review tutoring tactic was the tactic, which was most frequently stated. Other tutoring tactics mentioned included mastery learning, repetition and positive reinforcement. Participants did not elaborate on their responses. The fact that this study was carried out in designates disadvantaged schools may be a contributing factor to this as there may have been a limited ability in articulating what was happening at a deeper level. However, as previously stated results indicate an increase across all tactics in terms of parents' understanding of what these tactics comprise and when to use them, which indicates that learning did in fact take place.

In summary, results indicate that P.A.C.T. had a positive effect on parents' knowledge. This is indicated by the increase from pre to post test in the percentage of people who stated an understanding of what each of the tutoring tactics comprised and

when each should be used. In particular, there was a significant increase from pre to post test in the percentage of parents indicating understanding of what mastery learning comprised and when to use it. Results also indicate a lack in computing skills and a need to equip parents with greater computing knowledge.

Table 7.35 Computer Challenges

Tina – I learnt to login
Andrea – Learning to use computer
Niamh – learn to use computer, to put in my name
Mary – to log in
Holly – how to switch on computer

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7.3.1.3 Role as Home Tutor

During the short questionnaires and on the post questionnaire participants were asked if their perception of the role as home tutor had changed because of using P.A.C.T., and if so to explain this change. For those participants who completed this section many reported a change and these are illustrated in Table 7.36.

Mathew, Paula and John report on the need for more structure during homework sessions. This may not be surprising as P.A.C.T. provides guidance for both parent and child through the different elements of practice. In addition, Breda reports a new understanding of the benefit of review.

Mathew, Paul and John also report the need to make homework more fun and positive. Joan's comment is succinct in so far as she simple states "encouragement works". Anna also reports a deeper sense of understanding of the need for praise in order to build the child's confidence. Interestingly, P.A.C.T. may not only assist in providing a positive environment for the child as Mary reports that when using P.A.C.T. she is more relaxed.

Emma and Holly suggest that P.A.C.T. may be of benefit in reminding parents of the need to give full attention during homework time. Both parents report on the benefit of spending one-to-one time with their child. When using P.A.C.T. parents are involved at

each step of the homework thus encouraging parents as well as children to remain engaged in the homework process.

Finally, some parents reported that P.A.C.T. encouraged an increased awareness of their child's affective state. Anna reports that now if her child is not in form for homework they can do it later thus demonstrating an understanding of the need for positive affective states in order for learning to take place. In addition, Rachael states that she learnt how her child was feeling.

In summary, parents' perception of their role as home tutor after using P.A.C.T. can be categorised in terms of the need to (1) provide more structure (2) give more attention (3) be more fun/positive (4) be more aware of the child's emotional needs.

Table 7.36 Role as Home Tutor

Mathew - Learnt about interaction, needs to be more fun, more structured.
Paula - Make it more fun, more structured, more consistent.
John - To make homework more fun, more structured, more consistent and more positive. Building the confidence of your child.
Breda – Don't think it changed but to be aware that reviewing work does help
Anna – Yes, the praise element. If the child wasn't in form, come back to it later. Always praise lots of it to build confidence.
Emma - It gave me a chance to have one to one with my child.
Joan - Encouragement works.
Holly - Spending a few minutes with one child is great.
Rachael - Learnt how Olwyn is feeling today?
Mary - Yes am more relaxed.

7.3.1.4 The Effect of P.A.C.T. on Parents Summary

In summary results, indicate an overall increase in self-efficacy between pre and post test most noticeably with positive reinforcement and review. Self-efficacy paths of participants receiving adaptive support show an increase across review, mastery learning and positive reinforcement. The same cannot be said for participants who did not receive adaptive support. On participants receiving adaptive support, results indicate the dichotomy between parental self-efficacy and desired level of support in so far as 63% of participants receiving adaptive support from P.A.C.T. requested additional support at some point throughout the study. Additionally, results indicate that P.A.C.T. had a positive effect on parents' knowledge. This is suggested by the increase from pre to post test in the percentage of people who indicated an understanding of what each tutoring tactics comprised and when each should be used. In particular, significant increases can be observed for the mastery learning and motivational game tutoring tactic. Results also indicate a lack in computing skills among parents, which needs to be addressed at a national level. Finally, on parents' perception of their role as home tutor, results suggest that P.A.C.T. may have a positive effect in increasing parents' awareness for the need for structure, to be more positive, to give more attention and finally to be more aware of the child's affective needs.

7.3.2 The provision of Affective Support

This section provides insights into effect of providing affective support for the child throughout the home tutoring process of mathematics. Firstly, results pertaining to the child's affective experience are presented. This indicates the breakdown of affective reports across the four basic emotions. This may be of benefit in identifying the effect of P.A.C.T. on the child's affective state. Secondly, results pertaining to the strategies used in eliciting affect will be presented. Finally, data indicating the effect of P.A.C.T. on the home tutoring process will be outlined. As P.A.C.T. adapted to the affective needs of the child for all participants a comparison of parents receiving full versus adaptive support (based on self-efficacy) is irrelevant and therefore will not be presented.

7.3.2.1 Affective Experiences

The tutoring model within P.A.C.T. is based on the premise that children learn best when they are happy and if a child is unhappy strategies should be employed in order to alter their affective state. With this in mind, there was an expectation that P.A.C.T. would assist in creating a positive homework environment, which may as a result lead to

positive affective states during homework time. In order for P.A.C.T. to suggest the next activity, the affective state of the child must be inputted. All inputs are logged in the child's user model. Therefore, it is possible to ascertain the child's affective experience, which is a breakdown of the number of occasions where the child was experiencing each of the four basic emotions (sad, happy, angry and fearful).

Figure 7.26 illustrates that in the main children were happy (67%) when using P.A.C.T. with an even distribution among the other three emotions namely, sad (10%), angry (10%) and fearful (13%). In order to explore this finding further it is necessary to identify the strategies used in determining the child's affective state and the effect of adapting the tutoring process based on that.

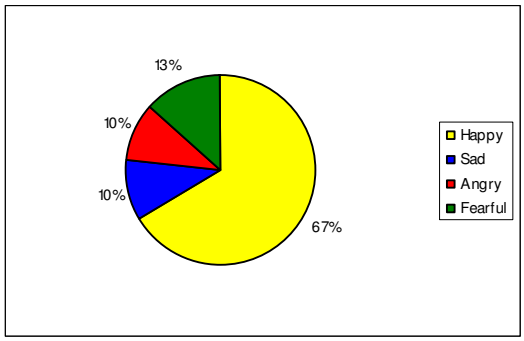


Figure 7.26 Affective Experiences

7.3.2.2 Strategies for Eliciting Affect

Based on the results from Study 1 parents were asked to select one of three strategies which best-represented how the child's affective state was elicited. These categories comprise self-report, collaborative-report and observed-report. The self-report strategy involves the child solely deciding which emoticon best represents their affective state. The collaborative-report strategy involves a discussion around the affective state of the child from which a decision emerges. Finally, the observed-report strategy involves the parent solely deciding which emoticon best represents the affective state of their child. Based on those who provided data for this question 55% stated that they predominantly used the self-report strategy while 45% reported that they predominantly used the collaborative-report strategy. There were no reports of using the observed-report strategy. This is not entirely surprising as due to the lack of computing skills among participants the child often assumed the role of navigator through the system. Therefore, it would

have been difficult for the parent to select an affective state for the child without any collaboration.

7.3.2.3 Adapting based on Affect

In addition to knowing the strategy used in eliciting emotion, it is also useful to understand the basis for decision-making. Three patterns of decision-making emerged from Study 1 namely, experimentation, trickery and gaming, and the feedback from Study 2 is analysed using these categories. The reader is reminded that experimentation involves the selection of an emoticon other that that which best represents the current affective state out of a curiosity of what may happen next. Trickery involves assuming an affective state other that that which one is currently experiencing. Finally, gaming the system involves using the system rules against itself for the child's own benefit. It is important to note that results described here are based on the parents' perception of events. Parents were asked during post questionnaire/short questionnaires to identify what they perceived to be the basis for their child's decision-making. Based on those who provided feedback 66% of parents reported that the predominant basis for decision-making was experimentation. The remaining 44% of participants reported that the child predominantly selected the emoticon, which best represented their current affective state. There were no reports of trickery or gaming. Unlike other systems, due to the design of P.A.C.T.'s tutoring model experimentation may not lead to limited learning as all paths through the system promote learning.

7.3.2.4 Affective Support Summary

In summary, results indicate that when using P.A.C.T. children indicated a happy affective state 67% of the time. On analysis of the strategy used for eliciting affect, 55% of responses indicated the use of a self-report strategy while 44% of responses indicated the use of a collaborative-report strategy. As the use of a collaborative-strategy may encourage a more refined basis for selecting emoticons, thus enabling greater learning there may be a need to promote greater collaboration around such activities. On analysis of the decision-making process for selection of emoticons, 66% of responses indicated experimentation while 33% indicated that the emoticon selected was a true representative of the child's affective state. This suggests a need for intelligent design of the tutoring model within systems, which adapt to the affective needs of the child, in order to avoid limited learning as a result of experimentation or gaming.

7.3.3 Role of P.A.C.T.

In any educational environment, it is interesting to identify where technology can be of most benefit, this was the motivation behind asking parents to identify their perception of the role of P.A.C.T. during the home tutoring process. Again, data was collected from post-questionnaire and short questionnaires. As parents found it challenging to give feedback, they were provided with six options in an endeavour to supply a straightforward mechanism for feedback. The particular options selected were based on results from Study 1 and comprised (1) fun/game (2) mediator (3) the boss (4) friend (5) teacher (6) other. This is illustrated in Figure 7.27. Additionally, the question was phrased in such a way to promote comprehension and parents could choose as many options as they wished.

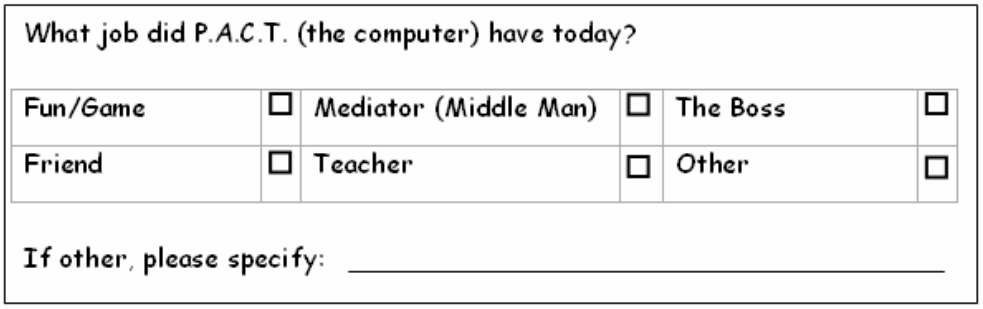


Figure 7.27 Role of Technology

100% of responses indicated that the role of P.A.C.T. was to provide fun/games. This can be more generically thought of as providing a positive learning environment. Additionally, 33% indicated that the role of P.A.C.T. was also mediator, 2% of responses indicated, that P.A.C.T. also played the role of boss and 1% of responses indicated that P.A.C.T. also played the role of friend. Interestingly, there were no indications that P.A.C.T. might play the role of teacher. This is encouraging, as P.A.C.T. was not developed in an endeavour to replace the teacher or indeed the parent as home tutor but rather to support the homework process.

7.3.3.1 Role of P.A.C.T. Summary

In summary results indicate that P.A.C.T. may be of most benefit in creating a more positive learning environment in the home. Additionally, PA.C.T. may be of benefit in mediating the homework process. Therefore, there may be a need for further research in an endeavour to exploit the benefits of technology in supporting the home tutoring process.

7.3.4 Study 2 Summary

In summary, results indicate that P.A.C.T. may be of benefit in increasing self-efficacy. In particular, results suggest that personalising the level of support received by parents may have a positive effect on self-efficacy. However, there is still a need for further research in the design of instruments to collect self-efficacy values within adaptive intelligent systems. Additionally results suggest that providing support throughout the home tutoring process can have an impact on parents' knowledge of home tutoring best practice. Increases were observed across all tutoring tactics in the number of parents' who gained understanding of what the tactic comprised and when to use it. However, there is evidence to suggest that a possible challenge of the home tutoring domain may be in equipping parents with the necessary computing skills. Finally, PA.C.T. may be of benefit in creating a positive learning environment and in mediating the homework process. To this end, results indicate the benefit of P.A.C.T. in supporting the home tutoring process in the domain of mathematics.

7.4 Discussion

Both studies presented in this chapter investigated the effect of using an adaptive educational system to support home tutoring. In particular, the studies investigated the effect of using such a system on parents' (1) self-efficacy (2) knowledge and (3) their perception of their role as home tutor. In addition, the studies investigated the effect of adapting to the affective needs of the child and finally the role of P.A.C.T. during the home tutoring process. Where these studies varied was the domain in which they were conducted. Study 1 was conducted in the domain of Suzuki violin, while Study 2 was conducted in mathematics. This section will provided analysis on the similarity of results across the two studies and identify what conclusions, if any, can be drawn from integrating the results from both studies. Table 7.37 provides a comparison of results from both studies and identifies whether the results were similar or not.

In both studies, an increase in self-efficacy across all tutoring tactics was observed. For Study 1 this is based on seven tutoring tactic, for Study 2 it is based on six tutoring tactics. The reason being is that the repetition tutoring tactic is omitted in Study 2 due to its natural implicit inclusion in the quantity of homework assigned by the teacher.

The data from Study 1 was further analysed in order to investigate the effect of adaptive versus non-adaptive support on parental self-efficacy using an independent sample t-test. Results were analysed using two approaches. Firstly, the post test scores of group 1 (full support) were compared with the post test scores of group 2 (adaptive support). Albeit that results did not identify any statistically significant difference results, results for the review (p=.084) tactic and repetition tactic (p=.093) were approaching statistical significance where the mean scores of group 2 (adaptive support) were higher than that of group 1 (full support). Secondly, an independent sample t-test was conducted using the difference between pre and post test scores for each of the tutoring tactics. Again, no statistical differences were identified, however, the results of positive reinforcement (p=.059) and review (p=.076) were approaching statistical significance where the mean scores of group 2 (adaptive support) were higher than that of group 1 (full support). Unfortunately, it was not possible to carry out such analysis for Study 2 due to small cell size. Despite some results approaching statistical significance, the results suggest that there may be little benefit in providing adaptive support for parents in this context.

For both studies a deep analysis was performed on the self-efficacy paths of the three most frequently suggested tutoring tactic. For Study 1 these comprised mastery learning, repetition and review. For Study 2 they comprised review, mastery learning and positive reinforcement. In terms of the self-efficacy paths of participants who received full support no clear patterns emerged in Study 1 or Study 2. The reason for this may be that as the self-efficacy value submitted by the parent did not influence the level of support provided by P.A.C.T. values were submitted in a slightly ad hoc manner.

Similarly, no clear patterns emerged from the self-efficacy paths of those receiving adaptive support in Study 1. Qualitative data indicates that this may be because of a dichotomy between parents perceived level of self-efficacy and desired level of support. More specifically, parents desire to enter high levels of self-efficacy resulted in P.A.C.T. providing low levels of support, which parents found unsatisfactory. As stated previously this was surprising as research suggests that highly efficacious students seek challenging learning experiences (Sewell & St George, 2000), which suggests that low levels of support would be adequate. However, interaction logs suggest the contrary with parents

re-analysing their self-efficacy in order to receive greater support leading to turmoil in the self-efficacy paths.

Bandura (1986) provides one possible explanation in his suggestion that the most functional efficacy judgments tend to exceed what one can actually accomplish. This suggests that parents may enter self-efficacy values that exceed their ability. Although, the benefit of high perceptions of capability in the face of low knowledge of tutoring tactics remains unknown, it is clear that efforts to decrease parental self-efficacy, in order for parents to receive appropriate levels of support should be avoided.

Therefore, in Study 2, a slight modification was made to the adaptive strategy in so far as once parents received the level of support corresponding to their self-efficacy value they had an opportunity to request further support. It appears from the data that this slight modification had a stabilising effect on the self-efficacy paths. A clear pattern emerged from the data consisting of overall increases in all three self-efficacy paths. The provision of additional support in Study 2 provides a mechanism to further investigate this possible dichotomy between parental self-efficacy and desired level of support.

Indeed, data collected in Study 2 corroborates the findings from Study 1. More specifically, data indicates that 31% of requests for further support in Study 2 resulted in parents progressing from a level of support corresponding to a self-efficacy value of 7 to a level of support corresponding to a self-efficacy value of 3-4. This represents a substantial difference. Although Bandura (1986) suggests that this overestimation serves to increase effort and persistence it provides an additional complexity for adaptive educational systems, which attempt to provide personalised support based on self-efficacy.

In terms of parents' knowledge of what each tutoring tactic comprised an increase in knowledge was observed from pre to post test among participants across both studies. In Study 1, a paired-sample t-test was conducted which showed a statistically significant increase in many tutoring tactics most notably mastery learning ($p=.024$) and motivational game ($p=.034$). Similarly, in Study 2 a significant increase (42%) can be observed form pre to post tests in the percentage of participants who understood what the mastery learning tactic comprised. Results also indicate an increase in knowledge of when to use particular tactics from pre to post test scores among participants across both studies. Statistically significant increases can be observed in Study 1 for mastery learning ($p=.004$) and motivational games ($p=.015$).

Table 7.37 Comparison of Results of Study 1 and Study 2

Analysis	Study 1 –Suzuki Violin	Study 2 –Maths	Comparable Result?
Self-Efficacy Pre & Post Test Scores	Increase in self-efficacy across all 7 tutoring tactic	Increase in self-efficacy across all 6 tutoring tactic	Yes
Full Support Self-Efficacy Path	Erratic self-efficacy paths no clear pattern emerged	Erratic self-efficacy path no clear pattern emerged. No overall increase in self-efficacy	Yes
Adaptive Support Self-Efficacy Path	Erratic self-efficacy paths no clear pattern emerged	Steady increase in self-efficacy paths	No
Knowledge	Increase in knowledge level among participants of what each tactic comprises and when each should be used	Increase in knowledge level among participants of what each tactic comprises and when each should be used	Yes
Role as Home Tutor	(1) provide more structure (2) give more attention (3) be more fun/positive (4) be more aware of the child's emotional needs	(1) provide more structure (2) give more attention (3) be more fun/positive (4) be more aware of the child's emotional needs	Yes
Affective Experience	70% Happy, 10% Sad 9% Angry, 11% Fearful	67% Happy, 10% Sad 10% Angry, 13% Fearful	Yes
Strategies for Eliciting Affect	Self-Report Collaborative-Report Observed-Report	Self-Report Collaborative-Report	Yes
Effect of providing Affective Support	Experimentation Trickery Gaming	Experimentation	Yes
Role of Technology	Creating a positive learning environment Mediator	Creating a positive learning environment Mediator, Boss, Friend	Yes

Similarly, significant increases in the percentage of parents who understood when to use the mastery learning (increase of 42%) and motivational game (increase of 52%) tactics were observed in Study 2. This suggests that P.A.C.T. may be of benefit in increasing parents' knowledge of home tutoring best practice, in particular, in providing an understanding of the range of skills, which can be used, and when to use them.

The data from Study 1 was further analysed in order to identify the effect of adaptive versus non-adaptive support on parents' knowledge. An independent sample t-test was conducted. Although no statistically significant differences were identified results based on parents knowledge of when to use repetition (p=.093) was approaching statistical significance where the mean score of group 2 (adaptive support) was higher than that of group 1(full support). Additionally, an independent sample t-test was conducted using the difference between pre and post test scores for each of the tutoring tactics. Again, no statistically significant differences were identified. However, results of participants' knowledge of when to use positive reinforcement (p=.059) were approaching statistical significance, again the mean scores of group 2 (adaptive support) were higher than that of group 1(full support). Unfortunately, it was not possible to carry out such analysis for Study B due to small cell size. Overall, despite some results approaching statistical significance the results suggest that there may be little benefit in providing adaptive support for parents in this context. This is quite surprising giving rise to a need for further more detailed studies.

Both studies also revealed that P.A.C.T may encourage parents to (1) provide more structure (2) give more attention (3) be more fun/positive (4) be more aware of the child's emotional needs in their role as home tutor. Perhaps it may not be altogether surprising that P.A.C.T. provided a structure for home practice. Additionally, it is not surprising that using P.A.C.T. might encourage parents to be more aware of their child's emotional needs. However, it was somewhat unexpected that P.A.CT. could encourage parents to be more attentive and more positive home tutors. Deep analysis of the findings suggests that due to the nature of P.A.C.T. and the need for such parental involvement in using it parents were encouraged to give their full attention to the home practice therefore transcending the desire to multi-task. Qualitative data indicated that they could see that giving their child their full attention had a positive effect on the learning environment and parent-child dynamic. In addition, data indicates that P.A.C.T. afforded parents the opportunity to discover that in a positive learning environment much can be accomplished with qualitative data suggesting that negativity is never necessary.

On the effect of P.A.C.T. adapting to the affective needs of the child results indicate substantial corroboration across both studies. Firstly, there is a high correlation between affective experiences in Study 1 and Study 2. Affective experiences comprised, happy 70% in Study 1 and 67% of the time in Study 2, sad 10% in both studies, angry 9% in Study 1 and 10% in Study 2 and fearful 11% in Study 1 and 13% in Study 2. Secondly, the collaborative-report strategy was the strategy, which was used most often across both studies. Results from both studies also indicate the use of the self-report strategy. The observed-report strategy was used in Study 1 but not at all in Study 2. Qualitative data may provide a reason for this in terms of the high dependency on the child in terms of their computing skills. Additionally, Study 1 provides qualitative data, which indicates the associated problems with using either the self-report strategy or observed-report strategy. This suggests that there may be a need to modify the instrument used in eliciting emotion to encourage collaboration. Finally, on the effect of adapting to the affective needs of the child results from both studies suggest the possible risk of gaming. In Study 1, three levels of gaming were observed experimentation, trickery and gaming itself. In Study 2, only experimentation was observed. Due to the design of P.A.C.T.'s tutoring model, experimentation or trickery may not lead to limited learning. However, there is a need for clever design when developing affectively intelligent systems so that gaming may not necessarily lead to limited learning.

Qualitative data from Study 1 suggests that P.A.C.T. can be of benefit during the home tutoring process in creating a positive learning environment and acting as mediator between parent and child. In Study 2, participants were provided with six options (based on the results of Study 1) with which to identify the role of P.A.C.T. during home practice. Participants could select as many options as they wished. 100% of responses indicated that P.A.C.T. might be of benefit in creating a positive learning environment. Additionally 33% indicated that P.A.C.T. might be of benefit in mediating between parent and child. Other responses indicated that P.A.C.T. might play the role of boss (2%) or friend (1%). This suggests that adaptive educational systems may have particular benefit in this domain of home tutoring and more specifically such systems may be of benefit where there is a need for mediation or for an external influence to positively influence the learning environment.

The reader is reminded that the empirical research questions at the core of Study 1 and 2 comprise:

- What is the effect of using P.A.C.T. on parents' (1) self-efficacy (2) knowledge and (3) perception of their role as home tutor?

- What is the effect of adapting to the affective needs of the child throughout the home tutoring process?

Additionally, data was also collected to investigate the role of P.A.C.T. throughout the home tutoring process. In summary, results indicate that P.A.C.T. had a similar effect on the home tutoring process in the specific domain of Suzuki violin and the more mainstream domain of mathematics. There were a number of findings, which were corroborated across both studies. These can be summarised as follows:

- The use of adaptive educational systems can have a positive effect on parental self-efficacy, knowledge of tactics and when to use them, and their perception of their role as home tutor.
- Adaptive educational systems, which adapt to the affective needs of the child, can be of benefit in promoting a positive learning environment.
- Adaptive educational systems may have a role to play in the home tutoring process in terms of assisting in the creation of a positive learning environment and acting as mediator.

8 Conclusions

8.1 Introduction

Adaptive educational systems may be of benefit in supporting learning environments where two or more users work together towards a common goal such as learning. However, in the design and development of such systems a number of research challenges exist. Outstanding research questions include: (1) is it possible to design and develop an architecture, which can simultaneously support multiple users with different roles such as tutor and tutee, (2) what is an appropriate educational theory to inform tutoring best practice and (3) what is an appropriate basis for adapting to the needs of the tutor and tutee?

This thesis has described how the adaptive educational system, P.A.C.T. addresses these challenges in order to create a positive learning environment for home tutoring. Firstly, it described how P.A.C.T.'s novel architecture provides simultaneous adaptive support for both tutor (parent) and tutee (child). Secondly, it described how the articulation and development of the set of novel tutoring rules informed by Talent Education philosophy defines tutoring best practice. Thirdly, it described the results from research studies, which identify the effectiveness of using self-efficacy as a basis for adaptive support for the tutor and the effectiveness of using affect as a basis for adaptive support for the tutee.

The following sections summarise the main research findings, the limitations of the research work and some directions for future research.

8.2 Summary of Research Findings

The primary contributions of this research can be summarised as:

- The design and development of an architecture, which supports dual-user adaptivity in the domain of home tutoring.
- The articulation and development of a set of novel tutoring rules based on Talent Education philosophy, which define tutoring best practice.
- Empirical evidence that indicates the effectiveness of adaptive strategies based on self-efficacy in supporting the parent as tutor and strategies based on affect in supporting the child as tutee.

Section 8.2.1, 8.2.2 and 8.2.3 describe these contributions in detail.

8.2.1 Dual-User Architecture

Albeit adaptive educational systems have been of benefit in supporting individual users in a myriad of domains, little research investigates the possibility of exploiting this technology to simultaneously support dual users. Despite adaptive collaborative systems providing some insights, this work is still at the early stages with little research exploring the possibility of supporting two users in different domains. P.A.C.T. supports the tutor in developing tutoring skills while simultaneously supporting the tutee in the particular academic domain (e.g. mathematics or Suzuki violin). The design and development of P.A.C.T.'s dual-user architecture provides several conclusions, which may guide the development of adaptive educational systems that support dual users.

- There is a need for the provision of dual user models to build and maintain a profile on each user based on behaviour and navigation. Providing dual user models allows for the personalisation of the learning environment to meet the needs of both users.
- There is a need to provide dual domain models in order to provide domain support for both users. The domain model is a representation of the material to be learnt. Providing dual domain models allows for the provision of simultaneous support for both users in different domains.
- The need for an adaptive engine, which lies at the core of the dual user architecture. The adaptive engine uses information from both user models to inform its pedagogical strategy.
- It is important to develop a presentation model, which has the ability to monitor the interactions between the system and both users. In the design of such a model, there are a number of important considerations for example: will learning take place in a shared space or will both users have separate work stations or is there a need to provide shared control using one input device thus increasing the need for collaboration?
- On implementation of a dual user architecture there is a need to consider the increased volume of data as a result of simultaneously supporting two users. The use of a design pattern that provides a central hub to control the interactions between many objects may be advisable.

In summary, it can be concluded that it is possible to design and develop a dual-user architecture, which simultaneously supports dual user adaptivity.

8.2.2 Tutoring Strategies

Talent Education philosophy was chosen as the basis for modelling home tutoring best practice for several reasons. It is a rich concept that differs to other educational philosophy in so far as it bridges the gap between home and school. Furthermore, it defines the importance of role of tutor during the home tutoring process without whom little can be achieved. However, there have been few attempts to encapsulate Suzuki's philosophy into a set of tutoring tactics, which define tutoring best practice. Such tactics may provide a basis for the development of adaptive systems that support the role of the tutor during the home tutoring process. As a result of the research undertaken as part of this thesis several conclusions can be drawn, which may provide a basis for future work in this area.

- It is possible through empirical studies to identify a set of tutoring tactics, which denote Talent Education philosophy. These comprise expert demonstration, mastery learning, motivational game, positive reinforcement, repetition, review and tutoring variation.
- The aforementioned tutoring tactics can form the basis of tutoring rules, which provides a set of best practice pedagogical strategies. In turn, these tutoring rules can form the basis of the adaptive engine, which allows for the provision of personalised support.
- Talent Education philosophy through the set of tutoring rules provides a mechanism for the provision of domain independent tutoring best practice. These tutoring rules can be used by the tutor when tutoring both Suzuki Violin and mathematics without the need for modification.
- Developing a range of content, which represents each tutoring tactic, can be challenging. However, the development of a variety of content seems to be important in order to spark interest and motivation.

In summary, it can be concluded that Talent Education philosophy provides a rich basis for the development of tutoring rules, which define home tutoring best practice.

8.2.3 Basis for Adaptivity

Empirical studies were conducted with P.A.C.T. in order to investigate if self-efficacy and affect are an appropriate basis for adapting to the needs of the tutor and tutee. In particular, empirical studies were conducted to investigate:

- The effect of using adaptive strategies on parental self-efficacy, knowledge and their perception of their role as home tutor.
- The effect of adapting to the affective needs of the child throughout the home tutoring process.

The following points summarise the main results of these studies:

- Adapting the level of support based on self-efficacy has a positive effect on parents' self-efficacy, knowledge and perception of their role of home tutor.
- These studies highlighted a dichotomy between parental self-efficacy and desired level of support. For example, despite parents entering high levels of self-efficacy, they also desired high levels of support in order to help them proceed through the tutoring process. Bandura (1986) provides one possible explanation in his suggestion that the most functional efficacy judgments tend to exceed what one can actually accomplish.
- In addition to providing personalised support, there may be benefit in providing a mechanism whereby individuals can request further support due to the dichotomy between parental self-efficacy and desired level of support.
- Adapting to the affective state of the child has a positive effect on the child. More specifically parents provided qualitative feedback, which suggests that children were happier when carrying out learning activities using P.A.C.T.
- Results suggest that in eliciting affect a collaborative-report strategy may be of most benefit. The collaborative-report strategy involves a discussion around the affective state of the child from which a decision emerges.
- When adapting the learning process based on the child's affective state, there may be a risk of gaming. At worst, this may involve the child using the system rules against itself for the child's own benefit. In particular, this may involve a child submitting an affective state that is not a true representation of how they were feeling in an endeavour to finish practice as quickly as possible. To this end, there is a need for intelligent design so that all paths through the tutoring process

promote learning. This may reduce the risk of gaming having a limiting effect on learning gain.

- Additionally, P.A.C.T. may be of most benefit during the home tutoring process in creating a positive learning environment and acting as mediator.

In summary, P.A.C.T. can have a positive impact on parents' self-efficacy, knowledge and their perception of heir role as home tutor. Additionally, the provision of affective support for the child can have a positive effect on the home tutoring process. Most interestingly, results indicate that parents with high levels of self-efficacy still desire high-levels of support. Finally, the provision of adaptive affective support provides the possibility of children gaming the system.

8.3 Limitations of Work

Undoubtedly, this research has provided some interesting research findings. However, it must be recognised that the significance of the research may be limited in certain respects. These limitations will now be discussed bearing in mind the complexity associated with developing an adaptive educational system, which simultaneously supports dual users.

- A forward chaining algorithm was chosen as the basis of the adaptive engine. For the task of identifying appropriate tutoring tactics, it works well. However, it may be too complex a solution as the powerfulness of such an algorithm is not fully exploited within P.A.C.T.. A simpler algorithm may have sufficed.
- This researched proposed a set of novel efficacy rules informed by Bloom's Taxonomy (Bloom 1956). However, to assess the validity of these rules further research would need to determine how effective they are in providing appropriate support based on self-efficacy. This could be achieved through the completion of further empirical studies.
- This research considered a set of four basic emotions in the provision of affective support for the child. However, much research suggests the need to consider other emotions such as frustration and flow in educational contexts (D'Mello et al., 2007). In addition, identifying the effect of P.A.C.T. on the child's learning might provide some additional interesting insights.
- Albeit that 277 resources were developed for P.A.C.T., there is a need for the development of further content. Particularly in terms of the review content for mathematics, children became disengaged when they were presented with the same

exercise too often. The development of further content would go some way in avoiding this situation.

- The duration of the experiment was short in so far as some participants may have only used P.A.C.T. on three occasions. To observe the effect of P.A.C.T. with greater accuracy, it would be necessary to encourage parents to use P.A.C.T. more often.
- The range of participants in the studies was limited. One study was conducted with parents who had elected to provide their child with educational opportunities outside the norm (i.e. music lessons). The other study was conducted with children from designated disadvantaged schools. A sample consisting of a broader range of schools and participants would allow the results to be generalised. In addition, the sample population was small with only 31 dyads participating in the experiments. To generalise the results it is necessary to conduct experiments with larger groups.
- The questionnaire used for the purpose of data collection during Study 2 was ineffective as parents had difficulties in completing the feedback forms. The use of different data collection instruments may have increased the level of feedback received.

8.4 Directions for Future Research

The work presented in this thesis represents one approach to developing adaptive systems that simultaneously support dual users. This section outlines a number of directions for further research.

8.4.1 Dual-User Architecture

- Currently P.A.C.T. supports the tutor (parent) in developing domain independent tutoring skills while simultaneously supporting the tutee (child) in developing knowledge in particular domains (e.g. Suzuki violin or mathematics). In addition to supporting the parent in developing tutoring best practice, a future version of P.A.C.T. might also provide support for P.A.C.T. in the tutee's domain. For the research studies described in this thesis the provision of support in the tutee's domain was unnecessary due to the level of the domain knowledge involved (children aged 4-5 years). However, in future research studies it may further enhance learning for both tutor and tutee.

- Currently, the content rules select particular content to present to both parent and child using a randomised selection process. However, the tutoring process may benefit from the use of different selection criteria; for example, P.A.C.T. may ensure that users are not presented with the same content over a number of sessions.
- Open learner models may increase motivation and further engagement in the learning process. Such models might involve presenting a skillomoter that represents parental self-efficacy for each of the tutoring tactics or building a picture, which indicates progress through each phase of the tutoring process.
- Applications like P.A.C.T. that support learning in the natural environment may benefit from ubiquitous technology such as mobile phones. Deporting P.A.C.T. over mobile technology may increase usage statistics due to the ever-present nature of the technology in question.

8.4.2 Tutoring Strategies

- Albeit that this research indicates how Talent Education philosophy may be of benefit in multiple domains, in order to truly generalise the application of Talent Education philosophy, there is a need to create content for multiple domains by different content authors.
- These studies suggest that Talent Education philosophy may be of benefit when tutoring young children (4-5 years). However, there is a need to investigate if this philosophy can also be applied across different age groups in various tutor-tutee contexts.
- It is quite demanding and time consuming to develop content using the principles of Talent Education philosophy, particularly if it is necessary to develop multiple representations of the same content. The formulation of templates or authoring tools for creating content may be of benefit and in particular, if such tools enable teachers or parents to become involved in developing content.

8.4.3 Basis for Adaptivity

- This research has attempted to increase parental self-efficacy using mastery experiences, the most influential of the four sources of self-efficacy (Bandura, 1986). To fully explore how adaptive educational systems might increase self-efficacy it is necessary to investigate the effect of incorporating the other sources

of self-efficacy namely, vicarious experiences, verbal persuasion and physiological states. Vicarious experiences might be incorporated using collaboration tools (e.g. discussions boards, wikis or blogs) where parents can share experiences. Verbal persuasion might be incorporated through messages of positive appraisal informed by parents' user models. Finally, positive physiological states may be promoted through the inclusion of affective support for parents.

- Empirical studies carried out for the purpose of this research have highlighted the dichotomy between parental self-efficacy and desired levels of support. There is a need for future research to investigate the use of more subtle instruments in the collection of self-efficacy values.
- The inclusion of a collaborative script to facilitate collaboration in elicitation of the child's affective state may have a positive effect on the tutoring process as results from this research suggest that the most effective strategy in eliciting affect is a collaborative-report strategy.
- Further empirical studies may involve investigating the effect of P.A.C.T. on user knowledge. This was outside the scope of this research. However, such a study investigating the effect of P.A.C.T. on both parents and children's learning gain might provide some interesting insights.

8.5 Conclusion

In summary, the main contributions of this research are:

- The design and development of an architecture, which supports dual-user adaptivity in the domain of home tutoring.
- The articulation and development of a set of novel tutoring rules based on Talent Education philosophy, which define tutoring best practice.
- Empirical evidence that indicates the effectiveness of adaptive strategies based on self-efficacy in supporting the parent as tutor and strategies based on affect in supporting the child as tutee.

This research presents interesting insights into the broader question of how adaptive technology can be exploited to simultaneously support dual users. It seems that providing a rich basis for adaptivity is a challenging task and it is not always clear how best to support both users.

The results of this study may be significant for researchers and practitioners. For researchers, it demonstrates that it is possible to develop dual-user adaptive educational systems that simultaneously support two users with different needs. For practitioners, it demonstrates that Talent Education philosophy may be applied in mainstream education. In particular, this research demonstrates some evidence of generalisability in so far as it illustrates how tutoring tactics informed by Talent Education can be applied in different domains, namely mathematics and Suzuki violin. Additionally it demonstrates to both researchers and practitioners how taking into account a tutor's perceived self-efficacy and tutee's affective state may have a positive effect on learning.

Appendix

Appendix A

Letters of Interest

Letter to Suzuki Violin Parents

Dear Suzuki Parent,

We know that parental involvement boosts academic success and student achievement. However, we also know that sometimes practice times at home can be challenging! To help you with your practice time at home, there is now the opportunity to get involved in the Parent and Child Tutor Programme.

The Parent and Child Tutor (P.A.C.T.), is a computer application that provides personalised support, for you the parent, during Violin practice with your child at home. P.A.C.T. takes us step by step through home practice and provides suggested activities, games and lots of interesting ideas. It also reminds us of the key concepts of Suzuki's philosophy.

This programme is aimed at Book 1 Suzuki parents and children. In order to get involved, all that is required of you is a computer with internet connection (preferably Broadband) and a commitment to use P.A.C.T. for 8-12 weeks. Computer skills are not required, as we will show you what to do.

So if you would like to get involved in this free trial of P.A.C.T. Please contact us at [phone number] or [email].

We look forward to hearing from you.

Kind Regards,

_____

Orla Lahart

Letter to Junior Infants Teachers

Dear Junior Infant Teacher,

We recognise the importance of parental involvement in children's homework and we know that this involvement can impact positively on a child's academic success. We also know that for numerous reasons parents do not get involved in homework activities. For this reason, we have developed the Parent and Child Tutor (P.A.C.T.).

P.A.C.T. is a computer application that provides personalised support for parents during Maths homework. P.A.C.T. takes the parent step by step through their child's Maths homework and provides additional games as well as lots of interesting ideas.

P.A.C.T. is aimed at Junior Infant children and their parents. If you think this may be of benefit to the children in your class all we ask is that you give a copy of the enclosed letter to the parents. Of course, P.A.C.T. was developed in accordance with the Primary School Mathematics curriculum and has been approved by experienced teachers.

If you have any questions or you would like a demonstration of P.A.C.T. Please contact us at [phone number] or [email].

We look forward to hearing from you.

Kind Regards,

_____

Orla Lahart

Letter to Mathematics Parents

Dear Parent,

We know that parental involvement in homework activities boosts academic success and student achievement. However, we also know that sometimes homework can be challenging! There is now an opportunity for you to use the Parent and Child Tutor (P.A.C.T.) which can assist you with your child's homework.

P.A.C.T. is a computer application that provides personalised support for you and your child during Maths homework. P.A.C.T. takes you step by step through your child's Maths homework and provides suggested activities, games and lots of interesting ideas.

This programme is aimed at Junior Infant children and their parents. In order to get involved, all that is required of you is a computer with internet connection (preferably Broadband) and a commitment to use P.A.C.T. for 4 weeks. Computer skills are not required, as we will show you what to do.

So if you would like to get involved in this free trial of P.A.C.T. Please contact us at [phone number] or [email].

We look forward to hearing from you.

Kind Regards,

_____

Orla Lahart

Induction Pack

Induction Pack Letter

Dear [Parent's Name],

Thank you for your interest in the Parent and Child Tutor (P.A.C.T.). I look forward to working with you over the next couple of weeks.

Your induction pack includes:

1. The Induction Tutorial CD
2. A User Manual

It is best to begin by watching the Induction Tutorial as it gives an overview of P.A.C.T. and how it can be used. It is about 8 minutes in duration. The User Manual contains additional instructions and support.

The web address for P.A.C.T. is http://www.parentandchildtutor.ie/maths.html and your login details are below. Please ensure you close both Internet Explorer windows after each practice.

Username: [username]

Password: [password]

If you have any queries please do not hesitate to contact me at [phone number] or [email].

Thank you,

_____

Orla Lahart

The Parent And Child Tutor

User Manual

This User Manual details everything you need to know to use the Parent and Child Tutor (P.A.C.T.).

Step 1 – Controlling the Volume

Make sure the volume is turned up on your computer. To check the volume, click on the volume button in the bottom right hand corner of your screen (Fig 1). Ensure that the volume is at its maximum (Fig 2) and that the mute box is not selected.

Figure 1Volume Button

Figure 2 Volume Controls

Step 2 – Launching P.A.C.T.

P.A.C.T. is a Web-based application this means that we must launch Internet Explorer. To do this either:

1. Double click on the Internet Explorer icon on the desktop.
2. Click on Start > Programs > Internet Explorer

Once Internet Explorer is open, enter the following web address, *www.parentandchiltutor.ie* (Fig. 3) and press Go. This should launch P.A.C.T. (Fig. 4)

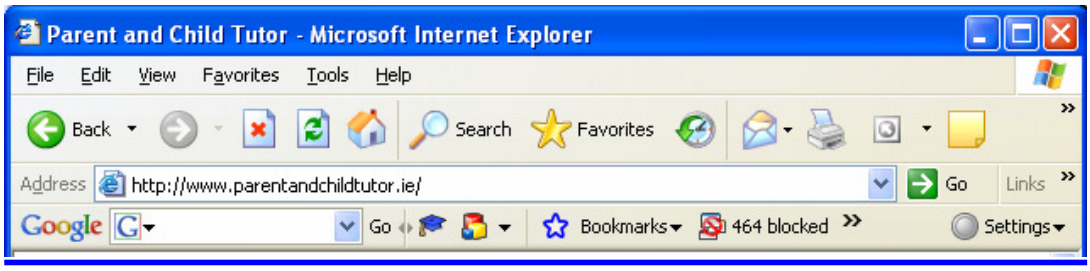


Figure 3 Launching P.A.C.T.

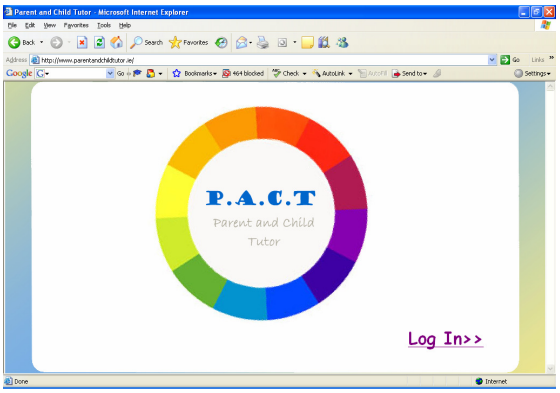


Figure 4 P.A.C.T.

Step 3 – Logging In

To log in it is necessary to enter the username and password, which was given to you. You are also asked to enter your child's current piece. Once all details have been entered, you can click *Log In* (Fig. 5).

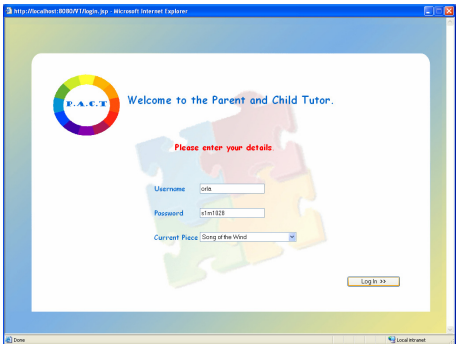
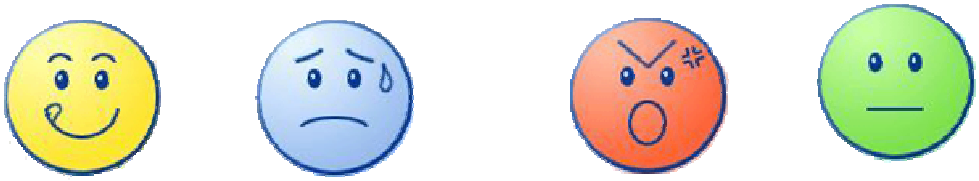


Figure 5 Logging In

Step 4 – Selecting the correct Emotional State

You are asked to enter your child's emotional state by selecting on of the emoticons (Fig. 6). It is important to note that these emoticons represent an array of emoticons, which can be classified under the broad categories of happy, sad, angry and fearful. For some examples of the types of emotions in each category, see Table 1.



Happy Sad Angry Fearful

Figure 6 Emoticons

Category	Examples			
Sad	Unmotivated	Gloomy	Miserable	Depressed
	Cheerless	Tired	Downbeat	Disheartened
Angry	Annoyed	Irritated	Agitated	Mad
	Fuming	Exasperated	Upset	Bothered
Fearful	Worried	Anxious	Timid	Afraid
	Scared	Apprehensive	Terrified	Frightened
Happy	Content	Pleased	Cheerful	In High Spirits
	Blissful	Joyful	Glad	Contented

Table 1 Emotions

Step 5 – Exiting P.A.C.T.

To exit P.A.C.T. close Internet Explorer by clicking on the x in the top right hand corner of the screen (Fig. 7). There will be two Internet Explorer windows open it is important to close both.

Figure 7 Exiting P.A.C.T.

Induction CD

Appendix B

Questionnaires

Pre-Questionnaire Suzuki Violin

Parent And Child Tutor

Name _____

Please answer each of the following questions in relation to the home tutoring process.

Do you know what Expert Demonstration is?	(no) 1 2 3 4 5 6 7 (yes)
Do you know when to use Expert Demonstration?	(no) 1 2 3 4 5 6 7 (yes)
How confident are you that you can use Expert Demonstration when appropriate?	(not) 1 2 3 4 5 6 7 (very)

Do you know what Mastery Learning is?	(no) 1 2 3 4 5 6 7

	(yes)
Do you know when to use Mastery Learning?	(no) 1 2 3 4 5 6 7 (yes)
How confident are you that you can use Mastery Learning when appropriate?	(not) 1 2 3 4 5 6 7 (very)

Do you know what a Motivational Game is?	(no) 1 2 3 4 5 6 7 (yes)
Do you know when to use a Motivational Game?	(no) 1 2 3 4 5 6 7 (yes)
How confident are you that you can use a Motivational Game when appropriate?	(not) 1 2 3 4 5 6 7 (very)

Do you know what Positive Reinforcement is?	(no) 1 2 3 4 5 6 7 (yes)
Do you know when to use Positive Reinforcement?	(no) 1 2 3 4 5 6 7 (yes)
How confident are you that you can use Positive Reinforcement when appropriate?	(not) 1 2 3 4 5 6 7 (very)

Do you know what Repetition is?	(no) 1 2 3 4 5 6 7

	(yes)
Do you know when to use Repetition?	(no) 1 2 3 4 5 6 7 (yes)
How confident are you that you can use Repetition when appropriate?	(not) 1 2 3 4 5 6 7 (very)

Do you know what Review is?	(no) 1 2 3 4 5 6 7 (yes)
Do you know when to use Review?	(no) 1 2 3 4 5 6 7 (yes)
How confident are you that you can use Review when appropriate?	(not) 1 2 3 4 5 6 7 (very)

Do you know what Tutoring Variation is?	(no) 1 2 3 4 5 6 7 (yes)
Do you know when to use Tutoring Variation?	(no) 1 2 3 4 5 6 7 (yes)
How confident are you that you can use Tutoring Variation when appropriate?	(not) 1 2 3 4 5 6 7 (very)

What role do you think P.A.C.T. will play when carrying out home practice with you child?

_____

_____

What would you expect of P.A.C.T. when carrying out home practice with your child?

_____

_____

Describe how you see your role as home tutor?

_____

_____

Describe what you think the attributes of a good home tutor are.

_____

_____

Thank you, for your valuable contributions.

Pre-Questionnaire Mathematics

Parent And Child Tutor

Parent's Name _____ Child's Name _____

Please answer each of the following questions in relation to the home tutoring process.

Do you know what Expert Demonstration is?	☐ Yes ☐ No
Do you know when to use Expert Demonstration?	☐ Yes ☐ No
How confident are you that you can use Expert Demonstration when appropriate?	(not) 1 2 3 4 5 6 7 (very)

Do you know what Mastery Learning is?	☐ Yes ☐ No
Do you know when to use Mastery Learning?	☐ Yes ☐ No
How confident are you that you can use Mastery Learning when appropriate?	(not) 1 2 3 4 5 6 7 (very)

Do you know what a Motivational Game is?	☐ Yes ☐ No
Do you know when to use a Motivational Game?	☐ Yes ☐ No
How confident are you that you can use a Motivational Game when appropriate?	(not) 1 2 3 4 5 6 7 (very)

Do you know what Positive Reinforcement is?	☐ Yes ☐ No
Do you know when to use Positive Reinforcement?	☐ Yes ☐ No
How confident are you that you can use Positive Reinforcement when appropriate?	(not) 1 2 3 4 5 6 7 (very)

Do you know what Review is?	☐ Yes ☐ No
Do you know when to use Review?	☐ Yes ☐ No
How confident are you that you can use Review when appropriate?	(not) 1 2 3 4 5 6 7 (very)

Do you know what Tutoring Variation is?	☐ Yes ☐ No
Do you know when to use Tutoring Variation?	☐ Yes ☐ No
How confident are you that you can use Tutoring Variation when appropriate?	(not) 1 2 3 4 5 6 7

	(very)

What job do you think P.A.C.T. will have during Maths homework with you child?

_____

_____

Describe how you see your job during Maths homework

_____

_____

Thank you, for your valuable contributions.

Short Questionnaire Mathematics

Parent And Child Tutor

Parent's Name _____ Child's Name _____

Name one thing you (the parent) learnt today?

_____

_____

Name one thing your child learnt today?

_____

_____

Has your idea of your job as home tutor changed today?

_____

_____

How would you rate your confidence in your job as home tutor today?

What job did P.A.C.T. (the computer) have today?

Fun/Game	☐	Mediator (Middle Man)	☐	The Boss	☐		
Friend	☐	Teacher	☐	Other	☐		

If other, please specify: _____

Post-Questionnaire Suzuki Violin

Parent And Child Tutor

Name _____

Please answer each of the following questions in relation to the home tutoring process.

Do you know what Expert Demonstration is?	☐ Yes ☐ No
Do you know when to use Expert Demonstration?	☐ Yes ☐ No
How confident are you that you can use Expert Demonstration when appropriate?	(not) 1 2 3 4 5 6 7 (very)

Do you know what Mastery Learning is?	☐ Yes ☐ No
Do you know when to use Mastery Learning?	☐ Yes ☐ No
How confident are you that you can use Mastery Learning when appropriate?	(not) 1 2 3 4 5 6 7 (very)

Do you know what a Motivational Game is?	☐ Yes ☐ No

Do you know when to use a Motivational Game?	☐ Yes ☐ No
How confident are you that you can use a Motivational Game when appropriate?	(not) 1 2 3 4 5 6 7 (very)

Do you know what Positive Reinforcement is?	☐ Yes ☐ No
Do you know when to use Positive Reinforcement?	☐ Yes ☐ No
How confident are you that you can use Positive Reinforcement when appropriate?	(not) 1 2 3 4 5 6 7 (very)

Do you know what Repetition is?	☐ Yes ☐ No
Do you know when to use Repetition?	☐ Yes ☐ No
How confident are you that you can use Repetition when appropriate?	(not) 1 2 3 4 5 6 7 (very)

Do you know what Review is?	☐ Yes ☐ No
Do you know when to use Review?	☐ Yes ☐ No
How confident are you that you can use Review when appropriate?	(not) 1 2 3 4 5 6 7 (very)

Do you know what Tutoring Variation is?	☐ Yes ☐ No

Do you know when to use Tutoring Variation?	☐ Yes ☐ No
How confident are you that you can use Tutoring Variation when appropriate?	(not) 1 2 3 4 5 6 7 (very)

What role do you think P.A.C.T. will play when carrying out home practice with you child?

_____

_____

What would you expect of P.A.C.T. when carrying out home practice with your child?

_____

_____

Describe how you see your role as home tutor?

_____

_____

Describe what you think are the attributes of a good home tutor.

_____

_____

Thank you, for your valuable contributions.

Post-Questionnaire Mathematics

Parent And Child Tutor

Parent's Name _____ Child's Name _____

Please answer each of the following questions in relation to the home tutoring process.

Do you know what Expert Demonstration is?	☐ Yes ☐ No
Do you know when to use Expert Demonstration?	☐ Yes ☐ No
How confident are you that you can use Expert Demonstration when appropriate?	(not) 1 2 3 4 5 6 7 (very)

Do you know what Mastery Learning is?	☐ Yes ☐ No
Do you know when to use Mastery Learning?	☐ Yes ☐ No
How confident are you that you can use Mastery Learning when appropriate?	(not) 1 2 3 4 5 6 7 (very)

Do you know what a Motivational Game is?	☐ Yes ☐ No
Do you know when to use a Motivational Game?	☐ Yes ☐ No

How confident are you that you can use a Motivational Game when appropriate?	(not) 1 2 3 4 5 6 7 (very)

Do you know what Positive Reinforcement is?	☐ Yes ☐ No
Do you know when to use Positive Reinforcement?	☐ Yes ☐ No
How confident are you that you can use Positive Reinforcement when appropriate?	(not) 1 2 3 4 5 6 7 (very)

Do you know what Review is?	☐ Yes ☐ No
Do you know when to use Review?	☐ Yes ☐ No
How confident are you that you can use Review when appropriate?	(not) 1 2 3 4 5 6 7 (very)

Do you know what Tutoring Variation is?	☐ Yes ☐ No
Do you know when to use Tutoring Variation?	☐ Yes ☐ No
How confident are you that you can use Tutoring Variation when appropriate?	(not) 1 2 3 4 5 6 7 (very)

Did P.A.C.T. meet your expectations?

☐ Yes ☐ No

Explain: _____

Has how you see your job as home tutor changed? If so, why?

☐ Yes ☐ No

Why? _____

When using P.A.C.T., who used the mouse?

☐ I did ☐ My child did ☐ We both did

Please tick the appropriate box

☐ My child always selected how they were feeling

☐ Sometimes my child picked a different face just to see what would happen

☐ My child liked tricking P.A.C.T. by pretending to be happy/sad/angry or fearful when they weren't

Thank you, for your valuable contributions.

Appendix C

P.A.C.T. Implementation

Presentation Model

The presentation model consists of Java Server Pages (JSP) informed by Cascading Style Sheet (CSS) technology. Parameters are passed in from the pedagogical model in order to determine the particular content to display. The following is an extract from the JSP, which generates the page for eliciting the child's affective state. An extract from the CSS is also presented.

Cascading Style Sheet

```
body.normal{
background-image:url('bg1.gif');
background-repeat:no-repeat;
background-position:center;
}
body.page1{
background-image:url('bgplain.gif');
background-repeat:no-repeat;
background-position:center;
}
img.logo{
position:relative;
TOP:80px;
LEFT:45px;
}
p.login{
font-family: "comic sans ms";
color="#0066CC";
text-align: center;
}
h1.login{
```

```
font-family: "comic sans ms";
color="#bce937";
}
h2.dependent{
font-family: "comic sans ms";
color="#0066CC";
}
img.dependentObj1{
position:absolute;
TOP: 400px;
LEFT:70px;
}
object.dependentObj1{
position:absolute;
TOP: 400px;
LEFT:70px;
}
```

Java Server Page

```
<HTML
<HEAD>
<link rel="stylesheet" type="text/css" href='<%=filenameStyle%>'/>
<title>Parent And Child Tutor
</title>
</HEAD>
<body class = "normal" ONLOAD="startTimer()" >
<script language="javascript">
                                var centiseconds = 0;
                                var secs = 0;

                                function startTimer() {
                                // 1000 milliseconds = 1 second
                                window.setInterval( "updateTime()", 100 );
                                }

                                function updateTime() {
                                centiseconds++;
                                secs = centiseconds/10;

                                }
```

```
                        function buildURL(linkParms){
                        var newURL;
                        var baseURL;
                        baseURL = "/servlet/MusicDispatcher";

                        var pageParms;
                        pageParms = "&" + "secs=" + secs;

                        newURL = baseURL + "?" + linkParms + pageParms;
                        location.href = newURL;
                        }
    // -->
   </script>

<input type="hidden" name="pageId" value="questions.jsp">

<Table width="100%" height= "95%" border="0" background="bg1.gif">
<tr height="5%"><td width="5%"> </td><td colspan="2"> </td>
<td width="5%"> </td></tr>
<tr height="30%"><td width="5%"> </td>
<td width="15%"><img src='<%=filenameLogo%>'></td>
<td>
                <h1 class = "question">
                The
                <% String phase = (String)session.getAttribute("phase");
                  if(phase != null)
                  {
                        if(phase.equals("new_material"))
                        {
                                out.print("new material");
                        }
                        else
                        {
                                out.print(phase);
                        }
                  }
                 %>phase        </h1>
 </td> <td width="5%"> </td>
</tr>
<tr height="30%"><td width="5%"> </td><td colspan="2">
<h2 class="question">
          <% String emotion = (String)session.getAttribute("emotion");
            if(emotion == null)
```

```
            {%>
                    How is  <%= session.getAttribute( "childsName" ) %> feeling now?
            <%}
            else
            {%>
                    <%= session.getAttribute( "childsName" ) %> was <%=
                    session.getAttribute( "emotion" ) %>. How is <%= session.getAttribute(
                    "childsName" ) %> feeling now?


          <%}%>
</h2>
</td><td width="5%"> </td></tr>
<tr ="35%"><td width="5%"> </td><td colspan="2">
<Table width = 80% align="center">
<tr>
<td><a  return true;
href="javascript:buildURL('pageId=questions.jsp&emotion=happy');">
<img src = '<%=filenameImage + "happy.gif"%>' border="0" alt="happy"></a></td>
<td><a  return true; href="javascript:buildURL('pageId=questions.jsp&emotion=sad');">
<img src = '<%=filenameImage + "sad.gif"%>' border="0" alt="sad"></a></td>
<td><a  return true;
href="javascript:buildURL('pageId=questions.jsp&emotion=angry');">
<img src = '<%=filenameImage + "angry.gif"%>' border="0" alt="angry"></a></td>
<td><a  return true;
href="javascript:buildURL('pageId=questions.jsp&emotion=fearful');">
<img src = '<%=filenameImage + "fearful.gif"%>' border="0" alt="fearful"></a></td>
</tr>
</Table>
 </td><td width="5%"> </td></tr>
 </Table>
 </BODY>
  </HTML>
```

Pedagogical Model

The pedagogical model is implemented using Java servlets running on an Apache Tomcat Web server. The servlets pass parameters to the JSP in order to presents appropriate data to the user. The following sample from the Dispatcher servlet illustrates how coming from the login page the servlet interfaces with the user model to retrieve the user's profile and identify the next page

```
public void  processRequest(HttpServletRequest request, HttpServletResponse response)
throws ServletException, IOException
{
        // geting current page
        String pageId = request.getParameter("pageId");

        //The user may be coming from Suzuki violin login or mathematics login
        if(pageId == null){
                pageId = "login.jsp";
        }
        if(pageId.equals("mathsLogin.jsp")){
                pageId = "login.jsp";
        }
        session.setAttribute("pageId", pageId);

        UserHelper userHelper = new UserHelper();

        if(pageId.equals("login.jsp")){
                String username = (String)request.getParameter( "username" );
                String password = (String)request.getParameter( "password" );

                session.setAttribute("username", username);
                session.setAttribute("password", password);

                Quser aUser = new Quser();
                aUser = userHelper.getUserByUsernamePassword( username, password
);

                if(aUser != null){
                        String childsNme = aUser.getChildsNme();
                        String parentsNme = aUser.getParentsNme();
                        int mode = aUser.getMode();
                        int preQ = aUser.getPreQ();
                        int postQ = aUser.getPostQ();
```

```
                    session.setAttribute( "childsName", childsNme );
                    session.setAttribute( "parentsName", parentsNme );
                    session.setAttribute( "mode", mode );
                    session.setAttribute( "preQ", preQ);
                    session.setAttribute( "postQ", postQ);
                    session.setAttribute( "BACK_T0_LOGIN", "false");
                    BACK_T0_LOGIN = false;
                }
                else{
                    BACK_T0_LOGIN = true;
                    session.setAttribute( "childsName", "default" );
                    session.setAttribute( "parentsName", "default" );
                    session.setAttribute( "preQ", "10");
                    session.setAttribute( "postQ", "10");
                    session.setAttribute( "BACK_T0_LOGIN", "true");
                }
            }
            int preQ  = Integer.parseInt(session.getAttribute("preQ").toString());
            int postQ = Integer.parseInt(session.getAttribute("postQ").toString());
            if(pageId.equals("login.jsp")){
                if(BACK_T0_LOGIN == true)
                    nextPage = "/mathsLogin.jsp";
                else
                if(preQ == 0)
                    nextPage = "/preQuestionnaire.jsp";
                else
                if(postQ == 0)
                    nextPage = "/postQuestionnaire.jsp";
                else
                    nextPage = "/questions.jsp";
            }
        }
```

Adaptive Engine

The adaptive engine as part pf the pedagogical model is also implemented using Java servlets. The pedagogical model interfaces with the adaptive engine to determine the next step in the tutoring process. The following sample from the RuleEngine servlet is an example of the tutoring rules used to identify the appropriate tutoring tactic to suggest during the beginning phase of the tutoring process.

```
public void initPACTRuleBase(BooleanRuleBase rb)
 {
        RuleVariable state = new RuleVariable(rb, "state");
        RuleVariable action = new RuleVariable(rb, "action");
        RuleVariable cur_phase = new RuleVariable(rb, "cur_phase");

         //Beginning
        RuleVariable prBeginning = new RuleVariable(rb, "prBeginning");
        RuleVariable mgBeginning = new RuleVariable(rb, "mgBeginning");
        RuleVariable mlBeginning = new RuleVariable(rb, "mlBeginning");
        RuleVariable rvBeginning = new RuleVariable(rb, "rvBeginning");

        Condition cEquals = new Condition("=");
        Condition cNotEquals = new Condition("!=");
        Condition cLessThan = new Condition("<");

        /* * * * *
         * Rule Definitions
         * Beginning  Phase
         *
         * * * **/

        //Angry
        Rule BgnPtce_A_PR = new Rule(rb, "BgnPtce_A_PR", new Clause[]{
                                        new Clause(state, cEquals, "angry"),
                                        new Clause(prBeginning, cEquals, "false"),
                                        new Clause(cur_phase, cEquals, "beginning")},
                                                new Clause(action, cEquals, "Positive
Reinforcement"));

        Rule BgnPtce_A_MG = new Rule(rb, "BgnPtce_A_MG", new Clause[]{
                                        new Clause(state, cEquals, "angry"),
                                        new Clause(cur_phase, cEquals, "beginning"),
                                        new Clause(prBeginning, cEquals, "true"),
```

```
                                        new Clause(mgBeginning, cEquals, "false")},
                                        new Clause(action, cEquals, "Motivational
Game"));

        Rule BgnPtce_A_Finish = new Rule(rb, "BgnPtce_A_Finish", new Clause[]{
                                        new Clause(state, cEquals, "angry"),
                                        new Clause(cur_phase, cEquals, "beginning"),
                                        new Clause(prBeginning, cEquals, "true"),
                                        new Clause(mgBeginning, cEquals, "true")},
                                        new Clause(action, cEquals, "Finish"));

        //Fearful
        Rule BgnPtce_F_PR = new Rule(rb, "BgnPtce_F_PR", new Clause[]{
                                        new Clause(state, cEquals, "fearful"),
                                        new Clause(prBeginning, cEquals, "false"),
                                        new Clause(cur_phase, cEquals, "beginning")},
                                        new Clause(action, cEquals, "Positive
Reinforcement"));

        Rule BgnPtce_F_RV = new Rule(rb, "BgnPtce_F_RV", new Clause[]{
                                        new Clause(state, cEquals, "fearful"),
                                        new Clause(cur_phase, cEquals, "beginning"),
                                        new Clause(prBeginning, cEquals, "true")},
                                        new Clause(action, cEquals, "Review"));

        //Happy
        Rule BgnPtce_H_ML = new Rule(rb, "BgnPtce_H_ML", new Clause[]{
                                        new Clause(state, cEquals, "happy"),
                                        new Clause(cur_phase, cEquals, "beginning"),
                                        new Clause(mlBeginning, cEquals, "false")},
                                        new Clause(action, cEquals, "Review"));

        Rule BgnPtce_H_PR = new Rule(rb, "BgnPtce_H_PR", new Clause[]{
                                        new Clause(state, cEquals, "happy"),
                                        new Clause(cur_phase, cEquals, "beginning"),
                                        new Clause(mlBeginning, cEquals, "true")},
                                        new Clause(action, cEquals, "Positive
Reinforcement"));

        //Sad
        Rule BgnPtce_S_MG = new Rule(rb, "BgnPtce_S_MG", new Clause[]{
                                        new Clause(state, cEquals, "sad"),
                                         new Clause(cur_phase, cEquals, "beginning"),
```

```
                                        new Clause(mgBeginning, cEquals, "false")},
                                        new Clause(action, cEquals, "Motivational
Game"));

        Rule BgnPtce_S_PR = new Rule(rb, "BgnPtce_S_PR", new Clause[]{
                                        new Clause(state, cEquals, "sad"),
                                        new Clause(mgBeginning, cEquals, "true"),
                                        new Clause(prBeginning, cEquals, "false"),
                                        new Clause(cur_phase, cEquals, "beginning")},
                                        new Clause(action, cEquals, "Positive
Reinforcement"));


        Rule BgnPtce_S_Finish = new Rule(rb, "BgnPtce_S_Finish", new Clause[]{
                                        new Clause(state, cEquals, "sad"),
                                        new Clause(mgBeginning, cEquals, "true"),
                                        new Clause(prBeginning, cEquals, "true"),
                                        new Clause(cur_phase, cEquals, "beginning")},
                                        new Clause(action, cEquals, "Finish"));
}
```

Appendix D

This appendix comprises two tables, which allow for a comparison of the summative statistics of Group 1(full support) and Group 2 (adaptive support). The first table provide the mean values for each group. The second table provides results of an independent sample t-test. The following provides an explanation of the terminology used in the tables

tvSEPre : tutoring variation tactic self-efficacy pre-test score

tvSEPost : tutoring variation tactic self-efficacy post test score

tvSEDiff : tutoring variation tactic self-efficacy post test score – pre test score

tvSEGain : tutoring variation tactic self-efficacy (post test score – pre test score) / pre test score

tvWhenPre : knowledge of when to use the tutoring variation tactic pre test score

tvWhatPre : knowledge of what the tutoring variation tactic comprises pre test score

The abbreviations for each of the tutoring tactics are as follows expert demonstration (ed), mastery learning (ml), motivational games (mg), positive reinforcement (pr), repetition (rp), review (rv) and tutoring variations (tv).

Results did not show statistical significance, however, those results approaching statistical significance are highlight in both tables.

Table 1 Group Statistics (Mean Values)

Note: mode 1 represents Groups 2 (adaptive support) mode 2 represents Group1 (full support).

	mode	N	Mean	Std. Deviation	Std. Error Mean
tvSEPre	1.00	5	2.6000	2.60768	1.16619
	2.00	6	4.1667	2.13698	.87242
tvSEPost	1.00	5	4.0000	2.73861	1.22474
	2.00	6	5.1667	1.72240	.70317
tvSEDiff	1.00	5	1.4000	4.61519	2.06398
	2.00	6	1.0000	2.52982	1.03280
tvSEGain	1.00	5	2.0286	2.79102	1.24818
	2.00	6	1.0139	2.44973	1.00010
edWhatPre	1.00	5	3.2000	3.03315	1.35647
	2.00	6	5.5000	2.25832	.92195

edWhatPost	1.00	5	6.4000	.54772	.24495
	2.00	6	5.0000	2.28035	.93095
edWhenPre	1.00	5	3.4000	3.28634	1.46969
	2.00	6	4.0000	1.67332	.68313
edWhenPost	1.00	5	5.8000	1.09545	.48990
	2.00	6	5.0000	2.28035	.93095
edSEPre	1.00	5	3.6000	2.79285	1.24900
	2.00	6	4.0000	1.67332	.68313
edSePost	1.00	5	6.0000	1.22474	.54772
	2.00	6	4.6667	2.16025	.88192
mlWhatPre	1.00	5	3.0000	2.82843	1.26491
	2.00	6	5.0000	2.19089	.89443
mlWhatPost	1.00	5	5.8000	.83666	.37417
	2.00	6	6.3333	.81650	.33333
mlWhenPre	1.00	5	3.0000	2.82843	1.26491
	2.00	6	4.1667	1.72240	.70317
mlWhenPost	1.00	5	5.8000	.83666	.37417
	2.00	6	6.1667	1.16905	.47726
mlSEPre	1.00	5	3.0000	2.82843	1.26491
	2.00	6	4.0000	1.67332	.68313
mlSEPost	1.00	5	5.8000	.83666	.37417
	2.00	6	5.1667	1.32916	.54263
mgWhatPre	1.00	5	5.4000	2.50998	1.12250
	2.00	6	5.6667	2.33809	.95452
mgWhatPost	1.00	5	6.6000	.89443	.40000
	2.00	6	6.6667	.81650	.33333
mgWhenPre	1.00	5	4.6000	2.19089	.97980
	2.00	6	4.5000	2.25832	.92195
mgWhenPost	1.00	5	6.6000	.89443	.40000
	2.00	6	6.3333	1.21106	.49441
mgSEPre	1.00	5	4.4000	2.07364	.92736
	2.00	6	4.1667	1.94079	.79232
mgSEPost	1.00	5	7.0000	.00000	.00000
	2.00	6	6.0000	1.54919	.63246
prWhatPre	1.00	5	5.4000	2.50998	1.12250
	2.00	6	6.6667	.51640	.21082
prWhatPost	1.00	5	6.8000	.44721	.20000
	2.00	6	6.6667	.81650	.33333
prWhenPre	1.00	5	4.8000	2.28035	1.01980
	2.00	6	6.3333	1.21106	.49441
prWhenPost	1.00	5	7.0000	.00000	.00000
	2.00	6	6.5000	1.22474	.50000
prSEPre	1.00	5	4.8000	2.28035	1.01980
	2.00	6	6.3333	1.21106	.49441
prSEPost	1.00	5	7.0000	.00000	.00000
	2.00	6	6.5000	1.22474	.50000
rpWhatPre	1.00	5	5.6000	2.60768	1.16619
	2.00	6	6.5000	.54772	.22361
rpWhatPost	1.00	5	7.0000	.00000	.00000

	2.00	6	6.8333	.40825	.16667
rpWhenPre	1.00	5	5.0000	2.54951	1.14018
	2.00	6	6.0000	1.26491	.51640
rpWhenPost	1.00	5	7.0000	.00000	.00000
	2.00	6	6.1667	.98319	.40139
rpSEPre	1.00	5	4.8000	2.38747	1.06771
	2.00	6	5.5000	1.37840	.56273
rpSEPost	1.00	5	7.0000	.00000	.00000
	2.00	6	6.1667	.98319	.40139
rvWhatPre	1.00	5	4.6000	2.88097	1.28841
	2.00	6	6.3333	.81650	.33333
rvWhatPost	1.00	5	7.0000	.00000	.00000
	2.00	6	6.8333	.40825	.16667
rvWhenPre	1.00	5	4.6000	2.88097	1.28841
	2.00	6	5.8333	1.47196	.60093
rvWhenPost	1.00	5	7.0000	.00000	.00000
	2.00	6	6.3333	1.03280	.42164
rvSEPre	1.00	5	4.4000	2.70185	1.20830
	2.00	6	5.8333	1.47196	.60093
rvSEPost	1.00	5	7.0000	.00000	.00000
	2.00	6	5.8333	1.32916	.54263
tvWhatPre	1.00	5	2.6000	2.60768	1.16619
	2.00	6	5.5000	2.25832	.92195
tvWhatPost	1.00	5	4.0000	2.73861	1.22474
	2.00	6	5.3333	1.50555	.61464
tvWhenPre	1.00	5	2.6000	2.60768	1.16619
	2.00	6	4.3333	2.16025	.88192
tvWhenPost	1.00	5	4.0000	2.73861	1.22474
	2.00	6	5.1667	1.72240	.70317
edWhatDiff	1.00	5	3.2000	3.03315	1.35647
	2.00	6	-.5000	3.93700	1.60728
edWhatGain	1.00	5	3.2048	2.94515	1.31711
	2.00	6	.7778	2.58039	1.05344
edWhenDiff	1.00	5	2.4000	2.79285	1.24900
	2.00	6	1.0000	2.96648	1.21106
edWhenGain	1.00	5	2.5714	2.54751	1.13928
	2.00	6	.9861	2.49021	1.01662
edSEDiff	1.00	5	2.4000	2.30217	1.02956
	2.00	6	.6667	3.26599	1.33333
edSEGain	1.00	5	1.8667	2.14217	.95801
	2.00	6	.9500	2.50898	1.02429
mlWhatDiff	1.00	5	2.8000	2.16795	.96954
	2.00	6	1.3333	2.73252	1.11555
mlWhatGain	1.00	5	2.6400	2.35542	1.05338
	2.00	6	1.1012	2.42333	.98932
mlWhenDiff	1.00	5	2.8000	2.16795	.96954
	2.00	6	2.0000	2.19089	.89443
mlWhenGain	1.00	5	2.6400	2.35542	1.05338
	2.00	6	1.2194	2.35576	.96173

mlSEDiff	1.00	5	2.8000	2.16795	.96954
	2.00	6	1.1667	2.56255	1.04616
mlSEGain	1.00	5	2.6400	2.35542	1.05338
	2.00	6	1.0500	2.43619	.99457
mgWhatDiff	1.00	5	1.2000	2.94958	1.31909
	2.00	6	1.0000	2.52982	1.03280
mgWhatGain	1.00	5	1.2095	2.68433	1.20047
	2.00	6	1.0000	2.45176	1.00093
mgWhenDiff	1.00	5	2.0000	2.23607	1.00000
	2.00	6	1.8333	2.31661	.94575
mgWhenGain	1.00	5	1.3500	2.59968	1.16261
	2.00	6	1.2222	2.37034	.96769
mgSEDiff	1.00	5	2.6000	2.07364	.92736
	2.00	6	1.8333	2.13698	.87242
mgSEGain	1.00	5	1.4967	2.52873	1.13088
	2.00	6	1.1778	2.36659	.96616
prWhatDiff	1.00	5	1.4000	2.07364	.92736
	2.00	6	.0000	.63246	.25820
prWhatGain	1.00	5	1.0667	2.20038	.98404
	2.00	6	.0000	.10541	.04303
prWhenDiff	1.00	5	2.2000	2.28035	1.01980
	2.00	6	.1667	.40825	.16667
prWhenGain	1.00	5	1.3933	2.58074	1.15414
	2.00	6	.0278	.06804	.02778
prSEDiff	1.00	5	2.2000	2.28035	1.01980
	2.00	6	.1667	.40825	.16667
prSEGain	1.00	5	1.3933	2.58074	1.15414
	2.00	6	.0278	.06804	.02778
rpWhatDiff	1.00	5	1.4000	2.60768	1.16619
	2.00	6	.3333	.81650	.33333
rpWhatGain	1.00	5	1.2333	2.66562	1.19210
	2.00	6	.0595	.12844	.05244
rpWhenDiff	1.00	5	2.0000	2.54951	1.14018
	2.00	6	.1667	.75277	.30732
rpWhenGain	1.00	5	1.3833	2.59915	1.16237
	2.00	6	.0456	.14014	.05721
rpSEDiff	1.00	5	2.2000	2.38747	1.06771
	2.00	6	.6667	.51640	.21082
rpSEGain	1.00	5	1.4167	2.57795	1.15289
	2.00	6	.1444	.11627	.04747
rvWhatDiff	1.00	5	2.4000	2.88097	1.28841
	2.00	6	.5000	.83666	.34157
rvWhatGain	1.00	5	1.7333	2.61034	1.16738
	2.00	6	.0944	.16387	.06690
rvWhenDiff	1.00	5	2.4000	2.88097	1.28841
	2.00	6	.5000	.54772	.22361
rvWhenGain	1.00	5	1.7333	2.61034	1.16738
	2.00	6	.1111	.12546	.05122
rvSEDiff	1.00	5	2.6000	2.70185	1.20830

	2.00	6	.0000	1.54919	.63246
rvSEGain	1.00	5	1.7667	2.58360	1.15542
	2.00	6	.0397	.25574	.10440

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