Interactivity, computers and orthodontic training for undergraduates

Thesis

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Institute of Educational Technology

Interactivity, Computers and Orthodontic Training for Undergraduates

Penny Grigg, MA (Ed), BSc (Hons)

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Abstract

This phenomenological study investigates the interactivity taking place when students use computer-assisted-learning (CAL) in orthodontics and what can be inferred about why these interactions occur. CAL has been proposed in orthodontics because it provides an opportunity to follow a case through to completion. This training is needed if only to give all dentists sufficient knowledge to identify and refer cases for treatment. Two programs have been developed for the pilot: an introductory e-book and a narrative case study based on real records that takes students through a series of decisions relating to case assessment, treatment planning and appliance design.

The mixed-methodology approach of the main study uses activity theory to provide a framework combining qualitative and quantitative data to analyse the interactivity of 48 students as they work through the case study. Observations and transcripts of recordings of conversations between pairs of students, together with post-session interviews, facilitate a deeper understanding of students' conceptions of orthodontics particularly when they explain their reasoning in negotiations over answers, clarified where necessary by data recorded by computer activity log-files. The linear sequence of questions in the program allows students' interactions to be compared on a "like-for-like" basis.

Activity systems are used to identify various tensions in students' responses whilst using CAL, facilitating a deeper understanding of the observed interactivity. A phenomenological profile of the students has been developed based on these interactions, particularly in response to the unexpected caused by the complex reality of the case. Further supporting quantitative data is obtained from a questionnaire survey and end-of-year examination results used to provide contextual background material particularly when presenting the results to a domain heavily dominated by a scientific epistemology.

Throughout the program many students seem to ignore features not in their immediate focus. Students' reactions to the unexpected (extraction of 7s) indicates about half of the students are so reliant on simplified taught procedure they are unable to relate the extractions to these "hidden" features. Other students adopt a deeper approach and are able to identify reasons why the unexpected occurs. The program has been found to promote an active approach to learning in most students, whether their approach is surface or deep. Most students learn from the feedback provided by the program, even when this feedback is not explicit on a point. Students also benefit from working with a partner. The deeper understanding of students' misconceptions afforded by the adopted research methodology enables the development of guidelines for the future design of CAL in dentistry.

Acknowledgements

I would especially like to thank the following for their help and guidance, particularly when things got 'sticky' – my internal supervisors at the Open University, Dr Gill Kirkup and Professor David Hawkridge. I would like to say in particular how much I have enjoyed studying for this PhD, and, looking back over the years, I can see just how far I've come in my understanding of the whole topic of educational technology.

Special thanks to the members of the dental school at Bristol University, starting with Professor Chris Stephens – this PhD would not have been possible without his assistance along the way! Thanks too to the dental students who allowed me to record and observe whilst they used computers to learn about orthodontics and took the time to answer questions during the post-session interviews, and to their tutors sitting patiently in the room next door. Other members of the dental school who should be acknowledged include, in no particular order: Richard Vowles, Tony Telford, Phil Sellen, Joe Green, Steve Greenwood, Iain Hawthorn, and Seth Kumordzie. My thanks, too, to Professor Nigel Harradine – who, during the course of this study, took me on as an orthodontic patient and showed what could be achieved with orthodontic treatment, even at my age!

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Outside the field of higher education, I would very much like to thank and acknowledge the help offered by Douglas Holt, Canon Theologian at Bristol Cathedral who helped me better understand the work of Wittgenstein. Finally, and by no means least, there are all those who provided me with domestic help and support, particularly Carole Hawkins, Mum and Dad, and my long-suffering family: husband Tony and four sons, Christopher, Andrew, Alexander and Daniel, who have had to put up with all the 'labour pains' that produced this thesis!

My thanks to everyone for all their help, and for all their patience in putting up with me over the years!

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On CD: Resource files derived from QSR/N6 generated reports of discourse analysis of a combination of qualitative and quantitative data collected when students used a computer to learn about orthodontics. The files contain a combination of transcripts taken from combined audio and video recordings of the students as they worked through the computerised Case Study "JB" together with relevant commentary collected during the QSR/N6 analysis of the data. A table listing the transcription and discourse analysis conventions used to generate these files can be found in Appendix A, table A3.

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Chapter 1: Introduction

Chapter 1: Introduction

1.1 The purpose of this thesis

The aim of this phenomenological study is to develop a better understanding of the interactivity taking place when students use computer-assisted learning (CAL) in orthodontics. Activity theory is used both as a heuristic device and to provide a framework for combining qualitative data collected from observations and transcripts video and audio recordings of students using CAL with relevant quantitative data gathered from computer log files of student activity, a pre-session questionnaire survey and post-session, end-of-year orthodontic examination results.

Modern dentistry embraces a wide variety of specialist subjects (Seward, 1998), so to get sufficient information to be meaningful but still be able to manage the amount of data collected this study is limited to one specialty: orthodontics. While the research focuses on one specialty, the procedural nature of dentistry means that the findings are likely to be applicable across a range of dental specialties.

1.2 The structure of the thesis

This chapter starts with the framework used to write this thesis. This is followed by a definition of orthodontics, a discussion of which patients might benefit from orthodontic treatment and what is meant by CAL. To explain the background and importance of the research the chapter looks at recent changes in dental education and orthodontic provision in the UK and the impact of these changes on dental education. After exploring the problems facing current orthodontic provision in the UK, the chapter ends with an overview of the previous relevant literature on CAL in dentistry and medicine and identifies the key research questions that are the focus of this study.

Chapter 2 reviews the underlying epistemology of the research to explain the adoption of a mixed-methods methodology. After describing the learning theories chosen to analyze the interactivity in this study, the problems associated with defining and classifying interactions are discussed. The chapter ends by explaining how activity theory, with its ability to act as a bridge between external and internal experiences of learning, has been used as a framework for understanding the data collected in the study.

Chapter 3 explores the social-historical-cultural background in which computers have been used to provide solutions to some of the problems facing dental education. After describing the advantages, disadvantages and different ways of classifying computer use, the chapter examines different ways in which computers could have been used in the study. The chapter concludes by highlighting the rationale for the development of the two orthodontic CAL packages used in this study.

Chapter 4 justifies the choice of paradigm adopted for this study, based on the findings of the earlier chapters. After arguing for the merits of a phenomenological, grounded theory approach, the chapter describes the research methodologies employed in the pilot and main studies. The chapter explains how discourse analysis techniques have been used as a baseline to analyze the data collected for the main study, allowing contextual themes to be identified and developed for later discussion as they emerged from the analysis of the data. After exploring the research context, the chapter ends with an overview of the background behind the development of the CAL programs used in the study.

Chapter 5 starts by describing two different ways in which teeth can be identified as students switch between both during the study. The chapter then reviews the development of the two CAL programs produced for the pilot before analyzing what happened during the pilot study when four volunteer students were observed, interviewed and recorded using the programs. The chapter ends by discussing what was learnt and what these findings imply for the research carried out in the main study.

The purpose of Chapter 6 is to analyse the interactivity that occurs when students work through a series of computerised questions classifying and assessing orthodontic case records presented on the screen. Quantitative data are used, where appropriate, to anchor and underpin the qualitative data collected from the students. The chapter starts by reviewing the quantitative data derived from log-files and the outcome of end-of-year examinations. Using activity theory as a framework, the chapter examines the interactivity observed whilst the students work through the case assessment section of the program, drawing inferences where possible about students' underlying conceptions of orthodontics that might underpin their activity in response to the questions presented by the program.

Chapter 7 explores the interactivity that occurs as students answer questions designed to take them through a suitable plan of treatment for JB. Using activity theory as a framework, it discusses students' responses to each decision in turn, concentrating on what happens when students encounter the unexpected. Of particular interest are students' reactions to decision 4, extraction choices, which are described in detail because this is where the complexity of the case departs radically from students' expectations of what is required.

Chapter 8 investigates the interactivity that is observed and recorded as students engage in the final activity in the program, where students are asked to reflect on how they might design the orthodontic removable appliances required to treat the case. Reasons are advanced as to why there is a change in the nature of this interactivity at this point in the program. Finally activity theory again provides a heuristic framework to explore the student interactivity that occurs as students work through a series of multiple-choice questions on designing appliances suitable for achieving the objectives of the case.

The purpose of Chapter 9 is to discuss the analysis of the results presented in the previous 3 chapters. This chapter starts by drawing together the main findings of the results chapters before examining possible differences in the interrelationships between the students based on these findings. The chapter concludes by proposing a series of guidelines for the future development of CAL in dentistry.

Finally, Chapter 10 summarizes the main findings of the research carried out for this thesis and the implications this study has for future research into computer-assisted learning in orthodontics. The chapter provides a critical reflection on the study and its contribution to knowledge and reviews the guidelines and recommendations for how CAL design in dentistry might be improved. The chapter ends by making suggestions for future research in this area.

1.3 Definitions

1.3.1 What is orthodontics?

Orthodontics is defined as the specialty concerned with preventing and correcting occlusal anomalies of the teeth where 'occlusal' refers to the relationship between the upper and lower surfaces of the teeth when they come into contact with each other. These "malocclusions" can be treated when such anomalies are severe enough to have an effect on either the physical and/or mental well–being of an individual (BDA 1954, Houston, Stephens and Tulley, 1992). To judge whether a patient requires treatment orthodontists use as a benchmark the concept of an 'ideal occlusion' from which to measure the degree of malocclusion. However this ideal is rarely seen in the natural dentition, especially in the UK, and differs from what orthodontists would define as a 'normal' occlusion, which can have minor deviations – as long as these irregularities do not cause any problems to the patient. A 'malocclusion' is thus defined as an occlusion that has significant deviations from the ideal which cause sufficient problems for a patient to require treatment (Houston, Stephens and Tulley, 1992).

1.3.2 Who needs orthodontic treatment?

Despite the development of indices that attempt to quantify the degree of "orthodontic treatment need" (Elderton and Clark, 1983) and to identify those patients who ought to receive orthodontic treatment from a publicly funded dental health care system with limited resources (Leighton and Moss, 1998) it is difficult to give hard and fast rules about who will benefit from treatment. Orthodontic treatment can be provided for:

- Physiological or pathological reasons: e.g., to correct general orofacial disorders or to prevent periodontal disease and/or dental caries.
- Psycho–social reasons: e.g., for children upset by teasing about their teeth.

These two categories are not mutually exclusive and there is no clear borderline between them. To complicate matters, even when two patients have the same arrangement of teeth, one patient may be happy not to have treatment that the other would find essential. This paradox is partly because of individual differences in how each patient regards their teeth and partly because the patient's lips can either make a dental anomaly obvious or cover it so that it is no longer noticeable – except, perhaps, to the patient (Shaw, O'Brien and Richmond, 1991a,b).

Orthodontics is therefore a good example of a topic whose '*ill–structured aspects of knowledge* pose problems for *advanced knowledge acquisition*' (Spiro *et. al.*, 1988, p.25). CAL offers the possibility of providing students with additional experiences to help them learn about the complexities of orthodontics. Although this potential will be discussed further in Chapter 3, the next section defines what CAL means in the context of this thesis.

1.3.3 What is CAL?

Computers can support teaching in several ways. For example, computers can be programmed both to provide students with information about a topic and to ask them to respond to questions as part of that program (e.g., a CAL program). Computers can also be used as a means of communication between students and teachers or other students, or they can be used as tools in a learning activity (e.g., using a spreadsheet and word processing package to produce an assignment) (Belanger and Jordan, 2000). The different ways in which computers can be used to support learn has led to a multitude of labels besides CAL, including Computer Assisted Instruction (CAI), Computer Aided Learning, Computer-

Assisted Language Learning (CALL), Computer-Based Education (CBE), Computer-Based Learning (CBL), Computer-Based Training (CBT), Computer Managed Instruction (CMI), Computer Managed Training (CMT), Computer Mediated Communication (CMC), Electronic Learning (e-learning) or Electronic Performance Support Systems (EPSS).

More recently people have tended to talk about e-learning material when referring to the use of material provided by computers to support learning (Belanger and Jordan, 2000). However CAL was the term used by the Computers in Teaching Initiative Centre for Medicine (CTICM) when based at Bristol University. As a consequence even now CAL is the term more commonly used to describe this type of material at the Dental School. Hence even though the package which forms the basis of this study now sits on a server and is accessed via an intranet the term CAL, rather than e-learning, is still used to refer to these programs at the dental school and has therefore been used to describe the programs developed for use in this study.

1.4 Background to the study: orthodontic training in the UK

The latter part of the 20th century saw a huge increase in both the range and complexity of dental treatment. This has had a correspondingly large impact on the dental curriculum and how dentistry was taught (Hallett, 1980; James, 1981; Leatherman, 1984; Pickard, 1980; Williams, 1981). As a result, newly qualified graduates are no longer expected to master all aspects of dentistry. However as GDPs they still require a minimum amount of orthodontic training. This training is necessary because, even if they decide to refer all such cases, they need to be able to recognise which of their patients would benefit most from orthodontic treatment since the only way patients get to specialists is if they are referred by GDPs. GDPs also need to be able to advise patients (and parents where appropriate) what such orthodontic treatment might involve (British Orthodontic Standards Working Party, 1990, 1991; General Dental Council, 2002; Gosney, 1986; Gravely, 1989;

Isaacson, 1992; Kay and Blinkhorn, 1987; Lowe, 1987; Lumsden, 1992; Parfitt and Rock, 1996; Parker, 1986; Stephens, 1983, 1985).

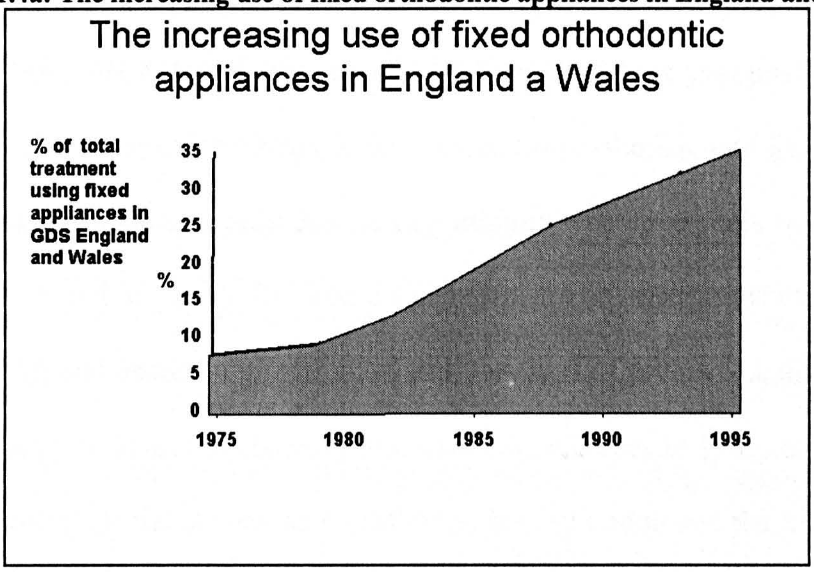
Therefore to qualify, students need to master the basic material, signs and symbol systems necessary to be able, at the very least, to communicate in the subject. In orthodontics they will need to start by classifying the patient's occlusion. Then they have to decide whether treatment is required and if so, what might be on offer. They must also recognise complex cases that should be referred for specialist orthodontic treatment. Even in the latter situation GDPs ought to be able to describe what will happen (for example to their patients) without necessarily carrying out the treatment themselves.

The difficulties in providing dentists with sufficient training in orthodontics are compounded by factors including an increase in demand for high standards of treatment and for more complex treatment as well as the corresponding increase in what dental students have to learn about orthodontics to master the subject. The danger is that if GPDs do 'not seem to know what to refer, to whom it should be sent or at what stage of dental development the referral is appropriate.' (British Orthodontic Standards Working Party, 1990, p.338), then a patient may get the idea that they need orthodontic treatment, even if it is inappropriate. Furthermore once patients decide they need orthodontic treatment, any discrepancy between a layperson's idea of malocclusion and what can be achieved and the dental profession's understanding can make it extremely difficult for specialists to persuade patients to change their minds (Hirst, 1990; Gosney, 1986; Parker, 1986).

Improvements in treatment methods, coupled with expectations of ever-higher standards of treatment from both dentists and patients, have resulted in more patients receiving fixed appliance treatment (Figure 1.4a), rather than being treated with simpler removable appliances (British Orthodontic Standards Working Party, 1990; Mason, 1994; Richmond, Shaw and Stephens, 1992, Richmond, Andrews and Roberts, 1993, Richmond *et. al.*, 1993; Stephens, 1987, 1988; Sullivan and Dibiase 1983; Williams, 1988).

This demand for higher standards of treatment is not driven primarily by how dentists perceive the irregularity as a problem, but more by the patient's perception of a problem, particularly aesthetically (Gosney, 1986; Parker, 1986) and may come into conflict with the NHS's priority of dealing with the impact of malocclusions on dental health. However, the psychological well-being of patients is important, and GDPs have argued that 'both appearance and dental fitness are worthy of our concern and deserving of our help' (Parker, 1986, p.125).

Figure 1.4a: The increasing use of fixed orthodontic appliances in England and Wales



from Dental Practice Board statistics (http://www.dpb.nhs.uk/gds/index.shtml)

One consequence of better orthodontic provision within city centres is that dental schools have been finding it more difficult to identify sufficient numbers of simple cases suitable for treatment by students. The cases referred to dental school consultants now tend to be complex ones, requiring the use of fixed appliances (Gravely, 1989). Whilst removable appliances are simple and can be used safely by undergraduates and GDPs, the complexities of learning how to use fixed appliances are beyond the undergraduate and do require a practitioner to go on a 3-year full-time postgraduate training course (Stephens, 2003).

The steady decline in the number of cases suitable for treatment by undergraduates can also be attributed partly to a rise in expected standards of treatment by supervising clinical teaching staff (Stephens and Harradine, 1988). In addition if orthodontists are left to determine the standards of occlusal result, an increasing proportion of cases will be identified as requiring fixed appliances, whilst improving standards of oral hygiene and caries control have further increased the proportion of children who can potentially benefit from fixed appliance treatment (Stephens and Harradine, 1988). However due to restrictions on NHS resources there are not enough orthodontic teachers within dental schools to cover the amount of training required (British Orthodontic Standards Working Party, 1991; Murray, 2002; Russell *et. al.*, 1999).

To some extent though the short-fall in actual numbers of non-teaching orthodontic specialists has been met following the recent introduction of three year post-graduate orthodontic training courses (Stephens, 2003), which brings the UK into line with the accepted European standard in orthodontics of a minimum of three years supervised training (Leighton and Moss, 1998). These specialists are not distributed evenly across the country, however, and despite a growth in overall numbers of specialists, distribution has remained very uneven across the country. For example, whereas in 1965 there were only three times as many specialists practising orthodontics in London and the SE compared to the Midlands, by 1991 this figure had grown to ten times as many (Table 1.4a), a pattern that remains unchanged today (Stephens, 2003).

Table 1.4a: Change in numbers of orthodontic specialists by region between 1965 and 1991

Orthodontic Specialists England and Wales 1965-1991		
	1965	**1991**
London and SE	49	183
Midlands	18	18
North	15	20
Wales	4	30

from Stephens, 2003.

Most specialists tend to be concentrated near cities and towns with large enough populations and/or pools of local GDPs to supply them with sufficient cases to maintain a viable specialist practice and these GDPs based in urban populations tend to be happy to refer most orthodontic cases to specialists. In more remote parts of the country orthodontic provision is left to GDPs unless patients are prepared to travel many miles even for what may actually be a very simple treatment (Brown, Stephens and Usiskin, 1982a,b; British

Orthodontic Standards Working Party, 1990; Gravely, 1989; Kelly and Springate, 1996; O'Brien, 1991; O'Brien *et. al.*, 1989; Stephens, Orton and Usiskin, 1985, Stephens, 1988). Thus GDPs in parts of the country poorly supplied with specialists are likely to carry out orthodontic treatment themselves (Brown, Stephens and Usiskin, 1982a,b; British Standards Working Party, 1990). For example, Table 1.4b shows the large difference in percentages of GDP Principals carrying out orthodontic treatment in practice in Health Authorities in the north east compared to those in London.

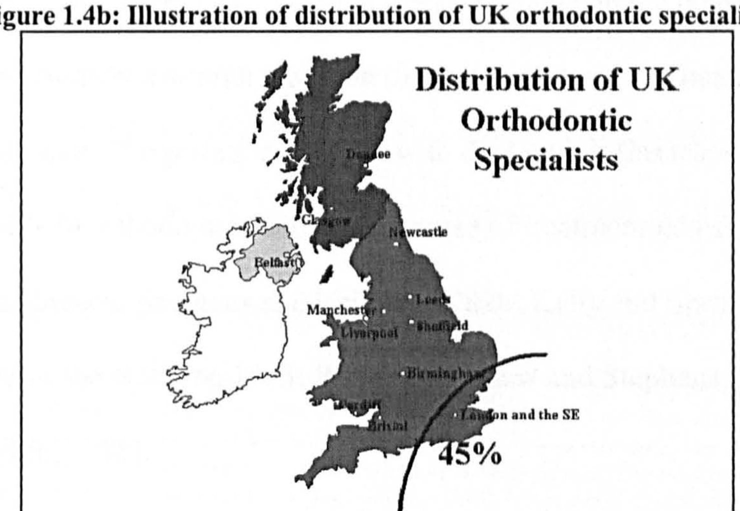
Table 1.4b: Percentage of GDP Principals carrying out some orthodontic treatment in practice London versus the North-East

Principals doing some orthodontic treatment in the General Dental Service					
Region	**Authority***	**Population 1991 Census figures****	**% Principals doing some orthodontic treatment******		
			1999/00	2000/01	2001/02
London	Kingston & Richmond	140,068	29	26	20
	Brent & Harrow	441,587	13	14	13
	Ealing, Hammersmith & Hounslow	553,905	16	16	14
North-East	County Durham	36,937	70	74	69
	East Riding	<1,000***	76	76	76
	Tees	86,845	78	77	79

* Authorities as defined by Dental Practice Board statistics, rather than those of the National Statistics Office.
** Figures taken from National Statistics on-line (http://www.statistics.gov.uk/geography/urban_rural.asp).
*** Defined as a rural area by the National Statistics office, where population <1,000.
**** Figures taken from Dental Practice Board statistics (http://www.dpb.nhs.uk/gds/index.shtml)

It is thus inevitable that in many parts of the country GDPs will continue to fill this gap in the provision of specialist services (Figure 1.4b), especially when considering the distribution of specialists per head of population (Table 1.4c).

Figure 1.4b: Illustration of distribution of UK orthodontic specialists



from Stephens, 2003

However it is unlikely that improvements in undergraduate dental educational standards alone will increase the proportion of practitioners who are prepared to undertake simple appliance treatment without the prior advice of a consultant orthodontist. The difficulty is that there is no longer sufficient time within the curriculum (even with a five-year undergraduate dental course) to provide enough training for newly qualified graduates to feel confident about carrying out orthodontic treatment themselves (Alexander, 1988; BDJ, 1988; British Orthodontic Society, 2002; British Orthodontic Standards Working Party, 1991; Gravely, 1989; Howat, 1990; Jacobson, 1988; Lowe, 1987; Mitchell, 1992, 1994; Parfitt and Rock, 1998; Parker, 1986; Richmond, Shaw and Stephens, 1992; Richmond, Andrews and Roberts, 1993, Richmond *et. al.*, 1993; Stephens, 1983, 1985, 1988; Williams, 1988).

Table 1.4c: Comparison of numbers of orthodontic specialists in London and the SE compared to the rest of England

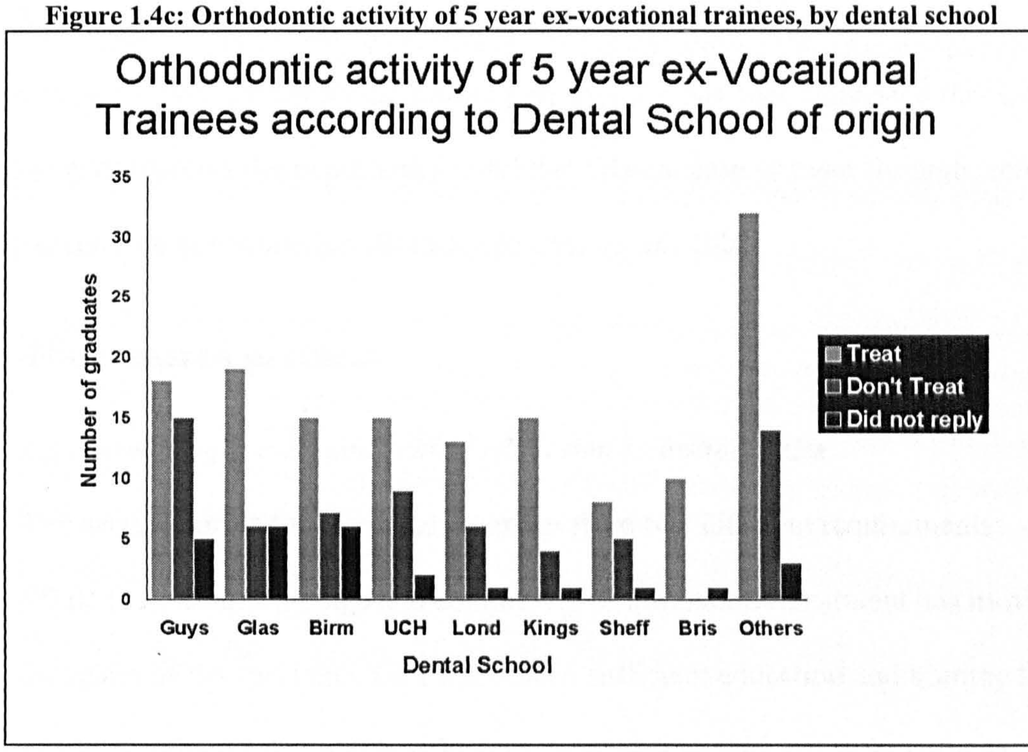
High Street GDPs with Specialist Qualifications in the UK (MOrth/DOrth) 1991		
Region	**Specialists**	**Specialists/Million Population**
England (London and SE)	183	**10.9**
England (remainder)	125	**2.9**
Wales	30	10.7
Scotland	38	6.5
N. Ireland	19	13.5

from Stephens, 2003

For the GDP who finds himself/herself under pressure from patients to provide orthodontic treatment because there is no local specialist, short postgraduate courses (1-2 days) do not provide an answer since it can be several months into a course of treatment before the GDP encounters a similar situation to what is covered on that course, by which time they are likely have 'forgotten' exactly how to deal with it (Isaacson, 1992). This delay is unavoidable in orthodontics because a course of treatment takes on average, two years to complete (Brown, Stephens and Usiskin, 1982b; Kelly and Springate, 1996; Richmond, Andrews and Roberts, 1993; Richmond, Shaw and Stephens, 1992; Richmond *et. al.*, 1993; Usiskin, 1988).

On graduation the requirements of vocational training means that most GDPs spend just a short time in their first position – usually one year as an associate mentored by an experienced GDP – before moving on. This transitional period also means that they, and their principals, may be reluctant to let them start treating orthodontic cases when they are unlikely to be around to complete the treatment (Brown, Stephens and Usiskin, 1982b; Isaacson, 1992; Richmond, Shaw and Stephens, 1992; Usiskin, 1988; Webb, 1982). Similarly, because so few GDPs actually practice orthodontics, students' mentors '… may not have the experience to supervise, confidently, a new graduate undertaking appliance treatment' (Isaacson, 1992, p.43). Therefore it can be several years before GDPs start to think about treating orthodontic cases themselves (Figure 1.4c). As such, even as far back as the early 1970s, orthodontics has been one of the most frequently requested post–graduate courses (British Orthodontic Standards Working Party, 1990; Lowe, 1987; Slack and Flood–Page, 1972).

Figure 1.4c: Orthodontic activity of 5 year ex-vocational trainees, by dental school



from Eaton and Stephens, 1991.

Although these short part-time courses are popular with GDPs, who have asked for more such courses to cope with the increasing demand for orthodontic treatment (Bowden, 1995; Kelly, 1995; Nichols, 1995), they are not considered an effective way of providing training (Cornish, 1995a; Johnston, 1989; Parfitt and Rock, 1996; Usiskin, 1990). The problem is that trying to learn a complex subject from attendance on irregularly spaced short courses can be extremely inefficient. Elsewhere it has been noted that, rather than dealing with the concept in the abstract, it is better to cover the ill-structuredness of a topic through a series of '...many concrete examples of uses' (Spiro *et. al.*, 1992, p.68).

A major problem trying to incorporate orthodontic experience within a one–year vocational training scheme is that there is not enough time to complete active appliance treatment. Students could manage some simple cases if the vocational training scheme was increased to a minimum of two years (British Orthodontic Standards Working Party, 1991; Isaacson, 1992; Jacobson, 1988; Mills, 1982; Usiskin, 1988). Ideally orthodontic training should be provided via three-year Masters in Orthodontics (MOrth) courses rather than the cheaper solution of short, part-time courses (British Orthodontic Standards Working Party, 1986; British Orthodontic Society, 2002; Cornish 1995b).

With all the practical difficulties in finding suitable teaching cases for undergraduates – even for purely diagnostic purposes – it has been suggested that CAL can be used to give students the opportunity to follow a dental case or cases through from initial presentation to completion (Brearley Masser *et. al.*, 2002).

1.5 The research problem

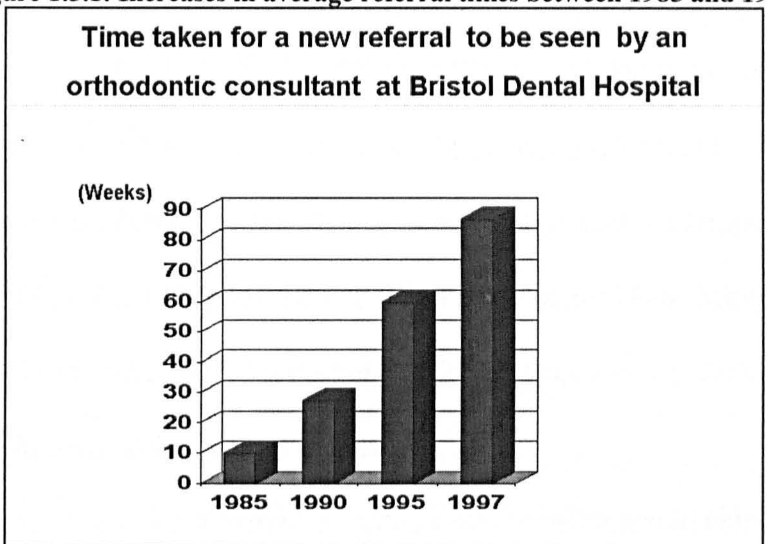
1.5.1 An overview of the drivers behind education in orthodontics

The need for orthodontic education arises from two different requirements:

1. While the increasing range and complexity of orthodontic treatment has moved into the realm of the specialist, GDPs still need sufficient education and training to recognise which cases will benefit from treatment so they can refer patients appropriately. They also need to be able to explain what is involved to their patients and their patients' parents (Stephens, 2003).

2. In rural areas there are few specialist orthodontists to whom GDPs can send patients. Hence GDPs may end up treating simple cases because it is difficult to persuade a consultant with a long waiting list of complex cases to accept straightforward cases (Figure 1.5.1).

Figure 1.5.1: Increases in average referral times between 1985 and 1997*



* from Stephens, 2003 – see also Willmot *et. al.*, 1995.

Orthodontic education at the undergraduate level needs to embrace theoretical knowledge, diagnostic and treatment skills. However both because of a lack of suitable cases and because of the time required to complete orthodontic treatment very few students have the chance to follow a simple case from initial presentation to completion of treatment. CAL offers the potential to provide students with a means to follow one (or more) cases from examination to completion within the duration of their course.

1.5.2 Previous literature on CAL in dentistry

Both financial and clinical constraints on teaching resources during a period of rapid advance in technology have continued to encourage the development of CAL to supplement student learning and to help provide General Dental Practitioners (GDPs) with the 'life-long' learning material they need to keep up-to-date (Stewart and MacMillan, 1992). However despite the variety of types of CAL used in dental education (Grigg and Stephens, 1998), the literature published to date about the use of CAL to support learning in medicine and dentistry has tended to focus on one of four broad categories:

1. Descriptions of CAL packages (Carrotte *et. al.*, 1996; Fung, Ellen and McCulloch,

1995; Ireland, 1996; Johnson, 1992; Marsh, *et. al.*, 2003; Miller, 2000; Porter *et. al.*, 1996a,b; van Sint *et. al.*, 2003; Walmsley and Pollard, 1997)

2. Descriptions of CAL packages with an evaluation of how well students do in comparison to those using more traditional learning methods (e.g., computers versus lectures, books or videos (Barkhordar, Pollard and Hobkirk, 2000; Clark, Weekrakone and Rock, 1997; Dewhurst and Williams, 1998; Dewitt and Palmer, 1999; Finch, 1999; Fouad and Burleson, 1997; Grimes, 2001; Hobson *et. al.*, 1998; Howerton *et. al.*, 2002; Letterie, 2003; Lewis, 2003; Lowe, Wright and Bearn, 2001; Luffingham, 1984; Matthew, Pollard and Frame, 1998; Mileman, Van Den Hout and Sanderink, 2003; Perryer *et. al.*, 2000; Quinn *et. al.*, 2003a,b; Rosenberg, Grad and Matear, 2003; Tan *et. al.*, 2002)).

3. Quantitative studies of students' attitudes and/or confidence in using computers (Brearley Masser *et. al.*, 2002; Day and Edwards, 1995; Dickmann *et. al.*, 2000; Eynon, Perryer and Walmsley, 2003; Fairclough and Carrotte, 1995; Grigg and Stephens, 1999; Grigg *et. al.*, 2001; Grimes, 2002; Gupta, White and Walmsley, 2004; Howerton *et. al.*, 2002 Leong, Baldwin and Adelman, 2003; Plasschaert *et. al.*, 1995; Ray and Hannigan, 1999; Schleyer, Torres-Urquidy and Straja, 2001; Walmsley *et. al.*, 2003; Welbury, *et. al.*, 2001)

4. Articles explaining how dental and medical educators can use the latest learning theories to develop CAL material to support their teaching (Carrotte, 1993; Chadwick and Bearn, 2002; Coulson and Feltovich, 1993; Falk-Nilsson *et. al.*, 2002; Newble and Entwistle, 1986; Spallek, 2003).

There is very little in the literature on dental education about the nature of interactivity when students use computers to learn about dentistry. An important benefit of such a study will be to provide CAL developers with an insight into what actually happens when students use computers to learn about orthodontics, allowing them to make use of this understanding when designing future dental CAL programs.

1.5.3 Key research questions

The lack of research into the nature of interactivity when students use computers to learn about dentistry provides an opportunity to explore in more depth exactly how students make use of CAL to learn about orthodontics. The focus of this research is to find out more about what happens when students use CAL, exploring what can be inferred about their underlying conceptions of orthodontics with a view to using this deeper understanding of how students learn to produce guidelines for future CAL development in dentistry.

Thus the three key research questions for this study are:

1. How do students interact with a computer program, each other and their tutor when they use CAL?
2. Using activity theory as a framework, what can be inferred about the conceptions of orthodontics held by students that might influence the observed interactivity?
3. What are the implications of the answers to 1 and 2 for the future design and development of orthodontic CAL?

1.6 Chapter summary

The chapter started by defining what is involved in the specialty of orthodontics, who might benefit from treatment and how the dental school in this study refers to computer programs used to support learning. The chapter then reviewed the problems facing providers of orthodontic education and treatment in the UK to explain the historical-social-cultural reasons why this study is important. The chapter gives a brief overview of the published literature on the use of CAL in medicine and dentistry, revealing that evaluations of the outcome of using CAL programs to date have relied either on student questionnaires or tried to compare pre- and post-test results, sometimes in comparison with other, 'more traditional' media (e.g., lectures). Because CAL has the potential to offer a solution to the problems facing orthodontic dental educators, the purpose of this study was to investigate how students interact with CAL, each other and their tutor when learning about orthodontics to broaden CAL developers' understanding of CAL interactivity within a framework based on activity theory.

Chapter 2: Activity Theory as a Framework for Investigating Interactivity

Chapter 2: Activity Theory as a Framework for Investigating Interactivity

2.1 Introduction to chapter 2

This chapter reviews the underlying epistemology of the research to explain the adoption of a mixed-methods methodology. In a domain dominated by a positivistic, evidence-based ontological approach it is argued that the findings of a primarily qualitative study are more acceptable if conceptualised by the collection and analysis of relevant quantitative data. After describing the learning theories chosen to analyze the interactivity in this study, the problems associated with defining and classifying interactions are discussed. The chapter ends by explaining how activity theory, with its ability to act as a bridge between external and internal experiences of learning, has been used as a framework for understanding the data collected in the study.

2.2 Paradigms of learning

Depending on their underlying theoretical positions groups of researchers may adopt different paradigms and methodologies for studying how people learn. These differences arise because each methodological approach is closely intertwined with its underpinning epistemology (Duffy and Jonassen, 1991; Jonassen, 2000). These epistemologies range from positivism at one extreme to relativism at the other. Each is supported by, and has grown out of, various underlying ontological systems that have been put forward as models for understanding the form, nature and preconditions of knowledge.

It has been argued that any dichotomies between the two extremes are more apparent than real, and that most educational research will be underpinned by an epistemology that lies somewhere between the two extremes (Bryman, 1992; Cobb, 1996; Hammersley, 1992). The ability to adopt a flexible methodological approach, depending on the researcher's objectives, can provide insights into students' behaviours and understandings that can be used to broaden researchers' understandings of the educational process at several different levels (Laurillard, 2002).

However dentistry is a domain dominated by quantitative research methodologies, underpinned by a strong positivistic belief system. Indeed a positivistic strategy has nearly always been adopted when reporting on findings on the use of CAL in dentistry (Section 1.5.2). Furthermore at any one point in time there is a recognised series of procedures regarded by the dental community as 'best' practice. Recent technological advances have made it easier for such quantitative evidence-based research to be carried out, collected and disseminated to all dental students, teachers and practitioners. In the dental field this research is considered to be an "objective" body of knowledge, based on current best practice, used as a benchmark to monitor subsequent dental performance (BDJ, 2001; Forrest and Miller, 2003; LTSN, 2002a; Richards, 2002a). This "body of knowledge" can be distinguished from personally held beliefs, hunches and opinions because it is regarded as "justified"; i.e. '… it has stood up to sustained scrutiny and been tested by the best available evidence' (Bruner, 1996, p.16).

On a pragmatic level the ability to share this "body of knowledge" among individuals facilitates communication across a particular domain. Hence, although students are expected '… to use their knowledge in a variety of ways, and to contribute personal and even original ways of thinking about their subject' (Laurillard, 2002, p.25) they also have to come to some form of consensus with the underlying paradigm and educational norms adopted by the community they wish to join (Marton and Booth, 1997). These "norms" give a combined personal and consensual character to academic work that allows learning to progress (Laurillard, 2002). From the patient's view the knowledge that specialists are using the most up-to-date techniques and procedures is important because, as one commentator put it:

> 'If I hire a surgeon to do heart surgery, PLEASE let me have one who has learned the trivial case and knows that my heart looks like every other human heart. Please don't let him negotiate new meanings and hook up my veins in some "self-chosen position to which [she/he] can commit [herself/himself]." I want her/him committed to the standard objective

view. The trivial case is not so trivial.' (Merrill, 1991, p.49).

The difficulty is that students are unlikely to experience and use that shared "body of knowledge" in exactly the same way, if only because their previous experiences can lead to differences in interpreting their own construction of that knowledge (Bruner, 1996). Although a positivistic approach may be extremely useful as a tool for assessing the effectiveness of a dental procedure, if educational research was confined to a purely quantitative approach such an extreme positivistic epistemology might run the risk of being unable to capture the underlying meaning behind the behaviour (Robson, 2002). A relativistic epistemology lets educational researchers probe beyond the standardised tools used for testing hypotheses by providing tools that permit the development of paradigms of human behaviour flexible enough to take account of the complexities that occur when students construct their own personal understanding of a topic.

The research questions in Chapter 1 seek to investigate human behaviour and fall naturally into a qualitative methodology that can take into account this complexity. The aim of this study is to go beyond providing a basic description of student interactivity by using a combination of qualitative and quantitative data to develop a deeper understanding of how students are using computers to learn about orthodontics. However the findings are more likely to be acceptable within the domain of dentistry if supported by quantitative data that can be used to contextualise the study if only because, in the words of Silverman, '... in a bureaucratic-technological society, numbers talk' (Silverman, 2001, p.35). A mixed methods approach can take advantage of the strengths of both epistemologies, affording a better insight of the phenomenon under investigation (Brannen, 1992a; Robson, 2002. As will be discussed later in this chapter, activity theory provides a framework for bringing together both types of data.

2.2.1 Pedagogical research focused on individuals

To be recognised as being good at dentistry, practitioners need to carry out recognised procedures for treating various clinical problems. These procedures are taught using a series of simplified procedures. If they feel they have sufficient compentency students will need to decide on a suitable course of treatment and be capable of carrying out that treatment to a satisfactory standard. The danger is that, as has been found in the medical field (Feltovich, Spiro and Coulson, 1989; Jonassen and Henning, 1999; Spiro *et al.*, 1992) these simplistic schemata may prevent students from dealing with the complexity of real cases when they get to an intermediary stage in their training.

Several different taxonomies of learning have been developed to help teachers organize learning tasks for their students. Useful for this study is a taxonomy developed from Bloom's original 'SOLO' taxonomy by Anderson *et al.* (2001). This two-dimensional taxonomy splits learning activities into level of knowledge and type of cognitive processes required to complete a given task. The taxonomy provides a starting point for analysing the activities students in this study are expected to complete. One dimension divides learning tasks into 4 knowledge elements: factual, conceptual, procedural and metacognitive. The other dimension has 6 cognitive processing elements: remembering, understanding; applying; analysing; evaluating and creating. It is argued that the skill level required to cope with each level on both dimensions increases along each dimension, with the recall of factual knowledge the simplest type of activity for students to master (Appendix A, Tables A1 and A2).

This two-dimensional schema can be criticised for its potential for rigidity, especially if applied without taking into account the natural complexity inherent in any learning situation. For example learning materials have been developed for use by one group of students at a very basic level and by another, more advanced group, at a higher level. This ability to "vertically stream" material can make it difficult to definitively assign a learning task to a particular knowledge/cognitive processing level, because the focus is on the task, rather than the students. Therefore assessing the learning material by itself may fail to take into consideration the different ways in which learners construct their own personal understanding of the world based on their previous experiences of a topic through active participation and interaction with the surrounding environment (Cunningham, 1991; Duffy and Bednar, 1991; Jonassen *et al.*, 1995; Perkins, 1992, Spiro *et al.*, 1991b). The taxonomy is useful in this study as one of a range of tools used to analyse the activity students are being asked to reflect upon in each section of the computerised case study.

The next step is to consider the impact of the context and nature of the learning task on how students learn (Papert, 1980). This approach allows students to be categorised depending on how they tackle a particular learning task. For example, researchers might differentiate between students who adopt a deep, active approach to learning (spending time exploring the subject, linking it to their own personal experience, *etc*), and those who adopt a surface, passive approach to learning (taking everything at face value, not 'engaging' with the subject) (Biggs, 1991, 1993; Entwistle, 1988a,b; Fransson, 1977; Marton and Säljö, 1976a,b; Säljö, 1979; Schmeck, 1988b; Svensson, 1977). The way in which students approach a particular learning task will directly influence the levels of understanding about that task that they subsequently achieve. It is argued that those who adopt a deep, active approach to learning being are more likely to experience a successful outcome than those who adopt a surface, passive approach (Entwistle, 1988a,b). Although other alternatives to research into learning styles exist, this "orientation to study" approach has been found to have 'a depth of empirical support not so immediately obvious for many models of learning style found in the literature' (Riding and Rayner, 1998, p.61).

Different labels have been given to each category of learning styles (or strategies), partly depending on the focus and interests of the researchers. Phenomenologically researchers have labelled these strategies either as serialistic (atomistic or operation learning) or holistic (global or comprehension learning) (Laurillard, 2002; Pask, 1976a,b, 1988; Svensson, 1977). Students who prefer a serialist approach will use tactics that enable them to learn in a step-wise fashion, focussing and concentrating on particulars in a linear strategy that progresses from one element of the learning task to the next. The alternative is a holistic approach, in which students attempt to link what is learnt into an overall framework or global understanding of the whole topic under study (Entwistle, 1988b). To master a topic, students need to learn how to combine both approaches (Entwistle, 1988a) in such a way that they can move between theme (the particular aspect of the topic in focus); thematic field (the parts of the experienced world closely related to the theme) and the margin (everything else which exists around the theme) (Marton and Booth, 1997).

This learning style perspective suggests that students need to construct their own understanding by a process of creating meaning from a variety of interactions between their previous experience of a subject and the new material being introduced within a context highly dependent upon the prevailing assumptions of the community the student seeks to join (Cunningham, 1991). Exploring the view that learning is situated within the context of what is being learnt suggests that "activity" (whether physical or mental) leads to learning (Vygotsky 1960b, 1966). This proposition assumes that students acquire knowledge about concepts by engaging in activity in a particular world culture (Brown, Collins and Duguid, 1989; Duffy and Jonassen, 1992a), with everyday knowledge defined as being situated in an individual's personal experience of the world.

The idea of learning as the social and psychological construction of meaning suggests that students may use different socio-cognitive processes when learning about a subject *in situ* compared to those used when learning about the same subject in a school setting. In the former, it is easier to construct knowledge in context based on an interpretation of experience through social interaction and collaboration (Carr *et al.*, 1998).

Academic knowledge is said to be a second order experience, because although still situated, it is facilitated by teachers who create and introduce students to learning environments that enable reflection on experience. Students learn about 'descriptions of the world rather than knowledge of the world' (Laurillard, 2002, p.53). Laurillard argues that this facilitation is necessary because academic learning depends on symbolic representation to represent a description of the world (e.g., through mathematics symbols, diagrams, musical notation, phonetics, *etc*). Students usually have to interpret these symbol systems before they can be used by (Vygotsky, 1960b), implying that the academic world is somehow very separate and distinct from the everyday world (Laurillard, 2002).

Although this distinction may be true for some academic subjects, it would appear to be artificial to suggest that, in dentistry, a student's experience of the world could be kept separate from his/her experience of descriptions of the world. Indeed, it becomes all but impossible to separate the two types of worlds once students enter the third year and start clinical training, observing and then working with real patients under the guidance of a consultant specialist. One way around this apparent paradox is to realise that everyday concepts can also act as mediators between the academic world of scientific concepts and the world of experience (Vygotsky, 1956, 1960a,b).

However, no matter how personal the learning experience, in dentistry students still have to learn how to communicate both with other members of the dental community and their patients. In any dental specialty, including orthodontics, students will need to learn both how and when to use the symbology of the speciality – i.e. what the orthodontic "signs" mean and be able to explain what they "signify" – if only to become proficient in acting as a mediator between orthodontic specialists and their patients.

There is also a difference between knowing about as opposed to knowing how (Bruner, 1996). This is particularly relevant in dentistry, where there is a very high emphasis on mastering practical skills. The difference can be illustrated with the example of someone who, although able to describe and demonstrate on dry land the actions they have to carry out in order to be able to swim, cannot put words into practice when they enter the water (Molenda, 1991). Being able to demonstrate proficiency in a topic is essential in dentistry where students, as well as being able to describe a concept, are also expected to be able, as Pask says of students elsewhere, 'to **use** the underlying relationships by operating on appropriate apparatus to demonstrate understanding' (Pask, 1976a, p.14).

2.2.2 *Communities of practice*

Extrapolating the idea that learning is dependent on context allows researchers to consider the community of practice around the students and the impact this community has on learning (Morgenbesser, 1987). Learning takes place within a social context where the process of meaning-making is shared with others (Fosnot, 1996a; Jonassen and Land, 2000). For every individual, part of the learning process involves developing an identity as a member of that community through exposure to its collective knowledge and by being gradually drawn further into that community (Bredo, 1999; Cole, 1996; Lave and Wenger, 1991; Norton, 1992; Smith, 2003; Wertsch, 1991). To become part of a community, a learner's goals will be dependent upon, and shared, by others within the learner's immediate community (Salomon, 1991). This concept of a community of practice is equally relevant in dentistry. The dental community consists of people qualified as dentists (including those with specialist knowledge) and those with other areas of expertise (e.g., dental nurses, hygienists, technicians, receptionists, *etc*,), any of whom could be involved in treating a patient.

Like other subjects, the 20th century saw an explosion in dental information. To master a topic, students have to learn both the basics and how to track down additional information about that subject as and when required. Learning now continues beyond the point where, in the past, students were judged to have completed their training. The undergraduate Batchelor of Dental Surgery (BDS) can be considered to be an entry-level qualification that acts as a gateway into the dental community. However to become specialists in one particular field, or even just to keep up-to-date with the latest procedures and practices, dentists continue studying via a variety of post-graduate CPD courses (Eaton and Rothwell, 1992; Mercert *et. al*., 1998). As the amount of knowledge about a particular discipline becomes too vast to be held by any one individual, it starts to be created and stored throughout the community associated with that discipline (Lave and Wenger, 1991; Wenger, 1998; Wenger, McDermott and Snyder, 2002).

This expansion in knowledge has led to changes in underlying pedagogy, prompting a move at institutional level by medical educationalists towards problem-based learning (PBL) where students learn through solving problems (e.g., case scenarios) than through more traditional means (Barrows and Tambly, 1980; Coulson and Feltovich, 1993; Engel, 1991; Finch, 1999; Newble and Clark, 1986; Schmidt, 1983). It has been suggested that PBL lets students integrate their knowledge more easily whilst still covering '... most of the concepts that they learn in the traditional lectures' (Tiene and Ingram, 2001, p.34). The danger with moving to PBL is that knowledge considered important by the community may not be covered by the set problems.

In an ideal situation the concept of a community of practice implies studying all members of the dental team as they learn about orthodontics. However the focus of this study was an in-depth study of the interactivity that occurred when students used a computer to learn about orthodontics. To try to collect enough data for such a study focused on interactivity across a whole community of practice would be beyond the scope of a part-time PhD. The advantage of considering the effect on learning of being part of a community was to enable the data collected to be used for a phenomenological study that could suggest guidelines for the future development of dental CAL.

The concept of a community of practice was useful to this study because it highlighted the importance of interaction in research into understanding how people learn (Brown, Collins and Duguid, 1989; Keegan 1990; Lave and Wenger, 1991, 1999; Moore, 1989; Shale and Garrison, 1990a,b; Thompson, 1990 and Wenger, 1998). The focus of this study was on individual learning resulting from a constructed process based on a series of personal interactions with the external world at one point in time, rather than a longitudinal study concentrating on the learning that occurs across a whole community of practice.

2.3 The nature of interactivity

Having highlighted the importance of interactivity in learning, this section explores the nature of those interactions. At a very basic level, an interaction can be defined as a two–way (or reciprocal) flow of information between two or more entities (student, teacher, machine, *etc*) where each is mutually influenced by the other(s) taking part (Hawkridge and Edirisingha, 1998; Wagner, 1994). This definition was considered too broad to be useful for this study, where a more detailed breakdown of interactivity was required. One option is to divide observed interactions into two categories: non-human and human. Non-human interactions would include student interactions with tools (e.g., computers, paper and pencil, models, *etc*), information (content, even when generated by humans), or environment. Human interactions would include students' interactions with teacher(s), students or others within the community (Dillon and Gunawardena, 1992; Moore, 1989; Reigeluth and Moore, 1999).

The difficulty with this classification is that, on the surface, a number of non-human interactions do not appear to fall under the broad definition of an interaction given above. This is particularly pertinent to student–content interactions, which are considered to be the most useful interactions in helping students to learn (Hawkridge and Edirisingha, 1998). However student–content interactions should not be understood as interactions in which both student and content act, and in turn act upon each other. Perhaps the 'content' in this interaction should more accurately include a student's previous understanding of a topic. When a teacher (whether in person or via some form of mediated instruction) presents new material to a student, by reacting to that material, both a student and his/her understanding can be said to change. A better analogy may be to consider that the material presented by the teacher acts as a 'catalyst' that results in a change in both a student's understanding and his/her experience of that topic.

2.3.1 Conversation Theory

One paradigm for understanding student–content interactivity is based on Conversation Theory (CT). CT is a relativistic learning theory in which a subject consists of topics that come together to form an entailment mesh of concepts in a variety of ways. This entailment mesh acts as a framework allowing students to learn about these topics through conversations that lead to shared understandings about the topics and how these topics are related. For students, these conversations can be external (with other people) or internal (with themselves) (Pask, 1975, 1976a, 1988; Scott, 1993). An internal conversation involves using another part of the mind as an "alterego" to monitor and interact with the learning process by taking up different and occasionally opposing viewpoints (Pask, 1988). The hypothesis is that, through a type of internal didactic conversation, a student has a mental conversation with him or herself about the content to understand better the topic being studied (Holmberg, 1986).

Two different approaches have been used to model these conversations (whether internal or external). An engineering analogy uses the idea of communication between electronic circuits to explain the learning process by which a learning (or educational) medium carries a message from a transmitter to a receiver. A behaviouristic, psychological analogy includes the effect of the message, although it is argued that '... we can only tell that the message has had any effect at all if we observe some sort of action or behaviour of the recipient' (Romiszowski, 1988, p.13).

The engineering analogy suggests there should be some form of observable action resulting from interaction between the student and the medium through which he/she is learning. But if understanding is achieved only when interaction occurs at an internal level, then the question arises as to how to observe these interactions. To get any feasible information about these types of interactions may require indirect, rather than direct methods of observation, e.g., by listening to conversations about the topic as a student negotiates with other students over a shared response to a question, or by using talk-back interviews to get students to explain their actions retrospectively after completing a learning task.

When students have a full understanding of a topic they should be able to use this internal conversation as a basis to apply their knowledge in a new situation (Pask, 1976a; 1988). This paradigm suggests that students would normally be able to demonstrate they have understood a topic by providing '... a verbal explanation of its meaning in accord with an accepted standard definition' (Pask, 1976a, p.14). The risk is that it is possible for a teacher and a student to demonstrate that two different ways of representing a concept may result in the same outcome, which is not the same thing as mutual understanding. Mutual understanding can only occur if the concept is reconstructed using modelling facilities in such a way that, alongside a subject matter representation, students are able to summarise 'the relationship between topics within the subject matter' (Pask, 1976a, p.15). Thus, conversation that leads to shared understanding can be considered a '... fundamental unit for investigating complex human learning' (Pask, 1976a, p.12).

Furthermore the concept of learning through conversations suggests that private speech can be used to solve problems (Vygotsky, 1960b; Fosnot, 1996a; Frawley, 1997) in that '... higher mental functions are the mediated, internalised result of social interaction' (Wertsch, 1981, p.147). By placing student-human interaction at the centre of effective learning, this approach attempts to describe and explain the process of teaching and learning rather than just the process of learning (Frawley, 1997; Rogoff, 1999; Vygotsky 1960b, 1966, 1978).

The problem with CT as an approach to learning is that common terms (such as understanding) have to be redefined in a more restricted and precise way (Pask, 1976a) compared to other researchers (e.g. Marton and Säljö, 1976a). Therefore although CT may be useful in scientific topics, where there is general agreement on the validity of an explanation (Kuhn, 1996), in subjects that have more than one way to reach a particular understanding of a topic, CT (and its ability – under very narrow definitions – to find out how students learn about a topic) may be limited.

2.3.2 Systems interactivity

One type of human–non-human interaction that can cause problems for both students and instructional designers is that between students and the learning medium itself ('student–interface interaction' or ***systems interactivity*** (Dillon and Gunawardena, 1992)). To extract the intended meaning from a learning task presented via any medium requires students to be literate in that medium's rules of interaction. Different media require students to master different sets of skills. The more familiar students are with using a technology and the complex cultural codes it contains (the adaptive dimension), the easier it is to concentrate on the learning task itself (the interactive dimension) (Hillman, Williams and Gunawardena, 1994; Jonassen, 1985; Salomon, 1974, 1981; Wagner, 1994).

Ideally systems interactivity should be transparent, allowing users to interact directly with content, either because the interface is simple to use, or because it becomes so familiar that students use it sub-consciously (analogous to an experienced driver sitting behind the wheel of a car (Dreyfus, 1987)). Unfortunately sophisticated Graphical User Interfaces (GUIs) can often mislead users into believing that they are interacting with the instructional content of a CAL package when in reality they are interacting with the computer. Furthermore, the interface itself may interfere with the ability of students to participate in the learning experience by requiring them to interact with the technological medium before getting to the content, particularly when using new technology for the first time (Hillman, Williams and Gunawardena, 1994). The danger is students will find it difficult to learn until they become literate in the symbolic representations used by the medium (Salomon, 1981). Until literacy is achieved, students' interactions are likely to be unimportant motor responses to the medium, at the expense of attention to content (Livengood, 1987; Wagner, 1994; Weller, 1988). So one question in this study is whether students were able to master the skills required to use CAL efficiently.

2.3.3 Student–teacher interactivity

Where student–human interactions are concerned CT suggests that teachers have an important role to play. Phenomenological studies show that teachers facilitate the learning process in a number of ways, e.g., by ensuring that students' learning interactions involve social dialogue are:

(i) *Discursive* (a two-way dialogue between student and teacher)

(ii) *Adaptive* (students can respond and act on feedback)

(iii) *Interactive* (both teachers and students can act on feedback)

(iv) *Reflective* (students have opportunities to reflect on the material) (Laurillard, 2002).

An ideal environment would provide opportunities for all four types of interactivity to be combined, a situation most likely to occur, it is argued, when students interact with a tutor in small groups. This discursive interactivity implies there should be agreement on learning and task goals for the topic between the teacher and student. To get this agreement, teachers and students need to gain access to each other's concepts of the task, in an environment where students can reflect on their experiences to fit them into an overall framework on the topic (Laurillard, 2002). Thus a discursive approach encourages students to interact with the subject being studied so their understanding, perception or cognitive structures change to draw closer to that of their teacher (Moore, 1989).

The need to make learning discursive would seem to contradict the idea of giving control of learning to the student by placing the teacher very firmly at the centre of the learning process. This paradox can be resolved by recognising that the nature of this role has changed. Instead of being a transmitter of knowledge, teachers are now considered facilitators in the learning process. Part of this role involves providing students with 'scaffolding', a term used for the support provided by a teacher or another student more experienced in a particular topic who helps someone learn about something that might otherwise be beyond that student's capabilities (Bruner, 1996). Like builders' scaffolding, this kind of help does not imply a rigid or permanent structure but the adoption of a student–centred strategy that supports learning which can be removed gradually until it is no longer needed to carry out the task (Smith, Cowie and Blades, 1998).

Letting students control the pace of their learning lets them reflect on a topic when it is most appropriate for them, rather than the teacher, thus maximising the potential of such 'reciprocal intention–action–reflection activities' (Jonassen and Land, 2000, p.v). For example students are said to have more control over their learning when watching a video recording of a television programme compared to the original broadcast, because they can pause, and even rewind the tape, when and as they need to reflect (Laurillard, 2002).

CAL, too, can give students opportunities to control their learning. For designers, there are three types of enabling contexts: externally imposed, externally induced or individually generated, which are used to describe the continuum ranging from total teacher control to a strategy in which students can select not only the means to solve a problem, but also the problem itself (Hannafin, Land and Oliver, 1999). The difficulty is that if given total control of their learning, students may choose to stay in a well–known area where they feel comfortable rather than exploring unknown territory, particularly when they are unfamiliar with the overall framework of the subject they are studying (Gay, 1986; Jonassen, 1985; Shin, Schallert and Savenye, 1994). This difficulty can be resolved by recognising that different learning situations may require flexibility in the degree of student–teacher control (Reigeluth and Moore, 1999). Perhaps the best method is to use a variety of design approaches, allowing students the opportunity to identify and practise with those that best suit their individual needs. This may be by designing packages to take advantage of differences in students' preferred learning styles or to help students practise skills in which they are particularly weak (Jonassen, 1985).

The concept of feedback is related to reflection, giving students the opportunity to reflect on a new activity, their previous experience, the relationship between any feedback received as a result of their activity and what that feedback implies for future activity in that area. This relationship forms part of a goal-action-feedback cycle where the feedback can either be intrinsic (as a result of the action itself) or extrinsic (an external comment on the student's action) (Laurillard, 2002).

Feedback is also closely linked to interactivity because, as the learner reacts to the material presented, so the teacher (either in person, or via the learning medium) should adapt and respond to the learner's input (Jonassen, 1985). Unfortunately, the learning medium itself (e.g., watching a television programme or reading a book) may encourage students to adopt a passive approach to learning, making it difficult to monitor from observation alone whether or not they have engaged with the learning task. To be useful feedback has to be meaningful (Collis, 1998; Yip and Barnes, 1997) – because '… action without feedback is completely unproductive for a learner' (Laurillard, 2002, p.55). Feedback can be used to indicate not just when students have made a mistake, but more importantly why. The problem is that explaining why is more difficult and requires considerably more information about students' experience and learning than just indicating that a mistake has been made. However once students are sufficiently proficient at a topic to be tacitly aware of what they are doing they can be encouraged to use intrinsic feedback to decide whether or not something 'feels' right. This tacit knowledge is something that would seem extremely useful in a practical subject like dentistry.

2.3.4 Student–student interactivity

Like student–teacher interactivity, student–student interactivity is a form of external didactic conversation through which students interact with others to gain a better understanding of the content being taught (Pask, 1984). Student–student interactivity covers all learning interactions between students (with or without the presence of teachers) (Moore, 1989). These types of interactions provide additional opportunities for reflection through conversations with students as well as with the teacher (Bredo, 1997; Pask, 1976a). Getting students to work and interact together can be a valuable activity in becoming 'part of a community of scholars and practitioners' (Jonassen *et al.*, 1995, p.7).

Although conversation theory is primarily concerned with student-teacher interactivity (Britain and Liber, 1999), it may not be necessary for CAL developers to program a computer to provide such a combination (Phillips, 1997a). Most learners would not be expected to learn in isolation, and more recent research has started to look at the impact of student-student interactivity (Stokes, 2004).

However, possibly due to the problem in identifying what particular role each student is playing in a learning interaction there is less information about student–student interactions in the literature than for student–teacher interactions. Therefore part of this study is particularly interested in interactions between students as they use CAL to see what information can be obtained about the learning situation and how students act as sources of knowledge for each other.

2.3.5 Student-other human interactivity

It is worthwhile mentioning that student–other human interactivity may play a role in how dental students learn, although it falls outside the remit of this study. From the third year onwards, unlike many other academic subjects, dental students enter a period of clinical training in which they learn about dentistry through direct interaction with patients. There is therefore potential for a future study to take into account the impact of student-patient interactivity on how dental students learn about orthodontics.

2.4 The learning environment and cultural mediation

Having highlighted the difficulties in classifying interactions, this section examines the relationship between a learning medium and the environment where learning takes place. These learning environments can include students' cultural background, their community of practice, and the specific tools and language symbols of that community (Kayser, *et al.*, 1999a). Students interpret these learning experiences in a variety of ways: 'through symbol, music, myth, storytelling, art, language, film, explanatory "scientific" models, and/or mathematical forms' (Fosnot, 1996a, p.26). If language symbols are classified as 'tools' that students use to communicate with other members of their community (Cole and Engeström, 1993; Leontiev, 1972, 1975; Vygotsky, 1956, 1960a,b), then all learning can be described as being mediated by tools which allow students to 'construct the world by interpreting, organizing, and transforming prior world views ...' (Fosnot, 1996a, p.23). Thus signs and signifiers can only be understood in relation to the context in which they are employed (Salomon, 1981).

The concept of a mediating device allows researchers to get around the problem of deciding whether learning is innate or external by "bridging" the gap between the two. It is important to be able to bridge the gap because a study combining both internal thought processes and external experiences allows a better understanding of the nature of the framework used by students to develop and construct their own interpretation of what they have experienced (Smith, Cowie and Blades, 1998).

If all learning is mediated then student–teacher interactions can be grouped with interactions between students and the media through which teaching is presented. In this context, medium refers either to the teacher in person or the teacher mediated through some other means (e.g., computer, text book). This definition of a medium highlights the importance of the teacher in motivating and stimulating students, and in taking action to clarify any misunderstandings, no matter how the content is presented to students despite running the risk of confusing student-interface interactions with student-teacher/content interactions.

2.5 Activity theory as a paradigm of learning

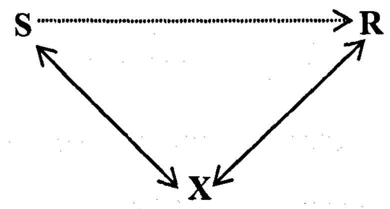
The concept of learning as part of a mediated activity system originated in Russia in the 1920s and 1930s (Vygotsky, 1978; Leont'ev, 1978; Luria, 1976, 1979). More recently the western world has adopted activity theory across a wide range of disciplines, from cognitive science, psychology and philosophy through to education theory and information systems design (Engeström, 1987, 1999a; Cole and Scribner, 1978; Kuutti, 1996; Nardi, 1996a; Wertsch, 1981, 1985, 1998). By combining the theory of evolution with the principles of dialectic and historical materialism, Vygotsky claimed that consciousness is an internalisation or 'internal reconstruction of an external operation' (Vygotsky, 1978, p.56). Internalisation is defined as the process by which human consciousness emerges and evolves as a result of social interaction (Vygotsky, 1978).

Although this definition appears to echo Cartesian dualism, it is argued that both internal and external processes are dependent upon each other and cannot exist independently (Kuutti, 1996). The two types of processes are linked through the existence of a mediating tool that bridges this boundary. Activity theory can be described as a radical expansion of cognitive science that examines activity by including the role of artefacts and the ways in which these artefacts can be 'integrated into social practice' (Nardi, 1996a, p.14).

Prior to Vygotsky signs and symbols were classified into three groups: likenesses (icons/ideas representing something by imitation), indications (indices showing something by connection, e.g., a signpost) or symbols (general signs associated by usage) (Peirce, 1894). Vygotsky's insight was to extend Engel's idea of tool-mediated human labour to include sign systems, semiotic mediation and language (Vygotsky, 1986). A sign thus becomes a potential mediator between stimulus and response in both an inter- as well as an intra-psychological process (Vygotsky, 1978). Mediation can thus be considered on several levels, ranging from the philosophical and methodological through to an empirical analysis of research on innovations (Miettinen, 1999). Behaviourism's simple Stimulus-Response formula (S—>R) can be modified into a more complex form by including '... an intermediate link between the stimulus and the response' (Vygotsky, 1927, 1978, p.39, Figure 2.5a).

Drawing on the ideas of Karl Marx and Charles Darwin, Vygotsky's theory highlights the importance of understanding the socio-historical-cultural context under which an activity has evolved. Echoing Marx Vygotsky placed an emphasis on the society and culture surrounding the activity. Using Darwin's theory of evolution, Vygotsky explained that it is important to take into account the historical context of the activity and how and why it arrived at its current when trying to develop a deeper understanding of what is taking place (Cole and Scribner, 1978; Wertsch, 1991).

Figure 2.5a: The mediating triangle
(from Vygotsky, 1978, p.40)

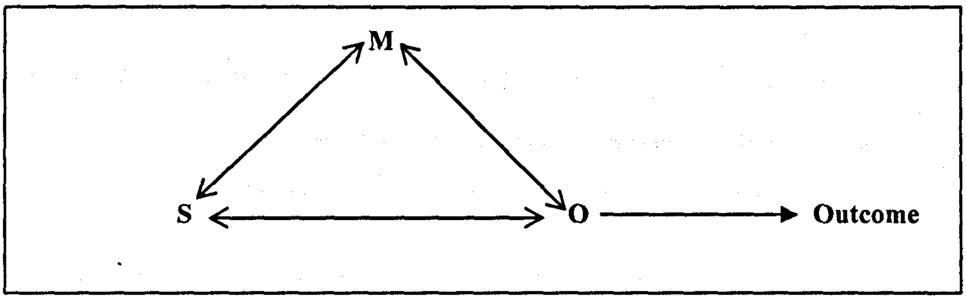


Where S is the stimulus, R the response and X the mediating link

This method differs from hypothesis testing because, Vygotsky argued, an important role of an experiment is to make 'visible processes that are ordinarily hidden beneath the surface of habitual behaviour' (Cole and Scribner, 1978, p.12). Vygotsky saw that higher psychological processes that occur when activity is under continuous change. Development can only be understood by determining the origin and mapping the history of those processes (Cole and Scribner, 1978). The implication is that uncovering the forces governing these changes means including an element of historical analysis into learning research (Andreassen, 2000). To this end Chapter 3 provides an overview of how computers are currently used to support learning in dentistry.

Activity theory sets out to understand the interdependency of the individual, other people and mediating artefacts in relation to a particular outcome (Nardi, 1996a). An activity network or system is used as the basic unit for studying interactivity, permitting the study of both internal and external factors in learning. This unit of analysis focuses on a triangle consisting of the individual (S), together with the outcome (O) and any mediating tool(s) (M) (Figure 2.5b)). As long as the object can be transformed, then any 'tool' can be considered part of an activity system, whether physical, 'soft' (e.g., a computer program), conceptual (e.g., a theory), or sign a system (e.g., technical language) (Jonassen and Rohrer-Murphy, 1999; Nardi, 1996a). Activity can thus act as both the basic unit of analysis (Kuutti, 1996) and as the object of research for analysing mental processes (Zinchenko, 1995).

Figure 2.5b: The common reformulation of Vygotsky's mediating triangle, with subject (S), mediating artefact (M) and objective (O) leading to the outcome of the activity
(Cole and Engeström, 1993)



The problem is that the mediating triangle, even in this modified form, fails to take into account the collective nature of human activity – that input from others 'both those present to the senses and those of prior generations, [plays] a crucial role in the formation of human cognitive capacities' (Cole and Engeström, 1993, p.6). This problem leads to the argument that object-orientedness (both internally and externally) should be the main focus of research (Leont'ev, 1978; Luria, 1976, 1979). Thus the process of internalisation of an external, instrument-based collective activity leads to a deeper understanding of what is happening psychologically (Glassman, 1996). Leont'ev's contribution is to differentiate between individual action and collective activity (Engeström and Miettinen, 1999), allowing social relations, and hence mediation by others, to be included in the triangle (Glassmann, 1996).

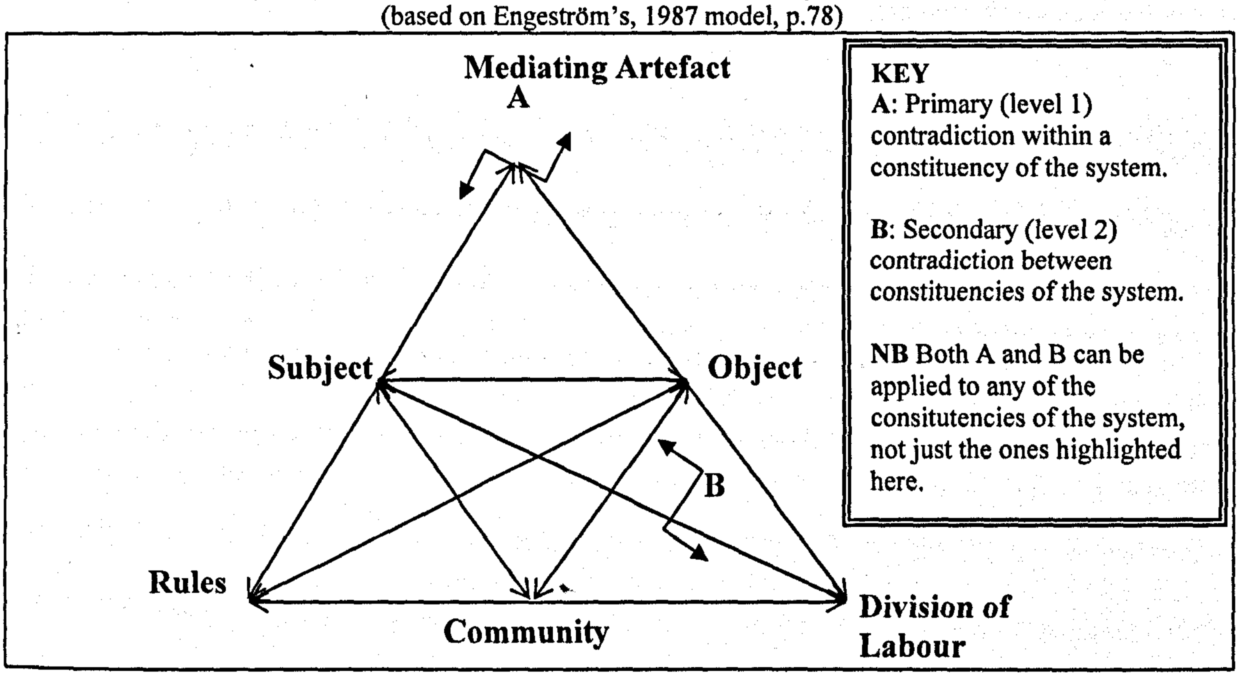
The development of a hierarchical activity structure, with a distinction between actions and activities, allows apparently meaningless actions to be taken into account by considering the activity of the social group as a whole. Individuals carry out conscious actions towards a common goal. Underlying these actions is the actual operation of those actions (often done sub-consciously, e.g., when driving a car), and above the actions is a top, activity level, describing the outcome of the actions which can be done unconsciously or consciously (Figure 2.5c).

However, the distributed nature of sign systems – where different communities use sign systems in different ways (Salomon, 1993b) – led to criticism of this three-level scheme because it did not offer an explanation for these differences in meaning (Andreassen, 2000). The proposed solution was to expand the mediational triangle to cover the minimum context needed for describing human activity (Figure 2.5d).

Figure 2.5c: The hierarchical structure of activity
(from Leont'ev, 1978)

Activity Level	Motive	Not conscious
Action level	Goal	Conscious
Operation level	Condition	Not conscious – Automatic processes

Figure 2.5d: The basic mediational triangle expanded to include other people (community), social rules (rules) and the division of labor between the subject and others
(based on Engeström's, 1987 model, p.78)



By including both other human beings and the community itself, activity theory provides a graphical and conceptual map of the major elements through which cognition is distributed (Cole and Engeström, 1993). Each sub-triangle becomes an activity in its own right, with the same internal structure as the overall system, with transitions and reorganisations going on constantly within and between the individual sub-systems. Therefore activity systems are 'complex formations in which equilibrium is an exception and tensions, disturbances, and local innovations are the rule and the engine of change' (Engeström, 1987, p.8).

The importance of this system is that it is the inner contradictions that are the disturbances leading to change and development (Cole and Engeström, 1993; Kuutti, 1996). Inner tensions within each constituency of the system can be referred to as primary (level 1) contradictions (Engeström, 1987), for example when students chose the wrong mediating artefact for a particular task (jagged arrow A). This tension may also be a secondary (level 2) contradiction between constituents of the system, for example when members of a group become confused about who should do which task (jagged arrow B).

Activity theory offers two other potential sources of tension to be identified: a tertiary (level 3) contradiction that lies '... between the object/motive of the dominant form of the central activity and the object/motive of a culturally more advanced form of the central activity' (Engeström. 1987, p.68) and a quaternary (level 4) contradiction between a central activity and similar, linked neighbouring activities. A tertiary contradiction can arise if there is a misunderstanding between student and tutor about what exactly the student is expected to achieve. An example of a quaternary contradiction would be one where students have to come to terms with the variation in a complex domain arising when sub-specialties use slightly different definitions for very similar specialist terminology.

Activity theory suggests computers can be seen as part of a network of resources, including students, their peers, subject experts and a variety of other materials including textbooks, videos, dental models and other learning sources. Such a community can help turn students into team members '... engaged in guided learning-through-exploration, communication, and collaboration that become integrated into a well-orchestrated learning environment.' (Salomon, 1991, p.43).

Activity theory has been criticised because of its generality and has to be redefined each time it is used in a different context or for a specific object. It is best used as a descriptive tool rather than a predictive theory because it does not offer any cookbook procedures for researchers to follow (Bertelsen and Bødker, 2002; Engeström, 1987; Nardi, 1996a). It is argued, however, that this criticism is, in fact, an advantage of using activity theory – because it allows the theory to be adapted to meet a specific context, rather than trying to force results into a particular theory box, which, as Kuhn pointed out, has often led to a revolution rather than an evolution in the underlying paradigm (Kuhn, 1996).

As a paradigm activity theory is used to model what happens in the context of data collected for this study. It is used as a conceptual tool to investigate contradictions in the activity systems and how these contradictions can lead to developmental change. Activity theory also acts as a heuristic device to draw attention to significant features of the activity under investigation (Andreassen, 2000). Activity theory therefore offers a structure for organizing an activity (Bertelsen and Bødker, 2002), concepts for describing that activity and a series of perspectives for exploring what happens at different levels within the activity (Nardi, 1996a).

2.6 Chapter summary

This chapter highlighted the importance of interactivity in the learning process, and argued that a combination of qualitative and quantitative research methods can provide a better understanding of that process. Activity theory, with its central idea of a mediating device and its social-historical-cultural perspective, was proposed as a framework to consider how dental students learn about orthodontics, and what they need to learn, in the context of the situation facing UK dental schools. On a methodological level, activity theory allowed the use of other learning paradigms to be drawn together as mediating tools to gain a deeper understanding of interactivity observed in this study.

Chapter 3: Interactivity, Computers and Dentistry

Chapter 3: Interactivity, Computers and Dentistry

3.1 Introduction

This chapter explores the social-historical-cultural background in which computers have been used to provide solutions to some of the problems facing dental education. After describing the advantages, disadvantages and different ways of classifying computer use, the chapter examines different ways in which computers could have been used in the study. The chapter concludes by highlighting the rationale for the development of the two orthodontic CAL packages used in this study.

3.2 Background

Computers have been used as learning tools in medicine and dentistry in the UK since the early 1970s (Campbell et al, 1980; Grigg and Stephens, 1998; Kenny and Davis, 1979; Murray *et al.*, 1976; Paine and McAra, 1993). Early advances in the use of computers in dental education were primarily driven by individual enthusiasts within the domain (Higher Education Funding Council for England, 1998), funded by institutions keen to take advantage of the perceived cost and quality benefits of being able to make multiple use of the same program (Carrotte *et al.*, 1996; Craig and Moreland, 1992; Dewhurst and Williams, 1998; Hannafin and Peck, 1988; Turner and Weerakone, 1992).

Following the introduction of the IBM PC an editorial in the British Dental Journal spoke optimistically of the role of computers in dental education and dental practice (Seward, 1981). PCs quickly had a major impact on healthcare administration (Greenwood *et al.*, 1997), but the early 1980s saw universities entering the harsher era of reduced higher education funding. In this climate (which led to a 10% reduction in staffing at UK dental schools) computers and other audio–visual aids were seen as a way both to support education needs and cope with declining human resources (BDJ, 1990; Grigg and

Stephens, 1998). Simple dental programs, already available for undergraduates, started to be used as a substitute for conventional teaching of factual information (Luffingham, 1984; Stephens and Dowell, 1983).

The UK established a structure for the production of CAL to avoid duplication of effort. The Computers in Dentistry Coordinating Group (CDCG) was launched in 1994 to address the use of computers in education, audit, practice management and communication. The CDCG, with its representatives from the BDA, the Dental System Supplies Association, the Department of Health, the Royal Colleges and University producers of CAL, acted to ensure the introduction of information technology in dentistry proceeded smoothly and that material produced for teaching matched the platforms increasingly used in practice management. BSCALiD was established in 1995 further accelerating the production of dental CAL (Grigg and Stephens, 1998).

The Computers in Teaching Initiative Centre for Medicine (CTICM) was another source of advice for those involved in the development of CAL in dentistry. CTICM was one of 23 centres based at universities across the UK whose role was to co–ordinate the development of computer technology for undergraduate teaching purposes. (Longstaffe, 1994). CTICM was replaced in 2000 by the Learning and Teaching Support Network Subject Centre for Medicine Dentistry and Veterinary Medicine (LTSN^{01}), based at Newcastle University, at: http://www.ltsn-01.ac.uk/ (accessed 15th March, 2005) now one of the subject centres for the Higher Education Academy at: http://www.heacademy.ac.uk/ (accessed 15th March, 2005).

In the 1990s the Department of Health via the Committee of Postgraduate Dental Deans (COPDEN) adopted a "shareware" approach to CAL development by which institutions could share the cost of producing CAL material by providing other institutions with access to their own material in return for access to material developed elsewhere (Grigg and Stephens, 1998). This approach helped reduce some of the developmental costs of dental CAL material. The distribution of this software was co-ordinated by the National Centre for Continuing Professional Education of Dentists (NCCPED), at: http://www.nccped.co.uk/pages/CALpgms1.html (accessed 30th September, 2004, reviewed by Bearn and Lowe, 2001).

3.3 Advantages

There are several advantages to using computers to support learning. From a pedagogical viewpoint, computers have the potential to shift control of what is learnt towards the student rather than the teacher (Graham, McNeil and Pettiford, 2000; Gupta, White and Walmsley, 2004; Latchem, Williamson and Henderson-Lancett, 1993a; Sherry, 1996; Welbury *et al.*, 2001). CAL can also provide the possibility of remote monitoring of student progress in a learning task, letting teachers spot particular difficulties in individual students that would not necessarily be obvious in the course of, say, a lecture (Davison and Porritt, 1999; Hannafin and Peck, 1988; Reynolds, 1996). In an era of limited resources this "remote monitoring" may let teachers use computers both to free themselves from more traditional methods of instruction whilst providing time to address these difficulties through activities such as one-on-one counselling (Carrotte *et al.*, 1996; Craig and Moreland, 1992; Grigg and Stephens, 1998; Laurillard, 2002; Reynolds, 1996).

Students benefit from using computers because they can, to some extent, adapt to individual differences. At a basic level instead of having to work through a task at a pace and time dictated by someone else, students can access a program when they want to, stopping and restarting at any point and returning to the program as many times as they require (Dewhurst and Williams, 1998; Grigg and Stephens, 1998; Gupta, White and Walmsley, 2004; Hannafin and Peck, 1988; Perkins, 1992; Reynolds, 1996; Schleyer and Pham, 2002; Ward and Newlands, 1998). CAL offers immediate feedback on performance and is said to increase student motivation, engagement, involvement and active learning (Barron and Orwig, 1994; Fouad and Burleson, 1997; Hannafin and Peck, 1988; Reynolds, 1996; Wagner, 1990). Even apparently monotonous 'drill & practice' sessions can help students to achieve mastery in an automatic fashion (Perkins, 1992).

Unless used for assessment students frequent regard CAL as non–judgemental and non–threatening. They can learn through making mistakes without worrying about appearing stupid in front of others (Grigg and Stephens, 1998). Giving students the opportunity to discover for themselves what happens when certain actions are taken (e.g., through simulations) can be an effective means of promoting learning (Perkins, 1992), although there may be a danger that students will focus on the wrong aspect of the simulation and miss the rationale behind it (Laurillard, 2002).

Like other educational media, CAL can help teachers explain something without having to use the real thing (Phillips and Jenkins, 1997a; Romiszowski, 1988). CAL gives opportunity, particularly in orthodontics, to follow a case through to completion by compressing the time needed to treat the case. CAL can provide examples of the simpler types of orthodontic patients that students are most likely to encounter as GDPs, helping to get around the problems faced by dental schools in identifying sufficient numbers of suitable cases for students to treat (Section 1.4.1). CAL can be used to give students 'simulated' practice before they practice on real patients (Hannafin and Peck, 1988; Fouad and Burleson, 1997; Wagner, 1990) by providing students with an opportunity to reflect upon theory and what it might mean whilst looking at records taken from a real patient.

There are different ways in which students might use computers to support learning (Newton and Rogers, 2001). In dentistry examples of how students might use a computer to support learning include:

1. Searching for resources or further information about a topic (Cook, 2001; Holt and Oliver, 2002; Lewis, 2003; Walmsley, 2004) – e.g. by using specialist databases such as the Centre for Evidence-Based Dentistry (http://www.ihs.ox.ac.uk/cebd/) or the Oral Health Specialist Library (http://libraries.nelh.nhs.uk/oralhealth/ (both

accessed 27th September, 2004).

2. Accessing lecture notes and administration documentation via a school's Virtual Learning Environment (VLE) (Cook, 2001; Gupta, White and Walmsley, 2004; Walmsley, 2004) – e.g. using Blackboard (http://www.blackboard.com/) or FirstClass (http://www.softarc.com/) (both accessed 27th September, 2004)

3. Going to a web "portal" to access specialist information about a particular topic within the domain (Bearn and Lowe, 2001; Cook, 2001; Gupta, White and Walmsley, 2004; Walmsley, 2004) – e.g. to download orthodontic lecture notes (e.g. http://www.ncl.ac.uk/dental/ortho/lectures.htm), seminars (e.g. http://www.cyberdontic.com) or webcasts (e.g. http://www.dentrek.com) online (all accessed 27th September, 2004).

4. Using specialist CAL material to learn about orthodontics (Belanger and Jordan, 2000; Howerton *et al.*, 2002). One recent example from Birmingham University (at: http://www.dentistry.bham.ac.uk/ecourse_samples/orthoviva3, accessed 15th March, 2005) consists of an image of a model that students can rotate from side to side using the mouse together with a series of case assessment MCQs with feedback limited to correct/incorrect. The next screen contains some, treatment planning self-marked free response questions for students to try (Gupta, White and Walmsley, 2004).

5. Using a word processor to prepare a document that presents their findings about a particular case or assignment set by their tutors (Belanger and Jordan, 2000; Newton and Rogers, 2001).

6. Using software ranging from a simple spreadsheet through to specialist statistical programmes such as SPSS (http://www.spss.com/ accessed 27th September, 2004) to analysis data collected as part of a project (Belanger and Jordan, 2000; Newton and Rogers, 2001).

7. Using computers as videoconferencing links to access expert knowledge over a distance (Cook *et.al.*, 2001, 2002; Stephens, Grigg and Cook, 1998; ORQUEST, 1998).

8. At the dental school in this study students with more advanced IT skills and an interest in using computers can choose to do a final year project involving researching a topic and producing a CAL program that, once checked by subject specialists for suitability, may go on to be used as a learning tool by other students (Vowles, 2004).

3.4 Disadvantages

However there is a downside to using computers to support learning which needs considering when producing CAL. Besides the problems of systems interactivity (Section 2.3.2), there is a danger that facilities on modern computers can encourage the production of intricate pieces of software to demonstrate the ability of the software development team rather than enriching students' learning experiences. This tendency can be avoided if developers concentrate on educational objectives and the context of the learning situation, rather than on what is possible using the latest technology (Laurillard, 1994, 2002; Sherry, 1996; Terpstra, 1992).

Another problem for institutions interested in CAL is that it can be relatively expensive to keep up-to-date with the latest hardware and software required to run the programs. Human resources are also required both to develop and to maintain these systems (Collins and Harden, 1999; Hannafin and Peck, 1988; Grigg and Stephens, 1998; Harvey, *et al.*, 2003; Holt and Oliver, 2002; Ray and Hannigan, 1999; Reynolds, 1996; van Braak, 2004).

Although higher education institutions have been keen to try and take advantage of the possibilities of reducing academic workload by encouraging the use of CAL there is a danger that those involved in teaching clinical subjects alongside treating patients may not see the development of CAL material as being a priority (Britain and Liber, 1999; Cook, 2001; Harvey, *et al.*, 2003; Learning and Teaching Support Network, 2002b). Most teaching material available to students is currently provided in the form of lecture notes/worksheets or administration documentation which would previously have been distributed on paper (Bearn and Lowe, 2001; Cook 2001; Evans, *et al.*, 2004; Greenwood, Cook and O'Leary, 2002; Gupta, White and Walmsley, 2004; Spallek, 2003; van Braak, 2004). All UK dental schools now provide students with access to lecture and administration material online (see Dental School Websites in References for examples of this approach). However most UK dental schools restrict access to CAL material to their own intranets (Bearn and Lowe, 2001), a situation unlikely to change particularly as CAL developers and lecturers become more concerned about copyright issues, patient confidentiality and the potential for plagiarism (Evans and Mahoney, 2003; Gupta, White and Walmsley, 2004; Walmsley, 2004). Some downloadable sample CAL material can be found at Birmingham School of Dentistry at: www.dentistry.bham.ac.uk/fordentists/caldownloads.asp (accessed 15th March, 2005).

The lack of enthusiasm for making further use of technology has increased recently, and even in America it seems the costs of running and maintaining VLEs and/or a lack of willingness to change teaching style have resulted in the situation in which:

> ... faculty who make e-learning a part of their teaching do so by having the electronics simplify tasks, not by fundamentally changing how the subject is taught. Lecture notes are readily translated into PowerPoint presentations. Course management tools ... are used to distribute course materials, grades, and assignments - but the course materials are simply scanned bulk packs and the assignments neither look nor feel different. (Zemsky and Massy, 2004, pp.22-23).

One problem in trying to meet the demand for innovative software is that teachers with little experience of computers can waste considerable time attempting to produce a single hour's worth of material that might be equally effective in a paper–based form (Britain and Liber, 1999; Carrotte *et al.*, 1996; Grigg and Stephens, 1998; Howerton *et al.*, 2002; Walmsley and Pollard, 1997). Problems also arise through design flaws in the programs – varying from lack of immediate feedback to a failure of the program to encourage students to adopt a reflective approach to learning (Laurillard, 2002). Finally, students may find it difficult to focus on learning because they no longer have direct contact with their teachers (Ward and Newlands, 1998). All these points will be considered further in the discussion for this study (Chapter 9).

3.5 Developing CAL programs

Best practice for developing learning material suggests that teachers and students should participate in an active dialogue where the teacher starts by presenting his/her conception of the learning task. By observing and responding to students' articulations, teachers can identify students' underlying beliefs about a topic (Chiou, 1992). Through this dialogue teachers can correct possible misconceptions, helping students to understand better of what is being explained (Laurillard, 2002; Norman, 1997).

The teacher's task is to provide an environment incorporating material and offering explanations and support that facilitate students' learning experiences, maximising meaningful and thoughtful interactions. This environment needs to be designed using strategies that enable students to interact with the topic, encouraging a deep, active approach to learning (Weston and Cranton, 1986).

Several attempts have been made to categorise the strategies adopted when teachers design learning material. These strategies can be grouped into two distinct camps: (i) a top-down approach concentrating on what can be done from the designers' point of view; (ii) a 'bottom-up' approach considers what needs to be done from the students' point of view. Categorising these strategies has led to the production of various guidelines for the development of CAL (e.g. Gagné, 1985; Gagné, Briggs and Wager, 1988; Hannafin and Reiger, 1989b; Romiszowski, 1988). Drawing on paradigms from behaviourism and cultural psychology these guidelines complement each other, with one set emphasising features of the design process frequently ignored by the other (Wilson and Cole, 1991).

The danger is that CAL developers may use these guidelines in a superficial way (Spector, Muraida and Marlino, 1992). For example, developing material that supports scaffolding can result in material that ranges from a rigid pre-specification at one extreme to a completely unstructured environment at the other (Spiro *et al.*, 1991b). The latter risks wasting students' '... time chasing intellectual red herrings or wandering up alleys that the teacher knows full well are blind.' (Mercer, 1991, p.76). This risk can be avoided if developers concentrate on what students need, rather than what designers can do, by considering learning from the students' perspective (Hannafin and Reiber, 1989a).

However if attention is focussed on student actions there is a danger that, without more explicit instructions, designers may get "lost" trying to translate theory into practice (Spector, Muraida and Marlino, 1992; Reigeluth, 1999a). Concentrating on students' observable actions does provide different systems for classifying CAL, for example by the type of learning tool provided to the student (Perkins, 1992) or by the degree of adaptivity, reactivity or flexibility of the program (Midoro *et* al., 1988). Although suitable for simple programs, this type of classification is unsuitable for complex programs.

One way to classify CAL is by considering the extent to which learners can participate in the learning, for example describing programs as informative, instructional or exploratory (Barker, 1987). In dentistry examples include:

1. Informative programs: a prosthetics/restorative program *Wears the Tooth* (Perryer *et al.*, 1998), an oral surgery program *Aspects of Minor Oral Surgery* (Matthew, Pollard and Frame, 1998), a dental terminology program (Grimes, 2001, 2002) and a multimedia program for informing patients about dental implants (Barkhordar, Pollard and Hobkirk, 2000). All these programs exist to provide students with information about a topic and the hypertext file developed for the pilot study can be counted in this category.

2. Instructional programs: a prosthetics/restorative program *The Neutral Zone* (Walmsley and Barclay, 1996), an endodontic diagnosis program (Fouad and Burleson, 1997), a caries detection program (Mileman, van den Hout and Sanderink, 2003, and in orthodontics case studies including *Self-Assessment Case Studies in Oral Medicine* (Hamburger and Pollard, 1995) and *Practical Orthodontic Assessment* (Stephens and Grigg, 1996a,b,c). All these programs provide students with a preset and planned route through the material. One of the Practical Orthodontic Assessment cases (JB) was modified for use in this study.

3. Exploratory programs: the operative dentistry manikin simulator, DentSim (Imber *et al.*, 2003), used by students to practice restorative dentistry. The very flexibility of an exploratory program can make it difficult for novices to understand what they are supposed to be doing (Mashiter, 1989). With no examples already available in orthodontics at the time of this study, developing an exploratory learning environment such as a microworld (Papert, 1980) would have required more resources and time than were available. Buying and modifying a commercial package was ruled out, partly because of the lack of suitable starting material but mainly due to the cost of such packages.[1]

CAL can also be categorised by media type (Laurillard, 2002), which will again prove useful in the discussion (Chapter 9). Starting with the *proviso* that some CAL programs can cross more than one category, the chosen media categories, based on Laurillard's (2002) classification, were: (i) Narrative; (ii) Interactive; (iii) Adaptive; (iv) Communicative; (v) Productive.

[1] For example the cost of a single copy of a basic American orthodontic program that only provided users with demonstrations of orthodontic techniques using video, animation, text and voice was $2200, beyond the resources of this PhD student (OrthoCD, at: http://www.cyberdontic.com/OrthoCD/ accessed 15th March, 2005, reviewed by Bearn and Lowe, 2001)

3.6 CAL as different types of learning media

3.6.1 Narrative media

The media in this category, by definition, "tell a story". The story's linear nature provides a framework illustrating the relationship between its different parts (Brown and Duguid, 2000; Bruner, 1990; Laurillard, 2002). Narrative media can be used to extend a learning experience, supplant the real world or persuade listeners of a line of argument. From a learning perspective stories help students learn by providing meaning and explanation to otherwise incomprehensible events and situations that deviate from the expected norm (Bruner, 1990).

One problem is that students may find it difficult to reflect on a subject whilst following the story, which can be alleviated by giving control as to how and when they read it so students have time to reflect when required. Structural cues (e.g., headings, paragraphs, captions, camera movement) can provide meaning by maintaining a sense of the overall structure of the story. It is argued that the main difficulty with purely narrative media is that students do not receive any immediate feedback on their progress because narrative media, by definition, cannot be discursive or interactive (Laurillard, 2002).

Expertise in a domain such as medicine (or dentistry) allows practitioners to draw on their experiences of previous knowledge to decide how to deal with new situations (Patel, Arocha and Kaufman, 1999). Narrative media can give students both a framework and background for guiding students through the procedures needed to diagnose, plan and treat a patient. The ability of narrative media to engage by telling a story can be powerful; an eye watering opthamology example (case DRG#131) – involving a fire ant – consists of just one paragraph presenting the case, an image and a sentence explaining how the case was treated and can be seen at: http://www.secointernational.com/dgr/dgr_list.mv (accessed 15th March, 2005).

Examples of narrative media in dental education include videos on how to perform basic dental procedures and textbooks of case studies that describe how dentists have treated cases in the past. One American orthodontic so-called "simulations" package, which consists solely of time-lapse movies of a series of cases of patients before, during and after treatment, with some information about how treatment was carried out, can be found at Sarver and Yanosky Orthodontics (http://www.sarverortho.com/page1.asp, accessed 15th March, 2005).

The case developed for the pilot and main phases of this study used a linear narrative framework based around records from a real patient to guide students through the procedures needed to diagnose, plan and treat an orthodontic case.

3.6.2 Interactive media

Interactive media is learning material where users can access a linear medium in any order they chose, for example a well-indexed book. Pedagogically, as well as sequencing users can benefit by being given more control over the learning activities and even the questions they chose to complete (Laurillard, 2002). Examples of interactive media include electronic books, hypermedia, multimedia resources and Web-based resources.

Electronic Books (e-books)

An e-book falls between narrative and interactive media, exhibiting features of both types of media. E-books use the metaphor of a book inside a computer, with the addition of functions such as audio, video or hypertext (Chiou, 1992). Reading and looking at data on screen differs from using a book, so for effective use, developers and users of e-books need to become familiar with the medium. This takes about the same amount of time as learning to be an effective lecturer or to produce effective videotape. Although it may take considerable time to produce an e-book, it can be easier to improve, update or modify material to take account of local needs compared to the costs of, say, reprinting a book

(Grigg and Stephens, 1998). Developers of e-books also need to be aware that providing students with access to the book may not be enough to help them construct an understanding of the topic because '...most people don't know how to apply the abstract principles they memorized ... to solving real–world problems' (Dede, 1996, pp.12–13).

A dental example of an e-book is the program *Aspects of Partial Denture Design* at: http://www.dentistry.bham.ac.uk/fordentists/calpreview.asp, accessed 15th March, 2005 (Davenport and Pollard, 1993), which was converted from Davenport *et al.*, (1988)'s book *Colour Atlas of Removable Partial Dentures.* Although it took longer to produce than a basic "question and answer" tutorial, the program's advantage was that users were able to hold a "dialogue" with the package through activities such as the manipulation of on–screen graphics (Pollard and Davenport, 1994).

Hypertext/hypermedia (hyperlinks)

Hyperlinks let users explore a topic by following links to connected material using different routes depending on what they are trying to achieve (Paine and McAra, 1993). The addition of media in the form of links to non-textual material (e.g. diagrams, images, animation, audio or video clips) gives rise to hypermedia. Like e-books, hyperlinks' advantage lies in both user control and access to a large body of related material. Students can construct their own frameworks of understanding whilst working through the package (Jonassen *et al.*, 1995; Laurillard, 2002). Without hyperlinks, e-books are just another type of multimedia resource. Hyperlinks support a constructivist model by giving access to complex networks that can transcend traditional knowledge boundaries (Norton, 1992).

The main disadvantage of hyperlinks is the loss of structure implied by this freedom to explore, which can reduce '... knowledge to fragments of information' (Laurillard, 2002). Offering learners a map of the system can help by providing reference points for tracking and to suggest possible avenues of exploration encouraging students to do more than skim the surface (Chiou, 1992; Phillips, 1997a; Whalley, 1990). Although hyperlinks offer multiple perspectives on a learning point, students may not get feedback on their progress because they are unable to interrogate the system (Laurillard, 2002; Shin, Schallert and Sevenye, 1994; Spallek, 2003).

Orthodontic examples of hypertext and hypermedia learning programs include one used to complement the undergraduate training programme at Birmingham University's dental school (Turner and Weerakone, 1992; 1993; Clarke, Weerakone and Rock, 1997), an Italian program on biomechanics in orthodontics at: http://www.libra-ortho.it/ (accessed 15th March, 2005; Fiorelli and Melsen, 2000), and a translation of a Japanese introductory program not available at the time of the pilot study, *Orthodontic Hyper Knowledge* at: http://www.medigit.co.jp/ (accessed 15th March, 2005; Bearn, 2000).

A hypermedia prototype, based on a chapter from an orthodontic textbook (Houston, Stephens and Tulley, 1992), was developed for the pilot phase of this study.

Web resources

Although not used in this study, web resources refer to hypermedia accessed over a network. The danger is the vast amount of information available over the Web can all too easily overwhelm students, making it impossible to learn anything useful. In this situation, even lifelong learners can struggle when tackling a new topic. Gateways, as a metaphor for a reading list, '... offer students both the freedoms of the scholar and the guidance they need as learners' (Laurillard, 2002, p.120). An example of a dental gateway, or portal, is DERWeb (Dental Education Resources on the Web) at: http://www.derweb.co.uk/ (accessed 15th March, 2005), developed by Sheffield University to provide a gateway to a variety of high-quality information about dental teaching material.

3.6.3 Adaptive media

Media that change their state in response to a user's actions can be described as adaptive (Laurillard, 2002). Examples of adaptive media include simulations, microworlds, tutorial programs, virtual environments, tutorial simulations and educational games.

Adaptive media are able to provide immediate feedback (intrinsic and/or extrinsic) by taking a user's input, transforming the underlying model and displaying the results (Land and Hannafin, 2000; Laurillard, 2002).

Electronic Image Libraries (EILs)

EILs are a parallel to 'Colour Atlases', which are books of images with descriptions frequently used in dental (and medical) education to provide students with an atlas or 'map' of a particular topic (for examples of Colour Atlases in orthodontics see Nightingale and Sandy, 2000; Welbury and Millett, 2000; Viazis, A.D. 1998). EILs are compatible with the concept of computer as an exploratory tool, where students are provided with resources but have to work out how to use those resources for themselves (Levy, 1999). Improvements in image quality and speed of retrieval allow these images to be linked in ways beyond that of a traditional book. They provide access to vast numbers of dental and medical images stored in databases and fall into a grey area between electronic books (narrative/interactive media) and hypermedia (interactive media). Examples include:

- The Bristol BioMed Image Archive at: http://www.ilrt.bris.ac.uk/bblt/ (accessed 15th March, 2005), set up to create, maintain and deliver a comprehensive collection of medical images in digital form for use in teaching and research, including dentistry (Evans and Mahoney, 2004).
- General and oral histology slides from the University of Southern California School of Dentistry at: http://www.usc.edu/hsc/dental/Resources/Courseware/index.htm (accessed 15th March, 2005).
- The Iowa database, at: www.uiowa.edu/~oprm/AtlasWIN/AtlasFrame.html (accessed 15th March, 2005), another large collection of medical and dental images useable in dental education.

Databases are ill-defined domains, and were not chosen for use in this study for this reason. Students need to develop specialist skills that allow them to track down information, sort, analyse and eventually create reports on what they find. Because interpreting information cannot be prescribed, these reports, and how they are arrived at, will depend on what the students want to achieve. Students can use different strategies to arrive at different conclusions, depending on their questions or hypotheses (Norton, 1992). Thus EILs can be classed as adaptive media (Laurillard, 2002).

Simulations

One type of simulation is a program that provides access to an underlying model of the real physical, social or psychological world for manipulation by students (Laurillard, 2002; Norton, 1992). As analogies of complex, real situations, simulations let students manipulate variables and, hopefully, enhance their understanding of the world by discovering something about the underlying relationships and theoretical concepts involved. Simulations are not worth developing for simple relationships which students should understand from description alone. "Variable-manipulation" simulations are distinguishable from animations because with animations the computer generates its own values to display, whereas in a simulation the user chooses the values whilst the computer adjusts and displays the output accordingly (Laurillard, 2002; Norton, 1992).

One disadvantage of a simulation is that, although students receive intrinsic feedback on what might happen if they carry out a particular action, there is little or no guidance on how to interpret the final result. To work, simulations require 'well-defined models and rule systems' (Laurillard, 2002, p.131), something which can frequently be difficult to provide in an ill-structured domain (Spiro *et al.*, 1991a).

Although not available at the time of this study, recent advances in technology have made possible orthodontic simulation programs that have been developed to show patients how they might look after treatment (PracticeWorks, 2004; Onyx Ceph, 2004; TOC Dental, 2004; 3D Tooth, 2004. These packages are said to be useful in helping patients visualize the proposed course of treatment and understand what to do to make that treatment successful (PracticeWorks, 2004).

Biomedical simulations

Medical and dental literature usually adopts an alternative definition of a simulation. This definition provides students with details based on a real problem where students get:

To experience cases before meeting real patients

To follow through cases that might otherwise take too long to complete

To gain experience of rare problems they might not meet during their training (Barrows, 1987, 1993; Ladyshewsky, 1999;).

This type of simulation uses the concept of interactive fiction to create a virtual universe where users, left to their own devices, can become co-authors (Norton, 1992). Like recreational fiction (e.g., video games), interactive fiction has evolved from the growing realisation of the importance of story telling in helping us to understand the world we live in (Bruner, 1990). So simulation as interactive fiction gets users to learn by putting theory into practice and dealing what that knowledge implies (Norton, 1992).

One example in dentistry is an endodontics diagnosis simulation package, which uses the title "simulation" because the program is designed to represent a real–life dental problem. Students answer a series of MCQs and receive feedback on each, but only progress to the next stage of the program if they choose the correct response (Fouad *et al.*, 1997). Another example lets students take on the role of a dentist asking a patient about a prosthetics problem, using the computer's response to draw conclusions and decide what treatment to offer. *George: a prosthetics consultation* is aimed at first year clinical students and can be found at: http://www.dentistry.bham.ac.uk/fordentists/calpreview.asp (accessed 15th March, 2005; Pollard and Walmsley, 1994).

Virtual environments

Virtual environments are simulations that use a graphical model rather than a generative mathematical model of the system to illustrate visual and positional properties rather than the system's behaviour. Students can manipulate either property in relation to some goal but, without intrinsic feedback, a virtual environment is only interactive to the extent that it provides an explorable environment (Laurillard, 2002).

Advances in computer technology raise the possibility of 'virtual reality' surgeries in both the medical and dental fields where users can discover what happens, for example if they decide to use a 'not–recommended' treatment option as opposed to current preferred practice (Johnson, 1992). Simulators are particularly useful '... when the operation being duplicated is irreversible and hence training is better done in simulation than in real life' (Buchanan, 2001). Although recent advances in technology have led to improvements, dental simulators tend to follow the same structure in which students are provided with the relevant information and then have to repeat appropriate actions until mastering the procedure (Buchanan, 2001). Virtual reality simulators have been developed in dentistry to provide students with practice at preparing cavities in restorative dentistry.

One example, DentSim, integrates a manikin head with a dental unit and a computerized tracking system, allowing students in restorative dentistry to practice cavity preparation (DenX Corp, Jerusalem, at: http://www.denx.com/dentsim_system_desc.html accessed 15th March, 2005). Currently assessment relies on a human instructor, who grades the students' efforts displayed on a computer screen, usually providing them with some form of feedback at the same time (Buchanan, 2001). By correlating students' performances in the simulator with final grades from their manikin course, the simulator was said to be useful as a predictive device capable of providing early identification of students who might be having problems with the manual skills required for cavity preparation (Imber *et. al.*, 2003), but was not yet ready to replace conventional training methods (Quinn *et. al.*, 2003a,b). Virtual reality simulators, that integrate equipment with computers, are not currently available in orthodontics.

Tutorial programs

Tutorial programs, in contrast, explicitly follow a teaching strategy. Ideally these tutorials give students extrinsic feedback on their progress, following a path through the program that takes into account the desired learning outcome (as defined by the developer) and adapts the presented material as a result of a student's previous actions. However, unlike teachers, computers are limited in how they present material to students. Developers therefore assume that students have basic understanding of terms, concepts and disease processes via '... some previous initial teaching of the topic, and ... focus instead on the practice of related tasks' (Laurillard, 2002, p.134).

One example of a dental adaptive program in endodontics is *Removal of Foreign Objects from Root Canals* at: http://www.dentistry.bham.ac.uk/fordentists/calpreview.asp (accessed 15th March, 2005; Guerisoli, *et al.*, undated). Endodontics is a dental specialty involving the prevention and/or treatment of injuries and/or diseases to the pulp of the tooth. In this program users answer a series of questions that identify a foreign object in a root canal and lead them to a suggested plan of treatment depending on the nature of the foreign object.

3.6.4 Communicative media

Communicative media take advantage of the potential for computers to support discursive interactions in situations that rely on a conversational framework for learning activity. Communicative media evolved to solve a logical, rather than a pedagogical problem, where students who were separated geographically could contact their tutor and other students using media such as email, telephone and videoconferencing. Examples of communicative media include: computer-mediated conferencing, digital document discussion environments, audio- and videoconferencing collaboration (Laurillard, 2002).

In dental education, videoconferencing has been used for post-graduate training of vocational trainees, giving students (and GDPs) access to a remote expert (Cook *et. al.*, 2001, 2002; Stephens, Grigg and Cook, 1998; ORQUEST, 1998). By transforming learning into discussion and collaborative work, communicative media have the potential to enable interactivity to increase between users as well as increasing user-content interactivity (Hall, White and Woolf, 1999), particularly now that domestic broadband and "free" videoconferencing packages are being bundled with operating systems.

An example of a website where GDPs can use a computer, both for CPD in the areas of communication skills, team-working, patient safety and ethics and law (Heard, 2004) and to communicate with other health care professionals, is the Healthcare Skills website, based at the London deanery (http://www.HealthcareSkills.nhs.uk, accessed 15th March, 2005) . Communicative media were not included as learning over a distance was not the focus of this study, but will inform part of the discussion in Chapter 9.

3.6.5 Productive media

This category covers media that allow students to articulate their conceptions. Productive media let students carry out design activities using computers as learning tools. Examples of this type of media include computers programmed to act as microworlds, collaborative microworlds or modelling tools (Laurillard, 2002).

Like simulations, microworlds work on the experiential level. However whilst students can only use a simulation for exploration and investigation, with a microworld they can create their own system, depending on their (rather than their teacher's) objectives (Laurillard, 2002). Perhaps the most famous example of an educational microworld was Papert's work in teaching mathematics using Logo (Papert, 1980). However despite the advantages of this type of media, no examples of dental microworlds were found that could be included in this study, probably due to the cost and effort of producing these programs in a very complex domain.

Modelling programs let students create a mathematically defined model of a system, run the system and compare the output of the program with data from a real system. Modelling differs from a simulation because students manipulate the model itself rather than just parameters within the model. Modelling differs from a microworld because the model is defined by the students rather than being implicit in the design of the program (Laurillard, 2002). The problem in dentistry is that the mouth is considered too complex for current technology to support such a program, if only because there are too many unknowns by virtue of the huge biological variability in what is "normal" (Stephens, 2004). Both microworlds and modelling can be used to encourage students to work collaboratively, with the benefits such social interactivity can bring to learning (Chapter 2).

However despite the possibilities for student expression offered by computer technology, very little innovative use has been made of its potential beyond the amplified paper-and-pen technology of word processing (Laurillard, 2002), mainly due to the length of time it takes both to learn the technique and to fumble through developing such programs. One solution has been to let students use a template system, developed to simplify the computer skills required by teachers, to produce their own CAL material. At the dental school in this study the CALScribe template has been used by students to produce CAL material as part of their final year project work. This material can be accessed by other students via the school's Intranet across a variety of topics, ranging from dental materials, pre-clinical dental anatomy through to oral surgery (Vowles, 2004).

These student-generated CAL programs appear to be types of both discursive (because they allow students to articulate their own conceptions of the topic) and productive media (Laurillard, 2002). Not surprisingly the students who produce CAL seem to learn more about a topic than those who use what they have produced (Stephens, 2004).

At the time of this study potential projects for students were chosen from dental specialties identified as lacking in CAL. As such, student produced orthodontic CAL material was not available for consideration in this research.

3.7 Using CAL to support learning

This analysis of different learning media suggests computers can help students through the paradigm shift when moving from learning and recalling facts to using knowledge to solve problems (Coulson and Feltovich, 1993; Engel, 1991; Finch, 1999; Graham, McNeill and Pettiford, 2000; Johnson, 1992). The computerised case in this study was based on an underlying paradigm involving a procedural model of orthodontics which structured content according to whether students needed to draw on conceptual or procedural knowledge. The structure was then used as a basis for organising instructions. It is suggested elsewhere that turning carefully sequenced "real-life" problems into a series of flow charts that move from problem analysis to implementation can encourage students to construct increasingly complex qualitative models of the domain (Wilson and Cole, 1991).

Teaching of clinical problem-solving usually occurs on diagnostic clinics attended by students during the final years of their course. The requirement to address patients' problems more efficiently in an increasingly cost–conscious health service means that clinics do not really provide the ideal opportunity for student participation. As well as the problems facing orthodontic education (Chapter 1) and the constraints on consultants' time that prioritise treating the patient rather than supporting learning, there are usually complicating issues such as fillings and oral hygiene that have to be sorted out before orthodontic treatment can be started. Another problem with real patients is that they attend in random order, as far as the complexity of the case is concerned. Finally, with only one set of models per patient (if the models are still available and have not been broken or lost), and a clinical student/staff ratio of 6 to 8 students per tutor group, there is usually only enough time for one student per patient to examine the occlusion in any detail, leaving the others to pick up what they can from the sidelines (Stephens, 2004).

As a consequence, the dental school in this study has, over a number of years, developed several orthodontic CAL case studies that provide students with a computerised example of these experiences, taking them step by step through a series of questions related to the procedures required to solve routine diagnostic problems (Long et al., 1994; Stephens and Grigg, 1994, 1996a,b,c). One of these cases was modified for the purposes of this study. The second package developed for the pilot study, a hypertext program not used in the main study, was based on material taken from an introductory orthodontic textbook. The reasons for developing these programs will be explored further in Chapters 4 and 5.

3.8 Chapter summary

This chapter highlighted some of the advantages and disadvantages of using computers to support learning, providing an overview of the historical context behind the development of dental CAL. The chapter discussed different ways in which CAL can be described and classified, using examples of available dental software to illustrate each category. The availability of learning material and restraints on resources were identified as reasons for deciding to develop two different types of CAL program in this study: a hypertext prototype of an orthodontic textbook used in the pilot study, and a computerised case study used in both the pilot and the main study.

Chapter 4: Methodology

Chapter 4: Research Methodology

4.1 Introduction

This chapter justifies the choice of paradigm adopted for this study, based on the findings of the earlier chapters. After arguing for the merits of a phenomenological, grounded theory approach, the chapter describes the research methodologies employed in the pilot and main studies. The chapter explains how discourse analysis techniques have been used as a baseline to analyse the data collected for the main study, allowing contextual themes to be identified and developed for later discussion as they emerge from the analysis of the data. After exploring the reseach context, the chapter ends with an overview of the background behind the development of the CAL programs used in the study.

4.2 Methodology

In Chapter 1 the purpose of this study is defined as an investigation into the nature of interactivity that occurs when dental students use computers to learn about orthodontics, focusing on what can be inferred about students' underlying conceptions based on the interactivity observed when students used CAL to learn about orthodontics. In this study, with its focus on analysing student interactivity, qualitative data are collected from an inductive analysis of interview, observation and recorded data and used to construct a deeper understanding of what happens (Bruner, 1992) within a contextual background provided by quantitative data collected from computerised log-files and a questionnaire survey.

In contrast to a deductive analysis, with its focus on testing a theoretical hypothesis, an inductive analysis allows resources to be focused on points of interest as they emerged from the data. This phenomenological approach favours a grounded theory rather than an experimental approach to data collection and analysis (Strauss and Corbin, 1998). The problem with this approach is that, under a narrow definition of reproducibility, it could be difficult to reproduce social phenomenon recorded in a naturalistic setting because of the near impossibility either of replicating original conditions under which data are collected, or of controlling for all possible variables outside a laboratory experiment. Under a wider definition of reproducibility it is possible however to conduct research using a similar theoretical perspective and collecting comparable data under the same set of conditions that can lead to a similar explanation for the phenomena under study (Strauss and Corbin, 1998).

The widespread acceptance of evidence-based dentistry described in Chapter 1 suggests that dentistry is likely to be ontologically geared towards an objectivist rather than a relativistic epistemology. A naturalistic/qualitative approach is more likely to be acceptable to those grounded in a scientific framework if quantitative data are available that can support the findings of the study (Feyerabend, 1993; Jadad and Delamothe, 2004; Lewis, 2003; Rosenberg, Grad and Matear, 2003). Furthermore, like students in other subjects (Marton and Booth 1997), the dental community's objectivist viewpoint suggests dental students may end up basing their understanding of dentistry on a limited number of models and conceptions.

Choosing activity theory as a paradigm for this study (Chapter 2) allows quantitative and qualitative data to be combined in a way that focuses on the outcome of activity, rather than on the individual. Activity theory thus enables the collected data to be grounded in an approach that combines a phenomenological analysis of qualitative data with a statistical analysis of quantitative data. The flexibility of activity theory makes it possible to consider both the possible influence of students' mental models and previous experiences of orthodontics and the impact that the CAL program itself has on the learning experience of the students.

4.2.1 The pilot study

In the first phase of this study resources are concentrated on the development of two different CAL programs (Chapter 3): a narrative, linear case study and a hypermedia introductory prototype of an orthodontic textbook (Section 4.4). In the pilot study, both programs and recording/interview methods are tested on four students (two for the hypermedia program, two for the case study) who volunteer to be observed using the programs. These observations take place just after the students have completed their second clinical end-of-year exams. During the pilot study the students are observed working on their own, in isolation from any other source of information (human or non-human). Video recording equipment monitors each student as they use one of the programs on a CAL development computer located in a materials laboratory at the dental school.

As well as observing and recording the interactivity that takes place, students are interviewed immediately after the session. Students are asked to recall what they have done using a computer-generated log-file of recorded activity as a memory prompt. After each session, activity transcripts are produced, which collate the log-files with the conversations recorded in the post-session interviews. These transcripts are analysed using discourse analysis techniques (Section 4.2.4). The purpose of analysing the transcripts from the pilot study is to identify focal points for the main study.

4.2.2 The main study

Both quantitative and qualitative data are collected and analysed for the main study. As well as providing a method of triangulation of data, and acting as a potential check on its reliability and validity (Banister *et al.*, 1994; Bell and Opie, 2002; Brannen, 1992b; Bryman, 1992; Holliday, 2002; Taylor, 2001), the quantitative data as contextualised background information provides a means of measuring the reality of the observed interactivity. This quantitative data also provide a linking mechanism to possible outcomes (Hammersley, 1992; Mason, 2002; Robson, 2000,2002). The collected quantitative data thus forms a framework for understanding the qualitative data, permitting a deeper description of the interactivity and ways of experiencing learning about orthodontics that occur during the study. The combined data provides a record of what occurs between students, the CAL program, their tutor and the interviewer as students use the CAL case study in one of six tutor groups working in the CAL room of the Dental School.

Students are free to choose to work either as individuals, in pairs, in teams (3 to 6 students) or in groups (7+ students). Because each grouping can work in its own way, this freedom to choose is important when considering the nature of interactivity (Reigeluth and Moore, 1999). The reasons for adopting this approach and for focusing on the computerized case study and one cohort of students have been discussed in Chapter 5.

The qualitative data for the main study includes:

1. Observation data collected by watching the behaviour of the students as they interacted with the computerised case study
2. Written transcripts of audio and video recordings of conversations and activities taking place whilst students used the programs
3. Written transcripts of audio and video recordings of short, post-session, unstructured interviews conducted immediately after the students have finished using the software, allowing observed points of interest to be explored in more detail.

Supporting quantitative data are collected from three sources: from a pre-session survey questionnaire, computer-recorded log-files of student activity within the program and end-of-year orthodontic examination results. One source of quantitative data ruled out of the study is a learning styles questionnaire study such as that described by Entwistle (1988a). This study, concentrating on the actual act of learning about orthodontics, is primarily interested in collecting qualitative data that will provide a richer and deeper description of interactivity rather than testing pre-determined hypotheses. With limited resources, there is little justification for spending extra time analysing data collected from such a questionnaire which will be more likely to describe students' preferred learning styles, rather than the actual learning strategies adopted within the context in which the learning takes place (Laurillard, 2002; Marton and Booth, 1997).

A short questionnaire is given to students at the start of each session in the main study (Appendix D, Table D1). The questionnaire asks students for some general background information (age, gender, *etc*) and for their self-assessed confidence levels on using different types of computer programs. This questionnaire is derived from one previously issued to final year students and thus provides a comparison with similar data collected from final year students in each of the four years preceding the study (Grigg and Stephens, 1999; Grigg *et al.*, 2001). This data has been used to check that there is nothing unusual about the cohort of dental students in the main study as well as incidentally giving students something to do whilst the Interviewer sets up and checks the recording equipment, something that can only be done once students have decided where (and with whom, if applicable) they are going to sit.

The second source of quantitative data comes from computer-generated log-files of students' recorded activity within the programs. This data provides a check on the validity of the transcripts of audio and video recordings. The data also helps clarify activity when it is not immediately clear from just the recording exactly what is going on. These files log information about which screens students visit, which records they access together with all their attempts to answer questions and what actions (if any) are recorded by the computer as having been taken as a result of feedback to those questions. The logs make it possible to anchor the qualitative data so that comparisons between different students refer to actions taken at the same point in the program. Statistical analysis of the log-file data can be found in Appendix D, Tables D3,6,7,8a,b).

Finally quantitative data are collected from the results of the end of year orthodontics exams taken by the cohort of students in the main study at the end of both the M and S years. This data provides a limited opportunity to correlate student progress over a longer time frame than that offered for the short period of close observation undertaken for the main study (Appendix D, Tables D4,5a,b). The different types of data collected for the study are laid out for comparison purposes in Table 4.2.2.

Table 4.2.2 Collected data by type

Collected Data	Qualitative	Quantitative
Observation Notes	✓	
Video Transcripts	✓	
Audio Transcripts	✓	
Questionnaire Survey		✓
Computerised Log-files		✓
End of M-Year and End of S-Year Orthodontic Examination Results		✓

4.2.3 Analysis of interactivity

Three main categories of research have led to different approaches to analyzing human-computer interactivity, grounded in the theories of instructional design, constructivist psychology or phenomenological research (Laurillard, 2002). Each category has its own underlying epistemology that heavily influences the ways in which research is carried out (Fosnot, 1996a).

Instructional design theory proves useful for providing initial ideas for developing the CAL programs used in this study. Instructional design methodologies grew out of the traditions of behavioural research via information processing theories, and are heavily influenced by the work of Gagné (Ference and Vockell, 1994; Gagné, 1985; Tiene and Ingram, 2001; Wilson and Meyers, 2000). As a consequence, instructional designers tend to concentrate on experimental research that looks at a learning task in isolation, and adopt a prescriptive approach to designing learning sessions. Although helpful to CAL designers the nature of this research, and the theories generated, may not translate well to other contexts or situations (Laurillard, 2002; Marton and Booth, 1997).

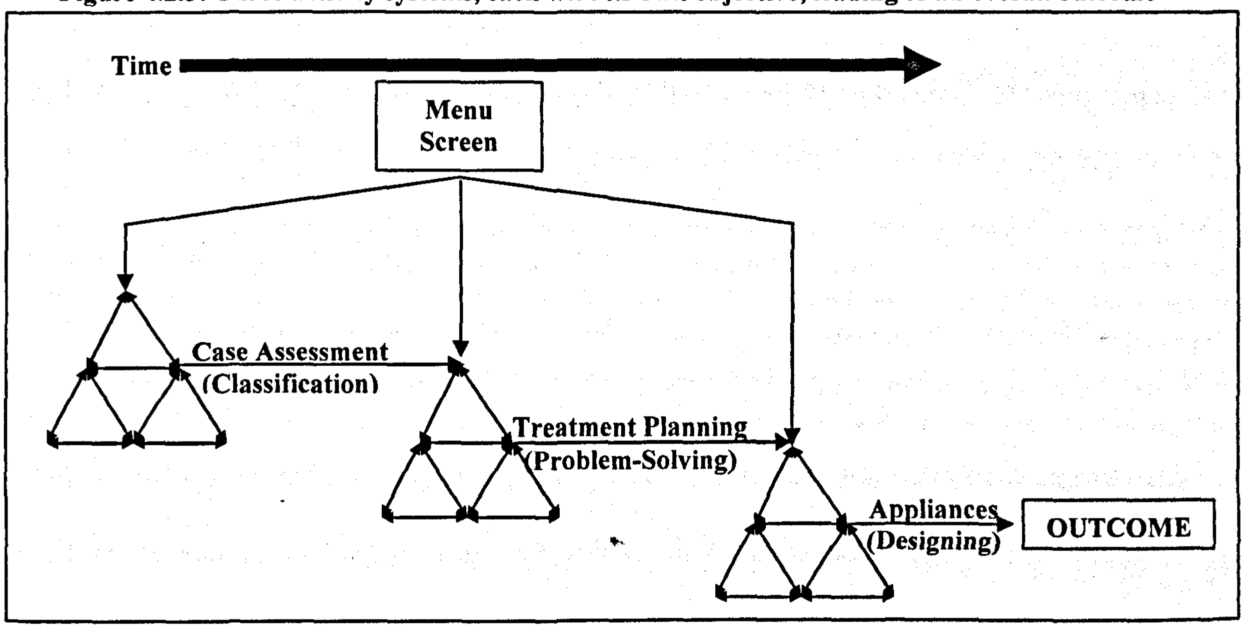
Constructivist psychology and phenomenology both offer research methodologies more suited to the research proposed in this study. Constructivist psychology is based on the idea that students learn by actively constructing their own reality, with teaching facilitating and supporting that process, rather than transmitting knowledge to students. By providing '... an account of how the individual learns through interaction with their world' (Laurillard, 2002, p.67), constructivism offers an alternative method of analysing the transcripts. This analysis involves classifying the interactions in terms of what each student does in responding to questions asked, either by the program or by other students, *etc* (Sabah *et al.*, 1999; Yelland, 1994). To provide a baseline from which to start analysing the data in this study, student interactions are initially divided into two main categories: human/non-human. Each category is further sub-divided into the groups in Table 4.2.3.

Table 4.2.3: Interaction categories (adapted from Reigeluth and Moore, 1999, p.62-63)

Human Interactions			Non-human interactions			
Student-student	Student-teacher	Other	Student-tools	Student-information	Student-environment/ manipulatives	Other

Activity theory has been used as a framework to examine the interactivity that occurred whilst the students are learning about orthodontics using a CAL case study. Figure 4.2.3 shows a two-dimensional representation of a three-dimensional figure that can illustrate how students have the same tools available to carry out the three different activities (case assessment, treatment planning and appliance design) that form the basis for each of the three sections of this orthodontic case study.

Figure 4.2.3: Three activity systems, each with its own objective, leading to an overall outcome



The case's narrative structure asks students to assess the problem, plan a course of treatment and design appliances suitable for carrying out this treatment. This structure has a natural specific time element hence students cannot start anywhere within the package. The linear nature of the case study follows a sequence of events in which treatment planning and appliance design cannot be completed successfully unless a full assessment of the case is carried out first. Similarly appliance design can only be carried out if students first plan how to treat the case. Each section can be considered an activity system in its own right, with the objective and outcome of one section becoming part of the dental record of the next. The linear structure of this narrative sequence is shown in Figure 4.2.3. It has been suggested elsewhere that the adoption of a narrative structure can be a very powerful tool in its own right, supporting learning by framing events within larger structures such as schemata or learning plans (Bruner, 1990).

The 48 students who take part in the main study (18 pairs and 11 individuals) potentially offer 29 opportunities to collect data for transcription both while students work through the computerised case study and when they are interviewed after completing the program. There are sufficient interactions between students to produce two transcripts for analysis of the combined conversations of the individual students in sessions 1 and 6. Insufficient audio data are recorded from 4 other individuals – George (session 3) and Pamela, Quentin and Ralph (session 5) – to provide material for transcription. A failure of the audio recording of the third pair in Session 5 (Terry and Steve) leaves 20 transcripts (17 pairs, 7 individuals (4 + 2 + 1)) that can be loaded into QSR/N6 for coding using the discourse analysis techniques described in Chapter 4.

Phenomenology provides an empirical base for investigating the relationship between an individual and a phenomenon, rather than testing hypotheses (Laurillard, 2002; Limberg, 2000). By using qualitative data to describe a limited number of categories of experience, phenomenology concentrates on variation, so that although each student learns as an individual, student experiences can be grouped together in such a way that there is a qualitative difference between each group (Marton and Booth, 1997).

By focusing on experience, phenomenological research differs from psychological research because 'the particular psychological function in which the structural and referential aspects are embodied is of secondary interest' (Marton and Booth, pp.114-115).

For this study a phenomenological approach provides a methodology that focuses on a few critical issues and the relationships between those issues, highlighting inconsistencies within learners' conceptions of what is expected of them (Marton and Ramsden, 1988) and using the results of these experiences to suggest guidelines for the future development of CAL in dentistry. Thus a phenomenological approach can let teachers take account of students' conceptions of a topic when developing learning materials (Laurillard, 2002).

In the past, phenomenological studies have suggested that learning is most effective if teachers provide students with interactivity that is discursive, adaptive, interactive and reflective (Section 2.3.3). Therefore the focus for the main study was to identify situations using as a baseline classification interactions that were recognized as being discursive, interactive and/or reflective. Adaptive themes were not so common in the transcripts, mainly because the question format used in the programs meant that, apart from initial feedback, the software was unable to adapt further in response to students' actions following receipt of this feedback. It is occasionally possible to identify interactions that can be classed as adaptive when students talked to each other about what was happening. However because feedback from the computer often acts as a trigger to these discussions rather than taking an active part in the interaction, these interactions have tended to be classified as reflective.

4.2.4 Discourse analysis and QSR/N6

Having classified the human-interactions from the transcripts and observation notes, the next stage is to analyse these interactions in more detail drawing, where necessary, on the quantitative data collected from the log-files to add context (Levinson, 1983). The software package QSR/N6 has been used to analyse the combined qualitative and quantitative data collected in the main study. N6 is the latest version of the NUD*IST program for qualitative data analysis,[2] and provides a means by which the variety of data

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[2] A qualitative data analysis program from QSR International at:

collected for this study can be analysed to identify key points of interest. N6 has been chosen because of the potential it offers for carrying out a contextual interpretative research study of complex data (Richards, 2002b). Discourse analysis techniques are used to identify further coding categories.

Several academic disciplines have contributed to the range of techniques available for discourse analysis, including anthropology, linguistics, neurology, philosophy, psychology, semiotics and sociology. The techniques developed within these disciplines can aid research into problems surrounding topics such as communication, social psychology and artificial intelligence (Brown and Yule, 1983; Cruse, 2004; Cutting, 2002; Fairclough, 2003; Hutchby, 2001; Hutchby and Wooffitt, 1998; Levinson, 1983; Martin, 2001; Schiffrin, 1994; Titscher, *et al.*, 2000). Although this motley collection of models and methodologies can be criticized for its vastness and diversity, it can potentially deal with wide ranging problems and phenomena 'in a more systematic and theoretically coherent way' (Schiffrin, 1994, p.5). The discourse analysis tools that prove useful for this study are primarily derived from research methodologies developed for the fields of speech act theory, ethnography of communication, discourse analysis and pragmatics. This research is not focused on an investigation of discursive patterns *per se*, but is a phenomenological study on interactivity. Therefore tools suitable for analysis are chosen, where relevant, from the range available and adapted for use in the specific circumstances in which this study takes place.

The baseline for understanding the resulting interactivity is drawn from transcripts of the conversations between students whilst they used the programs. Selected details from the computer log-files and the video recordings were added to clarify students' underlying meanings where transcripts alone were insufficient to provide an analysis of the interaction (ten Have, 1999). Furthermore as well as analysing the actual language used by the

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http://www.qsrinternational.com, accessed 15th March, 2005.

students to articulate their thoughts about the case study, by taking account of the context in which the students were working, discourse markers such as interjections (e.g., *oh*) and indexical or directional expressions (e.g., *this*, *that, there, here, now)* were also used to gain a deeper understanding of student reactions (Hutchins and Palen, 1997; Titscher et al., 2000).

Transcribing the recordings

Each of the video and audio recordings has been transcribed using conventions chosen from those available for discourse analysis (Appendix A, Table A3). The video and audio tapes have been transcribed as follows: the tape is first played without stopping to identify key themes that have not been noticed during the observations. Having provided an overview, each tape is then transcribed in detail, with relevant sections of the tape being replayed until all possible activity has been recorded in the transcript. Once completed, each tape is played through one last time to confirm the accuracy of the transcription and ensure that there are no mistakes in the written record.

Further clarity is achieved by cross-referencing the relevant section of the log-file to the transcript to confirm what the computer has recorded of activity taken by the students at any particular point in the program. The log-files prove to be particularly useful at points when tapes are not altogether clear about what has taken place. Finally all the transcripts are converted from word to text documents and loaded into QSR/N6, for encoding. Resource files derived from QSR/N6 generated reports of discourse analysis of the combined qualitative and quantitative data can be found on the CD.

Finally, because the focus of this study is on a phenomenological, rather than a linguistic, analysis of the data, the full range of available conventions have not been used where the extra information is felt to add little, if anything, to the overall findings and is therefore considered irrelevant at the level of analysis carried out in this study.

Encoding of data using QSR/N6

The minimum requirement for each unit of text in the data analysis was that they were theoretically justified, unambiguously defined and should not overlap (Titscher, *et al.*, 2000). The linear nature of the computerised case JB meant the most logical break points in the main study was to divide each transcript according to students' responses to each question rather than into units based on length of time or text. This "question-unit" allowed students' responses to the same stimuli to be compared, e.g., to the same question and/or feedback. The first activity using QSR/N6 was to encode the transcription data to compare student responses to each question in the computerised case study (plus their reactions to any feedback). Because of similarities between several of the questions, the second pass of encoding using QSR/N6 grouped together students' responses to these questions, comparing like with like.

During these first two encoding operations, note was made of emergent themes, taking as a baseline the phenomenological themes of reflection, discursion and interaction as described above. These were further classified using four "speech act theory" sub-categories, namely: representational, directional, expressional and declarational interactivity (Cruse, 2004; Cutting, 2002; Levinson, 1983). The fifth speech act theory sub-category, commisional, related to discourse where someone promises to commit to some future action, a category of interactivity not recorded in this study. Other themes, primarily relating to the content and context of the material being studied, were chosen as they emerged from the data facilitating a discussion of themes within a framework of activity theory. Where relevant, the phenomenological and Speech Act Theory categories outlined above were subsumed into these contextually more relevant emergent themes and were thus useful as a baseline from which to build a deeper understanding of students' interactivity when using CAL to learn about orthodontics. The baseline and emergent themes themes identified in the QSR/N6 analysis have been laid out for comparison purposes in Table 4.2.4.

Where appropriate these themes will be discussed in more detail in the following chapters. The final stage of the coding was to go through each transcript in detail several times, highlighting other features as they emerged from the data and combining the results, where appropriate, with the quantitative data to provide as rich a description as possible of interactivity.

Table 4.2.4: List of key themes identified from observation notes and the transcription process

Baseline Themes	
Activity Discursive activity: - with partner/other students/interviewer/tutor Interactivity: - with partner/other students/interviewer/tutor Reflectivity: - before answering questions/pre-feedback/post-feedback Adaptivity: - with partner/other students/interviewer/tutor	**Speech Act categories** Directional Declarational Expressional Representational
	Community Student partner Other students Interviewer Tutors (in next room) Tutor (in session 6)
Emergent Themes	
Focal points Appresentation: focus/margin/background Procedural oversimplication	**Approaches to learning** Learning from reasoning Learning from 'Trial & Error"/ "guessing" Learning from elimination of incorrect responses
Mediating tools: Dental records: Face/Ceph/Left/Right/Labial/Occl/OPT, Case Summary Hands/fingers: - as pointers to direct attention of partner/other - as substitutes to indicate position of teeth Pen/pencil/paper: - to draw diagrams as 'aide memoires' - to explain appliances to other students Use of previous experience: - positively/negatively Glossary help file/Introductory e-book Textbooks Library	**Specific Orthodontic references** Partially erupted upper right canine Posterior crowding Labial/anterior/incisor crowding: mild/requiring treatment Age of patient logical (10 years) (approaching 12 /dentally advanced) Definitions of orthodontic terms – e.g. references to "balancing"/"compensating" extractions References to specific dental records (e.g. Cephalometric diagram as Ceph/Lateral Skull Tracing/Cephalomets/Lat Skull etc)

4.3 Research context

This section explores the research context, the students involved, the methods of inquiry and data collection and the way in which this data can be analysed. The background and rationale for this study were reviewed in Chapters 1 and 2 and ways in which computers might be used for learning in Chapter 3. This section looks more closely at the local context of the dental school involved in this study.

4.3.1 The dental students

In the Bristol Dental School there are approximately 50 students in each year. For many years the gender split has been roughly 50:50 – the university having been the first to offer places where women could study on the same footing as men. As part of a highly-respected, traditional, red-brick university, the Dental School is popular with students and can request high 'A' level grades (typical offers are AAB, ABB).[3] Students are expected to have three 'A' levels, nearly always in scientific subjects – one of which must be 'A' level chemistry. Therefore students in this study are expected to have broadly similar educational backgrounds both with respect to each other and to students in previous years.

All students in the study have completed two years pre-clinical education in the University's School of Medical Sciences covering subjects including: basic medical sciences, behavioural science, molecular pathology, microbiology, and pharmacology. Transfer to the Dental School for clinical training occurred at the end of the second year. With three years of study left, each cohort of clinical students in the Dental School is referred to as either the 'J' (Junior) year, the 'M' (Middle) year or the 'S' (Senior) year. To avoid confusion, this terminology is adopted when referring to students in this thesis.

4.3.2 Orthodontic training

Students are introduced to orthodontics through a series of formal lectures at the beginning of their J-year, *i.e.* during the first term of their clinical course. Alongside this training, students undertake an operative technique course where they learn the wirebending techniques they will use on orthodontic clinics. They also have access to a series of computerised MCQ questions relating to orthodontics, which are available either on CD-ROM from the library or via a local Intranet. Students are not expected to be capable of answering these questions until at least a year into their clinical course.

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[3] The average 'A' level score for the university is 340+, data obtained from the University of Bristol Dental School's website at: http://www.bris.ac.uk/prospectus/undergraduate/2005/sections/MDYF/ORDS/admissions, accessed 15th March, 2005).

One way of describing students who are no longer novices is that they are at a stage of advanced, post-introductory learning, where they need to look at specific aspects of their topic from a number of "criss-crossed landscapes" (Spiro *et. al.*, 1988). This concept of "criss–crossed landscapes" was an extension of a model of the use of language suggested by Wittgenstein (1953) when writing his book, *Philosophical Investigations*. This model, based on a series of 'sketches of landscapes ... made in the course of ... long and involved journeyings' (Wittgenstein, 1953; p.vii), suggests a deeper understanding of each 'landscape', or 'idea on the use of language' can only be gained by examining that landscape from as many different perspectives as possible (Wittgenstein, 1953).

J-year students fit the profile of beginners/novices as they are just beginning their initiation into the domain (Patel, Arocha and Kaufman, 1999). This introductory stage involves students starting to learn the symbol representation of the topic (Jonassen, 1991). The kind of learning students experience during their first year can be criticised as falling into the trap described by Spiro *et al.* if, by the end of the year, students are only expected to pass memory tests that can be passed as long as students have just a superficial awareness of key concepts and facts because they are asked only to reproduce what has been learned, rather than tested to any greater depth in the subject (Spiro *et al.*, 1991a)

M-year students see patients at various stages of treatment in the orthodontic clinic working under the supervision of clinical tutors. These tutors are either orthodontic consultants or specialists who could be considered to be experts in their specialty where an expert is defined as someone who has mastered problem-solving within a particular domain (Eysenck and Keane, 1995). M-year students are at an intermediate – or "*advanced, post-introductory*" – stage of learning, fitting a profile in which they can be said to be neither complete novices nor sub-experts in the domain (Patel, Arocha and Kaufman, 1999; Spiro *et al.*, 1991a). M-year students can also be described as cognitive apprentices, developing cognitive skills in authentic domain activities. This apprenticeship begins with clinical tutors making explicit and modelling their procedures for dealing with real patients. The role of the tutors, in any subject, has been described as being one that supports students whilst they practice thereby eventually empowering '... the students to continue independently.' (Brown, Collins and Duguid, p.39).

During the year, M-year students have access to all 20 computerised orthodontic case studies (Stephens and Grigg, 1994; Grigg and Stephens, 1998) via CD-ROM or the local Intranet. When these cases originally made available to students over the school's Intranet, they were accessed via a menu system that split cases into two groups, labelled "simple" and "complex", depending on degree of difficulty of treatment. This sub-grouping of cases was changed when it was discovered students tended to avoid the cases described as complex. At the time of this study students could chose cases according to one of four occlusal categories of malocclusion (Section 1.3.1).

These studies provide students with real-life examples (multiple perspectives) of the range of orthodontic cases they might be expected to encounter in real life (Spiro *et al.*, 1991b). The use of records from several real-life orthodontics cases to illustrate certain key points from a variety of perspectives can help encourage students to gain a deeper understanding of the complexities of orthodontics (Spiro, *et. al.*, 1988). One way of presenting students with this information, and providing them with feedback, is to use computer technology. This has the added advantage of allowing students access to this information as a revision guide at any time in the future, and much closer to when they might actually encounter such a case in reality. Thus multiple perspectives are said to play an important role in learning a complex subject by preventing students from overgeneralising the knowledge in that domain (Jonassen, 1991).

Each student is assigned to one of six tutor groups for all dental specialties for the duration of their course. As they gain more experience of orthodontics students are expected to present cases to their tutor groups for discussion, receiving clarification of anything they do not understand and picking up on any points of interest. These tutorial groups continue in the S-year, by when students are expected to be able to identify and refer any orthodontic cases they might encounter in general dental practice (i.e. they should have sufficient expertise across all aspects of dentistry to be registerable as professional dentists). This readiness is confirmed formally in the final BDS clinical examination in orthodontics at the end of the S-year.

The cohort of students chosen for the main study are observed at the start of the M-year, when they first work through an orthodontic case having previously completed a series of basic lectures on orthodontic assessment and treatment. The students are observed and recorded working through a computerised orthodontic case study during one of six tutor group sessions at the start of the academic year. There were 51 students in the M-year, but as one student fails to complete the year total student numbers are taken as 50. During the week of the main study 48 students take part, 24 males and 24 females (one female student having taken part in the pilot; another female absent through illness). The 50:50 split is a result of the departmental gender balance being roughly equal for many years (Stephens, 2002) and not to any methodological decision on the part of the study.

The number of available computers and the size of the tutor groups means there are sufficient resources for students to work through the case as individuals. Students are therefore given the choice to work either as individuals or with other students. Having been encouraged throughout the first two years of the clinical course to act as "dental nurses" for each other 37 students, possibly through "force of habit", choose to work with one or more partners. The main reason for students acting as "dental nurses" is mainly because there are not enough dental nurses for them to do otherwise. Although there have been concerns about this shortage for several years, Bristol Dental School has taken the decision to structure this shortage rather than leaving it to chance. By allowing students to develop their basic clinical skills over two years, the expectation is that students will be able to work more efficiently when they have access to a nurse in their final year. Bristol students only have access to a dental nurse in their final year unless working on a procedure which requires a trained nursed to be able to carry out a special procedure (Stephens, 2004).

There are other advantages to this arrangement, not least the opportunity it provides for students to appreciate and value the skills of a dental nurse. Working in pairs at the chairside on clinic gives students a discursive opportunity to learn together whilst trying to solve a common problem. And, particularly in orthodontics where appliance adjustments are undertaken monthly, both students can gain in consecutive months from each having a go at undertaking repetitive clinical procedure. It also gives students a chance to experience the rewards of teaching each other. Dental nurses benefit if only because they no longer get bored and impatient waiting for students to work out what they should be doing – especially when students are initially very slow at carrying out practical procedures (Stephens, 2004).

By the time they enter the M-year students are expected to be comfortable with working in pairs in all departments. In addition students become used to organising themselves in pairs in other problem-solving activities as well as on clinic. Finally other timetable rotations, for example, when individual students were pulled out of specialist clinics to work in primary care (which operated on a rota within the general clinical rota) mean that students frequently swap partners and get used to working with others in their group. This activity helped to promote both discussion and acceptance of the concept of having a standard approach to working procedures between the nurse and dentists so that staffing flexibility could be obtained in a group dental practice (Stephens, 2004).

Eleven students (5 female and 6 male) choose to work as individuals. Apart from an all-female team of 3, the remaining students opt to work in 12 same-sex pairs (6 male and 5 female) or 6 mixed-sex pairs. To simplify analysis, the all-female team of 3 has been grouped with the pairs in the following discussion, making 6 all-female groups with two or more students.

To preserve confidentiality and not embarrass anyone taking part in this study all participants have been given a pseudonym (Table 4.3.1). For the main study these pseudonyms have been assigned where the only consistency has been to ensure that each name matches the gender of the student it is assigned to. The names are listed in alphabetical order, with Adam referring to the male student sitting closest to the library end of the CAL room in session one, Bill to the next closest male student, and so on, so that Xavier refers to the male student sitting furthest away from the library in session 6.

Table 4.3.1: Seating plan for each session, showing which computers were used by which students, together with their pseudonyms

Session 1 16th Oct – am	Session 2 16th Oct – pm	Session 3 19th Oct – am	Session 4 19th Oct – pm	Session 5 20th Oct – am	Session 6 20th Oct – pm	Comp.
Tutors: Alan	Brian	Clive	Denise	Elaine	Fergus (substitute Gareth)	
					Xenie	1
		James & Ian (Kevin)[1]		Terry & Steve	Winifred	2
Charles		Laura & Henry		Tina & Sophie	Xavier	3
Debbie	Isabel & Helen	George	Olga & Peter	Ralph	Victoria	4
Bill & Adam	Frank & Gita	Kate & Jennifer	Oscar & Nigel	Rachel & Queenie		5
	Edward & David		Michael & Natalie	Quentin	Wayne & Una	6
Christine Belinda & Anne	Felicity & Elizabeth		Mary & Leonard	Pamela		7
					Victor & Ulysses	8
Library End of CAL room						

[1]Kevin (i2) arrived as the other students left, and worked through the case on his own.

Recording takes place using 2 video cameras and 4 audio recorders. The video cameras record the pair or individual closest to the library with audio equipment used to record pairs first, then individuals where there are sufficient spare recorders. From the angle of the video recording to the right of the students it is also possible to pick up actions taken by other students in the CAL room, for example when pointing to something on the screen. Combining these actions with the computer-recorded log-files and students' conversations usually make it possible to identify what the students are referring to when they use indexical words such as 'that', 'there', 'them', *etc*, in discourse identified as directional.

The author acts as both observer and interviewer. To avoid confusion, the author is referred to as the Interviewer throughout the transcripts. The tutor in session 2, Brian in the transcripts, has been responsible for developing the content for case JB and is Head of the Department of Child Dental Health at the time of this study.

In the first five sessions the tutors for each group of students sits in a prosthetics laboratory next door to the CAL room where they can be available to answer any questions the students might have about the case. The reason why tutors are absent from the CAL room is to see whether students can find answers to these questions from within the program itself, rather than turning immediately to a tutor for a response. In session 6 a substitute tutor, Gareth, agrees to be present in the CAL room whilst students work through the program – the tutor for the group in the session being unavailable on that day.

4.4 CAL design

Using the above as a theoretical foundation for the research, the study itself has been carried out in three stages: preparatory work, pilot study and then the main study. This section discusses the programming tool chosen for developing the CAL programs used in the study.

One of the advantages of using a computer as a tool for learning lies in its ability to let the user interact with and manipulate media resources (Phillips and Jenkins, 1997b). At the time of the study several different authoring languages were available for developing CAL packages, including standard programming languages, object-oriented languages and visual programming environments. The greatest flexibility for balancing ease-of-use, functionality and operation speed is with standard programming languages. The disadvantage with these languages is the level of programming skills required before CAL packages can be produced. Object-oriented languages, where programs can be built using libraries of objects, offer nearly the same level of potential, but again require advanced level programming skills. At the other extreme are generic packages such as word processors. Although comparatively easy to learn to use, this type of software was rejected because of its lack of functionality and flexibility for the development of CAL material used in this study.

Despite the loss of some functionality in terms of speed of operation and flexibility of approach, the program used to develop the CAL is an example of a visual programming environment which integrates programming language with drawing tools and interaction elements. Different paradigms have been used to produce these visual programming environments (Phillips and Jenkins, 1997b), including:-

1. Stack-based environments, based on the metaphor of a stack of "cards". Objects, with their own properties and programming code (or script), are added to the cards, which can be linked to each other in a variety of ways, although it can be difficult to maintain an overview of the project as it develops. Examples include: Allegiant SuperCard, Oracle Media Objects and Asymetrix ToolBook
2. Flowchart-based environments use a flowchart to represent the structure of the program, with elements within the program symbolized by graphical icons. These programs are very easy for non-programmers to use, but lack the flexibility that comes with the provision of more advanced scripting seen in stack-based environments. Examples include: Authorware and ICON Author
3. Time-based environments where CAL programs can be treated as complex animations, where multimedia objects (sprites) can perform on a stage. The disadvantage of such an approach is the difficulty of translating a project with discrete concepts into such a continuous time-frame. The leading example of a time-based environment at the time of this study was Macromedia Director (Phillips and Jenkins, 1997b)

In the early 1990s a computerised question template, CALScribe, was developed by the Education Technology Services at the University of Bristol, based on Asymetrix's ToolBook authoring package (Asymetrix, Seattle, WA, USA). The main reason the institution opted to use ToolBook is that there is no licensing fee to pay when runtime versions of ToolBook are distributed, minimising some of the costs associated with distributing the software (Chapter 3).

At the start of this study CALScribe had been upgraded to work with the latest version of ToolBook, version 4.0. ToolBook was therefore the programming language most familiar to the author. As a stack-based environment that facilitated a narrative approach to programming, ToolBook's book type structure offered opportunities for programming the hypermedia introductory orthodontics CAL program, whilst a version of the orthodontic case study was already available in ToolBook/CALScribe version 3.0a.

The CAL programs produced for this study have been written using ToolBook CBT 4.0, a version that provides more flexibility than the CALScribe template. ToolBook was chosen because its stack-based environment was considered the best option given the nature of the CAL programs and the author's familiarity with the program.

4.5 Chapter summary

This chapter explored the underlying paradigm supporting the methodological techniques used in the study and explained why a mixed methods approach was adopted for the study, within a framework of activity theory. The software program QSR/N6 and discourse analysis techniques were used as tools to analyse the qualitative data collected in the main study in combination with quantitative, contextual background material provided from computerised log-files of students' actions and a questionnaire survey. To provide further context for the study, the chapter described the background, dental expertise and training of the students taking part in the research. The chapter ended with an overview of the programming tool used to develop the two CAL programs in the study.

Chapter 5: The Pilot Study

Chapter 5: The pilot study

5.1 Introduction

This chapter starts by describing two different ways in which teeth can be identified as students switch between both during the study. The chapter then reviews the development of the two CAL programs produced for the pilot before analyzing what happens during the pilot study when four volunteer students were observed, interviewed and recorded using the programs. The chapter ends by discussing what has been learnt and what these findings imply for the research carried out in the main study.

5.2 Tooth identification

Throughout the study students used two different methods for identifying teeth. Although it would be possible to adopt one notation method, the results of the pilot study (Section 5.4) indicated that a better understanding of the interactivity that occurred when students used CAL to learn about orthodontics could be obtained by retaining both forms of notation in the transcripts. This section outlines the two methods, showing the relationship between each identification system.

The first method of tooth identification was one with which students were most familiar and was used extensively across all dental departments. The other – Féderation Dentaire Internationale (FDI) notation – was a form of terminology commonly used by orthodontic specialists in Europe. Students were specifically asked to use FDI notation to identify teeth during the case study. Although matters could have been simplified by using one method to refer to the teeth throughout this thesis, both have been retained to illustrate how the symbol systems of orthodontics gradually became incorporated into each student's understanding of dentistry during the course of the program.

The two different tooth identification systems are described below. As the case study involved a patient who had lost all her milk teeth, only the adult dentition has been described. Students were most familiar with identifying teeth by tooth type: i.e. incisor, canine, premolar and molar. From the centre outwards, students refer to each tooth as: central incisor, lateral incisor, canine, first and second premolar, first, second and third molars. Teeth were also labelled as being in the upper or lower arch or on the left or right side of the mouth (Figure 5.2a).

Figure 5.2a: Example of tooth identification for adult dentition, occlusal view (looking into an open mouth) of teeth, labelling of teeth in upper right quadrant only

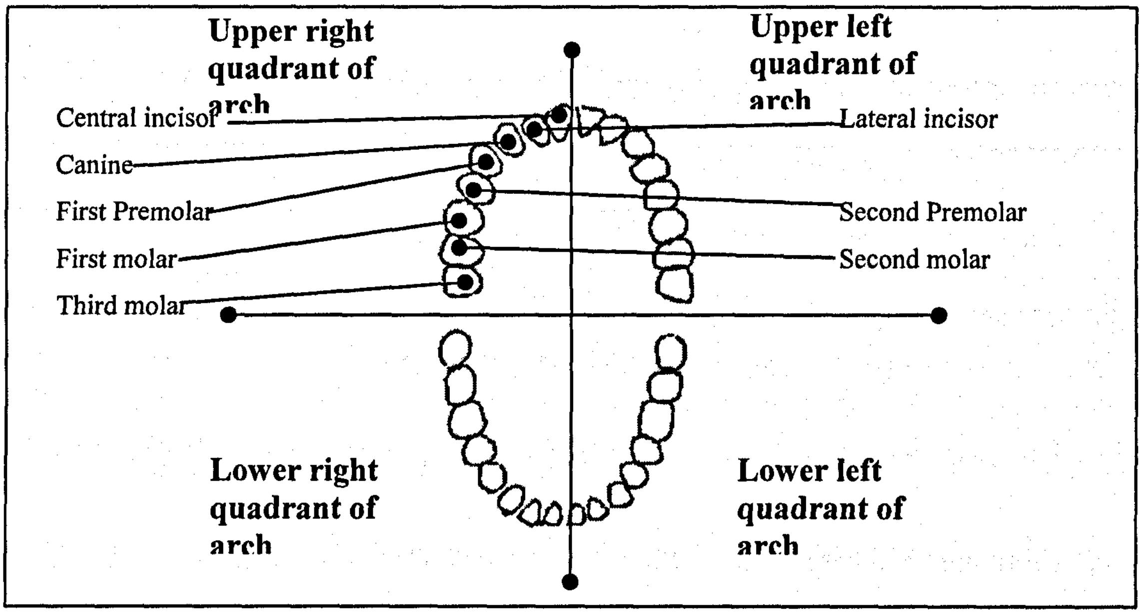
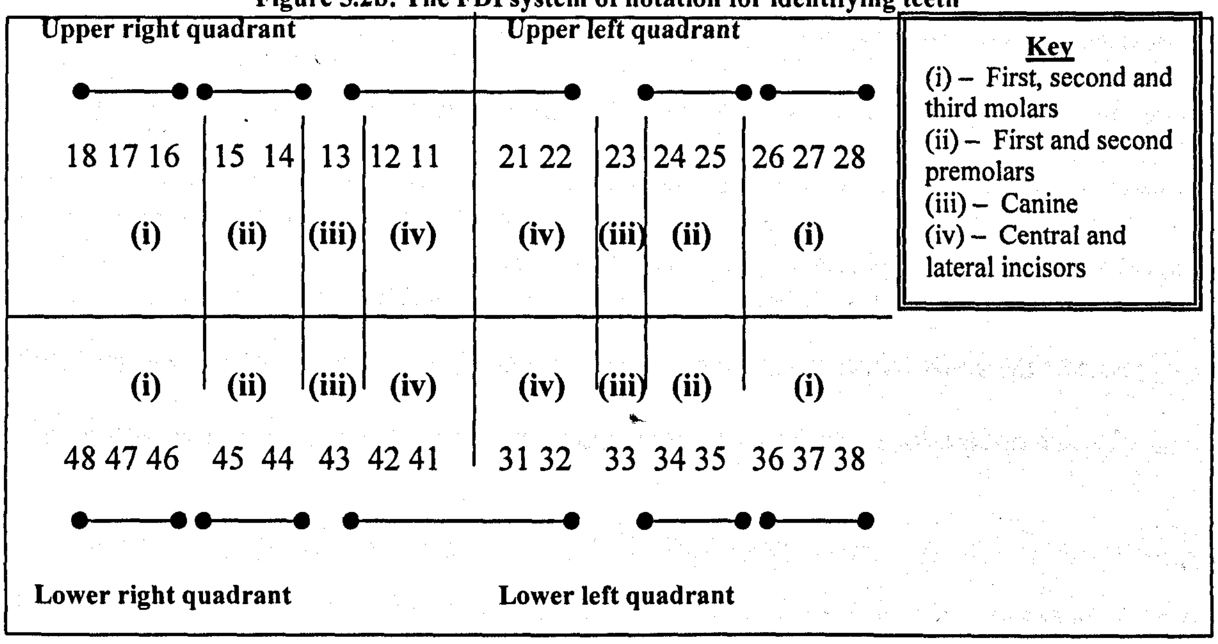


Figure 5.2b shows the FDI two-digit system of notation.

Figure 5.2b: The FDI system of notation for identifying teeth



FDI notation uses the numbers 1 to 8 to signify the permanent tooth number, moving from the midline of the mouth outwards where 1 refers to the central incisor, 2 to the lateral incisor and so on out to 8 for the third molar. Each is preceded by a number identifying the quadrant of the mouth, with 1 for upper right, 2 for upper left, 3 for lower left and 4 for lower right. For example, "13" represents the upper right canine. To further clarify students' conversations, Table 5.2 provides brief definitions of orthodontic symbols and technical terms needed to understand and use to classify the teeth.

Table 5.2: Definitions of tooth surfaces

Label	Refers to:
Anterior	The direction towards the front of the body
Buccal	The surfaces of premolars and molars facing the cheeks
Distal	Moving/pointing away from the midline of the jaw
Labial	Being next to, or towards, the lips
Lingual	Being next to, or towards, the tongue
Mandibular	Relating or referring to the lower jaw (mandible)
Maxillary	Relating or referring to the upper jaw (maxilla)
Mesial	Moving/pointing towards the midline of the jaw
Palatal	How something relates to the roof of the mouth (the palate)
Posterior	The direction towards the back of the body
Procline	Leaning forwards i.e. labial inclination of anterior teeth
Retrocline	Leaning backwards i.e. lingual or palatal inclination of anterior teeth

5.3 Preparatory work for the pilot study

To understand how orthodontic CAL might be developed in future, this section reviews the background and development of the two programs developed for the pilot study: a computerised case study for M-year students and an introductory e-book for J-year students. As the computerised case study JB was taken forward for use in the main study, it will be described first.

5.3.1 The orthodontic case study

Any domain in which knowledge is applied to a naturally occurring, constrained situation (e.g. a medical case study) can be described as substantially ill-structured in which effective learning needs to be grounded in an authentic situation (Bednar *et al.*, 1992; Spiro *et al.*, 1991a). All students from the M-year onwards are encouraged to work through a series of orthodontic case studies developed from "board studies". In an orthodontic board study students give a presentation to their tutor group about a case presented on a board displaying dental records together with life size photographs of the plaster cast models of the patient's teeth. To support this activity a series of questions has been developed that goes through the procedures needed to make decisions about how to diagnose and treat each case. In the original "board studies" these questions were presented as *aide memoires* on clipboards.

The CALScribe template used to develop the orthodontic case study template presents students with both dental records and questions on the screen. This "template within a template" matches the description of a *transaction shell* (Merrill, 1999; Reigeluth, 1999a), which can be used by teachers with moderate rather than advanced IT skills as long as they are '... knowledgeable in the subject matter of the lesson' (Spector, Muraida and Marlino, 1992, p.49). Using a transaction shell allows subject specialists to get material out to students with minimal effort, although at the risk of losing many of the advantages offered by technology (Grigg and Stephens, 1998). The problem with this approach is that, as a restricted version of ToolBook, the CALScribe version lacks flexibility because the template structure makes it impossible to modify the computerised case for the purposes of this study.

The first case to be computerised, JB (Stephens and Grigg, 1994; Long *et al.*, 1994), has been rewritten using ToolBook version CTB 4.0. JB has been chosen for this study because, having been used to learn about orthodontics by both undergraduate and postgraduate students for many years, the questions, records and orthodontic content can be regarded as fully tested and debugged. In the original version students access each part of the case via a separate menu. In 1998 additional questions related to appliance design were added to cases which can be treated with simple removable appliances. Seven of the original twenty cases proved suitable for removable appliance treatment and were modified by adding a section on appliance design at the end of the treatment planning section. Three of these cases required treating in two stages (including case JB); the others could be treated with just one appliance.

Upgrading to ToolBook CBT 4.0 allows student activity to be recorded as they worked through the program and by bringing all three activities together in one file, encourages students to work through the whole case without interruption. Changes introduced as a result of the upgrade includes the addition of digitised photographs, together with text, from the completion records of the outcome of the original treatment, a monitoring and recording function to support the collection of quantitative data whilst students use the program to learn about orthodontics and links to a hypertext version of a glossary file allowing students to access extra information relating to each question through a word search facility.

Audio and video media have not been incorporated into the updated program because at the time of the study most students access the programs in the CAL room in the dental school. Under these conditions a lack of headphones, speakers and the close proximity of other users rules out the use of audio media. The length of treatment time, and the "reality" where GDPs rely on photographs, x-rays and models to record and monitor orthodontic patients, made it possible to use still images instead of video, considerably reducing the file size of the program.

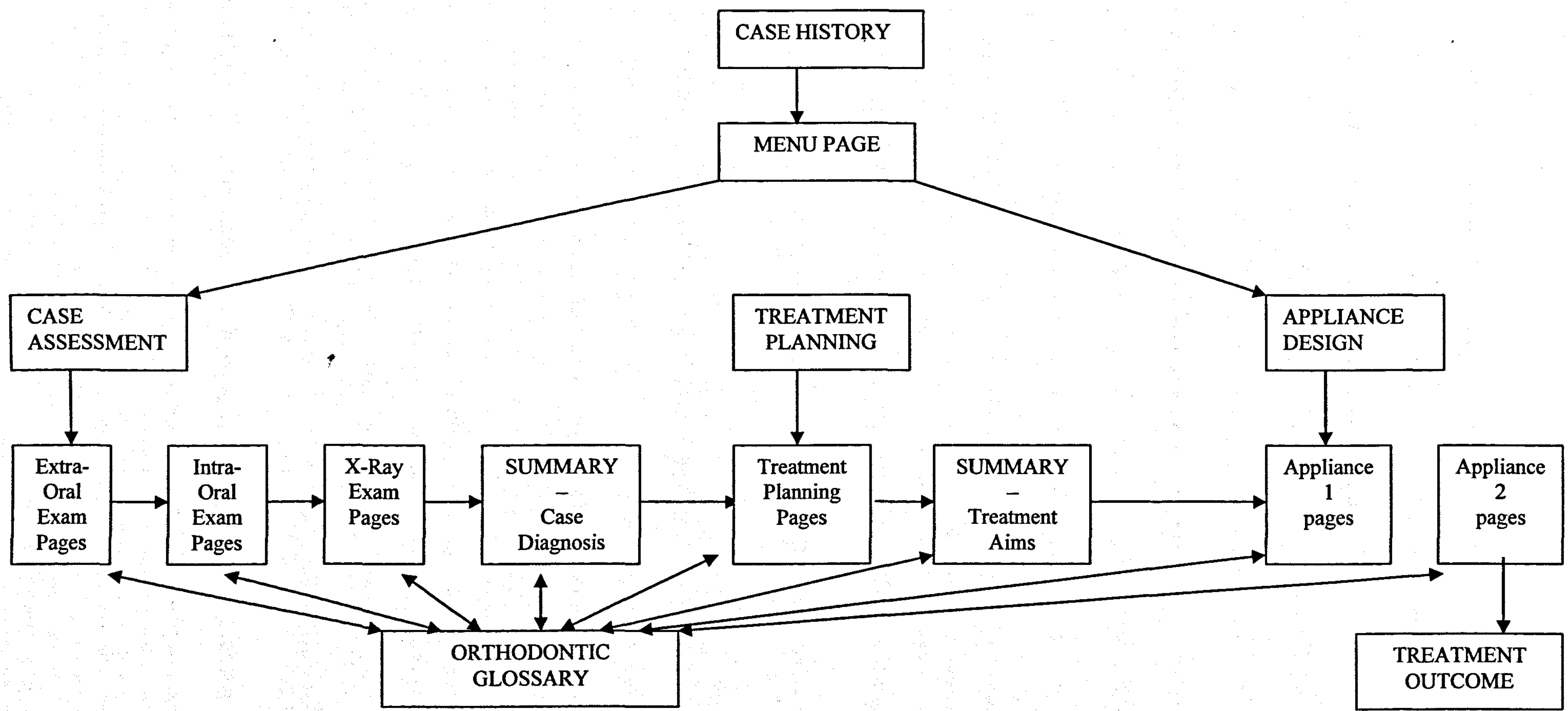
The program assumes that students have had sufficient training in orthodontics to have moved past the novice level and is designed to be used from the M-year onwards. The overall structure of the case can be seen in the flowchart in Figure 5.3.1a.

A link button to the case summary is provided from the end of the assessment, letting students refer back to the diagnosis as they work through the rest of the case. The menu page lets students skip earlier sections of the program so they do not have to work through the case in a linear fashion. Thus as they gain experience students can go straight to the treatment planning or appliance design sections, relying on just the images of the dental records to make decisions about how to treat the case.

To minimise confusion a consistent design layout has been chosen for the screen, including the colour of the background and font/colour of text (Phillips and Di Giorgio, 1997, Figure 5.3.1b). After an introductory screen with reading list, students were provided with a case history and images of relevant dental records for a patient, JB.

Figure 5.3.1a: Flow chart for computerised case study JB

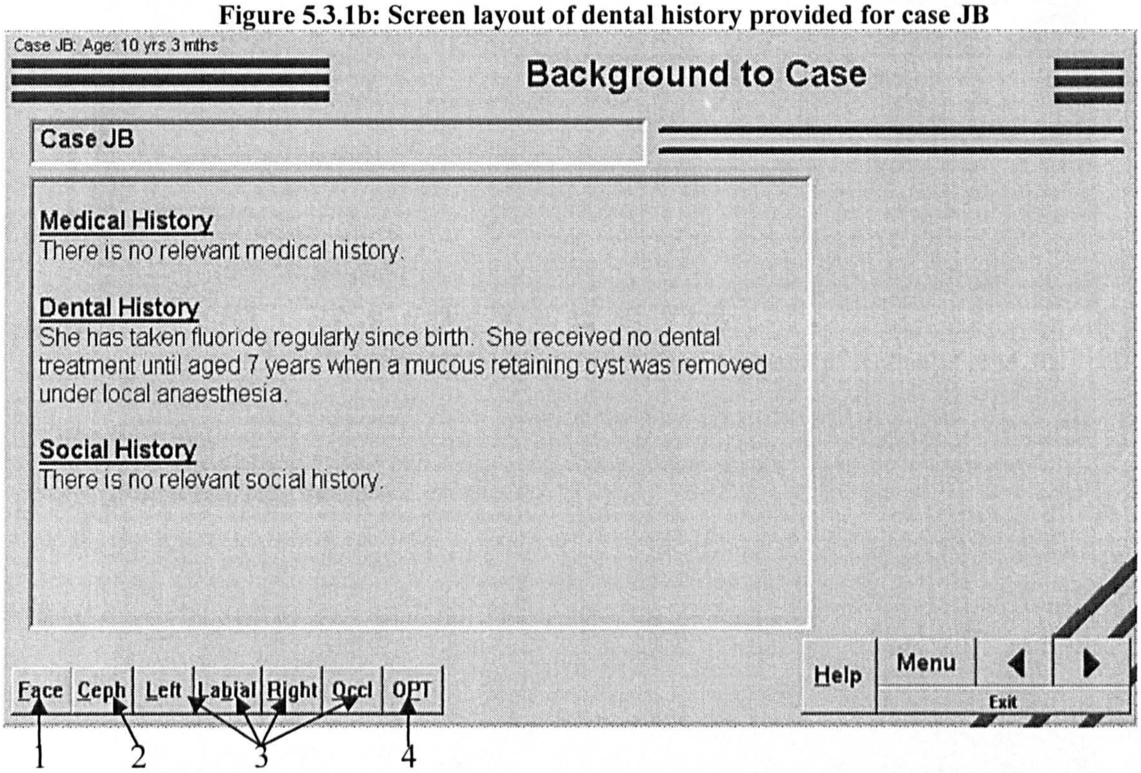
There is one button on every page in the case study linked to a hypertext orthodontic glossary file with full keyword search facility. There is also a link to and from case diagnosis summary on every page from treatment planning stage onwards (links to and from the summary not shown to avoid confusion)



The pre-treatment dental records consist of:

1. A digitally scanned image of a photograph of JB's face (Face)
2. A cephalometric diagram (Ceph) showing an analysis of skull measurements (a line drawing from a skull x-ray used to classify orthodontic cases)
3. Three digitised images of models taken of the teeth (Left, Right, Labial (frontal) views of the teeth in occlusion (biting together)), and one of the occlusal (Occl) view (models of upper and lower arches taken from above)
4. An orthopantomograph (OPT – a panoramic radiograph (X-ray) of the teeth).

Figure 5.3.1b: Screen layout of dental history provided for case JB



Links are provided to images of dental records on every page, with records displayed in a popup window on the right (Figure 5.3.1c, (A)). At the top right (B) a heading indicated the activity (e.g., extra-oral examination). The question appears in a frame on the left (C), and answers are either in MCQ (D) or free response format (Figure 5.3.1d, E). Some of the latter are programmed as concealed MCQs (Laurillard, 2002). Depending on the question, minimal or indepth feedback is provided when the questions are marked (F).

In the appliance design section students are provided with a diagram of the teeth in the upper arch, to which the relevant functional elements of each appliance have been added after students answer all the questions relating to each stage of the design.

Figure 5.3.1c: Example of MCQ question used in the Case Assessment section of case JB

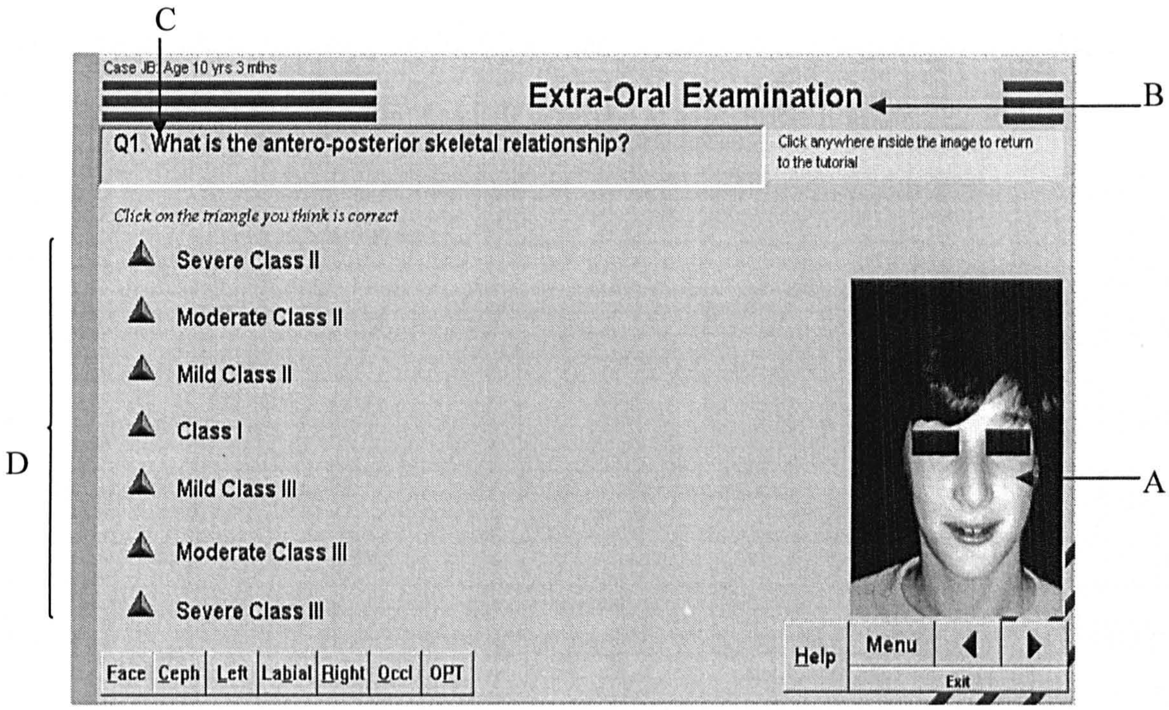
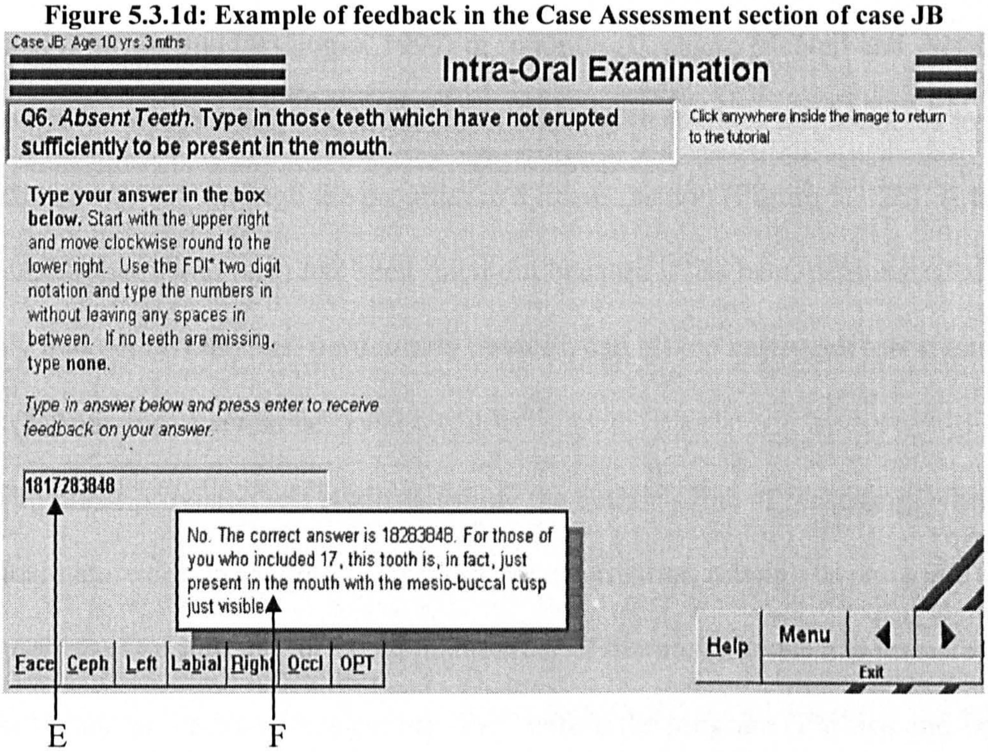


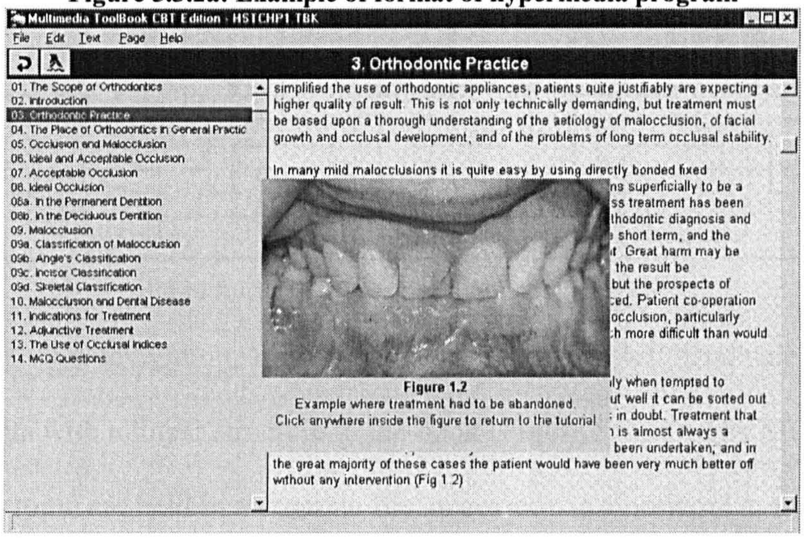
Figure 5.3.1d: Example of feedback in the Case Assessment section of case JB



5.3.2 Developing a hypermedia program

The introductory e-book is aimed primarily at students who had received enough training to cope with the terminology to start learning about orthodontics (*i.e.* J-year). At the time of this study one of the set reading books was an introductory orthodontic textbook (Houston, Stephens and Tulley, 1992). Three chapters from the book have been chosen for conversion, combining text and images from the textbook with hyperlinks linking different parts of the text followed by a section where students can answer MCQs relating to factual information derived from each chapter of the book (Figure 5.3.2a).

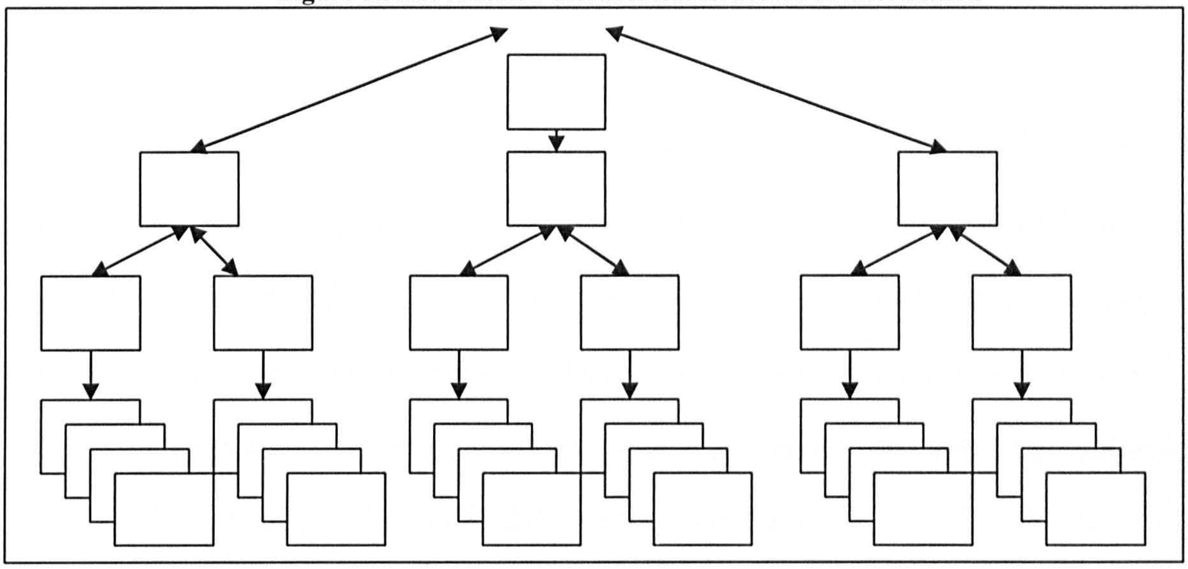
Figure 5.3.2a: Example of format of hypermedia program



The introductory hypermedia e-book developed for the pilot used a mixed-hierarchical (Phillips and Di Giogio, 1997) or modular (Graham, McNeil and Pettiford, 2000) navigation where linear and hierarchical nodes give students quick access to any topic or they can move through the program in a linear fashion (Figure 5.3.2b). A totally unstructured hypermedia form has been ruled out because it has been demonstrated previously that dental students, particularly novices, can all too easily get lost if using such a format (Turner and Weerakone, 1992).

The linear provision lets students follow the author's line of reasoning, whilst the hierarchical nature allows students to track down information relating to one topic very quickly. As this is an introductory text, the number of hierarchy levels has been kept to a minimum to help prevent students getting 'lost' within the program (Phillips and Di Giorgio, 1997). A mixed-hierarchical approach offers a potential hybrid that can let students dive off into hypertext but then get back on track to answer the question when they have finished their information gathering (Stephens, 2002).

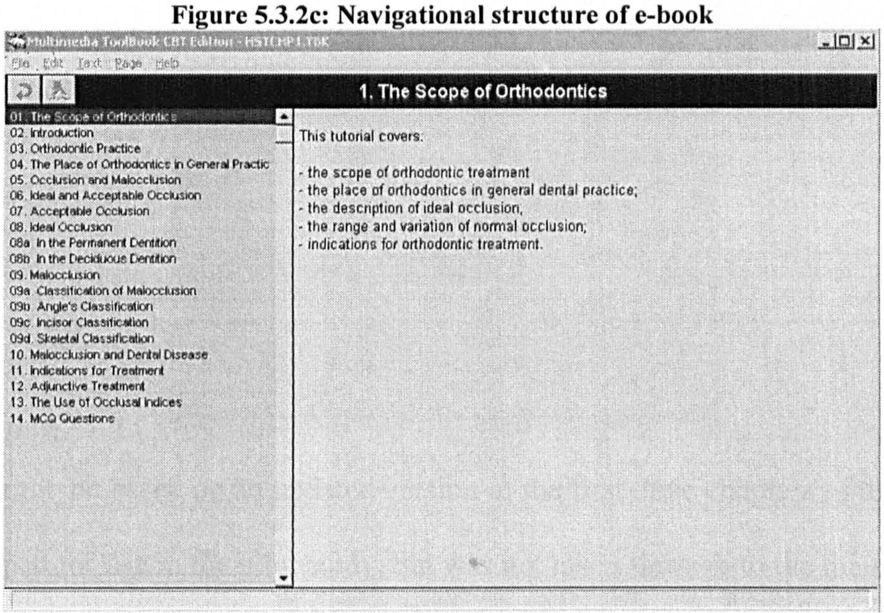
Figure 5.3.2b: A mixed-hierarchical structure of information



taken from Phillips and Di Giorgio, 1997, p.66

To assist with navigation, a list of sub-headings on the left hand side of the screen provides students with a linear structure to the book (Figure 5.3.2c). The MCQ questions relating to each topic are held in a separate file, accessed via a hotword at the end of the lst of sub-headings.

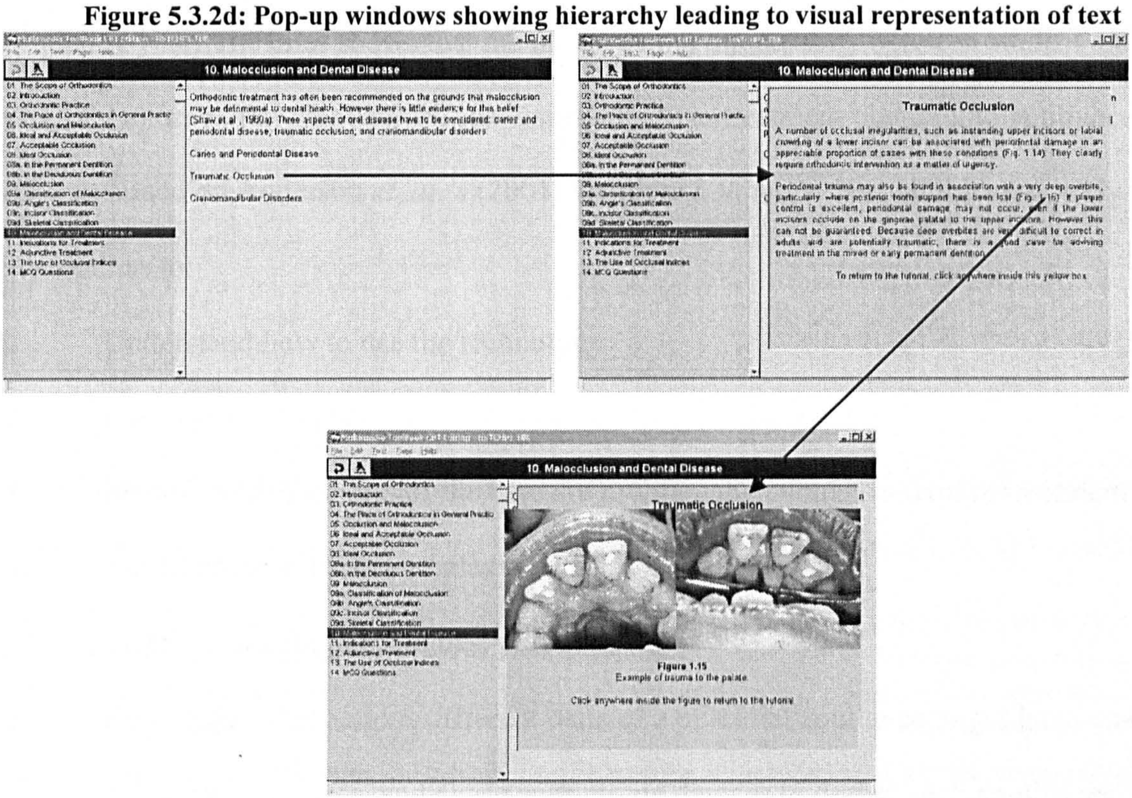
Figure 5.3.2c: Navigational structure of e-book



Text relating to each sub-heading appears in the right hand columns. Embedded within the text are hotwords which either provide links to pop-up windows with related sub-topics, or links to images illustrating points of text (Figure 5.3.2d). Mixing visual and textual information offers students a means by which they can 'mentally integrate visual and verbal representations' (Mayer, 2001, pp.4-5). Students are provided with keyword and full text search facilities, allowing them to track down specific items of interest included within the program.

This program can be considered an introductory package which students can use in different ways – for example working through the questions and linking to relevant material in the hypermedia part, working through the text in a narrative fashion, using the menu or a forwarding button to move to the next topic, or by finding their own route through the material. The program has been written so that the route taken by each student through the program can be recorded for analysis purposes.

Figure 5.3.2d: Pop-up windows showing hierarchy leading to visual representation of text



A prototype based on an updated version of the first three chapters of the book has been developed for use in the pilot study, but was not taken through to the main study. However a similar file (without the MCQs) was provided to students in the main study alongside an orthodontic glossary help file developed using the same structural format. Both can be accessed either through links from the computerised case or via stand-alone icons displayed on the desktop.

5.4 The pilot study

The purpose of the pilot study is to assess both the usability of the CAL programs and the suitability of the chosen methodology for answering the research questions, particularly what happens when students interact with CAL, each other and their tutor to learn about orthodontics, and what can be inferred about students' underlying conceptions that might explain why this interactivity was observed.

5.4.1 Case JB

Two students from the M-year (Yvonne and Zac) have been observed, recorded and interviewed whilst working through the case study in May/June 1999, at the end of the academic year. The pilot shows that the nature of the interactivity between student and program alters as they move from case assessment via treatment planning to appliance design. Based on Anderson *et. al.'s* (2001) taxonomy, to work through the case study, a student has to:

1. Understand how to use the technology
2. Categorise the case
3. Identify which aspects of the case are problematic enough to require treatment
4. Recall possible treatment plans
5. Match treatment plans to best practice
6. Remember what actions different parts of a potential appliance might have on the outcome of the case, and chose appropriate devices to design such appliances.

The computer-recorded log-files are used in post-session interviews to help students recall their actions as they worked through the program. Analysing the transcripts of the interviews reveals two main focal points for gaining a deeper understanding of interactivity for the main study. Both students mention that they are not as familiar with using FDI notation to identify missing teeth in question 6 as they are with the more conventional form of tooth identification, suggesting that it would be worth while investigating how students at the start of the M-year might go about familiarise themselves with orthodontic terminology and symbol systems, particularly with regards to FDI notation. Another issue that crops up during the case assessment section is that both students find it difficult (but not impossible) to judge the canine relationship on the right hand side, due to the presence of the partially erupted upper right canine. At the end of the case assessment, Yvonne wants to know more about upper molar stacking and has been referred back to her tutor for more information on this topic.

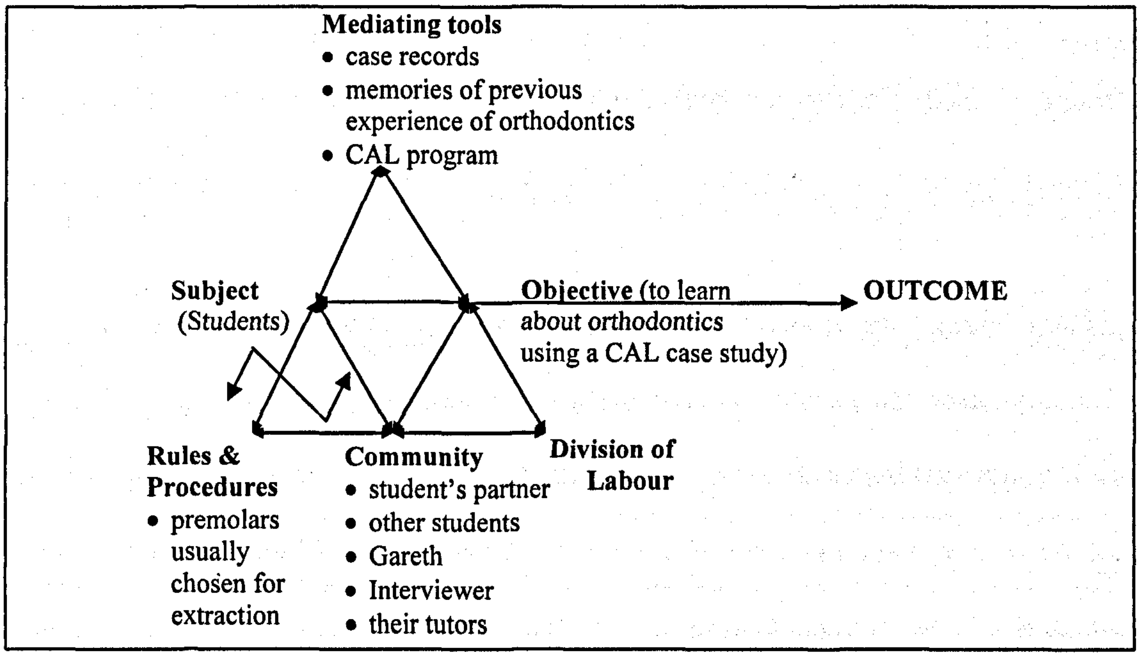
In the treatment planning section the log-files reveal that one student wants to treat the case immediately, the other feels it can be left untreated. Neither student comments on their choice in the post-session interview. However more importantly, both do express surprise at being asked to extract second molars rather than the expected premolars in the treatment planning section, raising the possibility of finding out more about students' reactions to the unexpected when the reality of the case does not fit into their preconceived model of orthodontics.

The latter point offers the greatest potential for further investigation. For example, Yvonne expresses surprise that 7s would be chosen for extraction if they were not badly diseased, and wonders if it is because of the crowding around the posterior teeth. A similar discussion took place with Zac, who initially talks about the need to "balance" extractions if 7s have been extracted in the lower arch (Section 7.3). For this case, Zac mentions that he would have preferred to have extracted the second premolars (the 5s) in both the lower and upper arches, because it feels less risky and seemed a better compromise option. Like Yvonne, Zac mentions that being asked to extract 7s, although making some sense, conflicted with what he understands has been taught about planning a course of orthodontic treatment. Zac goes on to mention both the crowded posterior teeth and the mild labial crowding as possible reasons for extracting 7s, but feels that "it still goes against everything we've been taught".

The students also talk about the other computerised orthodontic case studies they have used during the M-year, and discuss how these cases, too, are generating discussion between students when working on the programs in the CAL room. This observation from the students suggests that allowing them to work in tutor groups would provide an opportunity to find out what aspects of the program lead naturally to reflective discussion between students rather than relying on a post-session talk-back interview to try and reveal these points.

Both students refer to a conflict with what they believed they have been taught; suggesting a potential misconception in understanding of orthodontics. Activity theory offers a framework for understanding this confusion over the choice of extractions, modelling, for example, Zac's apparent confusion about being asked to extract 7s (Figure 5.4).

Figure 5.4: A framework showing a contradiction between students and their understanding of orthodontic rules and procedures



One research aspect is to consider to what extent students' previous experiences of orthodontics and teaching of orthodontics might influence their approach to learning about orthodontics. Having received feedback from the CAL program, Zac is able to put forward both the crowded posterior teeth and the mild labial crowding as reasons for extracting the 7s, but still seems uncomfortable at having to go against what he believes he has been taught about extracting premolars.

Therefore two questions for the main study are:

1. How do students go about putting theory into practice for the first time?

2. What do students do when they find out that they are being asked to do the unexpected (*i.e.* extraction 7s rather than 4s)?

5.4.2 The e-book

Two J-year students use the introductory e-book in the pilot study. Observations and video recordings of students as they use this program show that, although free to move through the program in any sequence, they both choose to move through the text in a linear fashion as they would read a textbook before attempting the MCQ questions. This linear approach, rather than using the program as a revision aid, persists despite the students being observed at the end of an academic year in which they have already received a basic introduction to orthodontics. Although it is possible that the menu structure is encouraging users '... to start at the beginning and keep going' (Phillips and Di Giorgio, 1997, p.67), a more likely scenario is that the material, having been taken from a textbook, continues to possess a book-like structure that influences students' behaviour when using the material as CAL.

Because both students sit quietly reading through the text on the screen, it is almost impossible to make any inferences about how they are interacting with the computer. In the post-session interview the main point by both students is that they said they enjoyed using the program and would like to have access to more information in this format, something which tied in with the findings of previous studies on students' attitudes towards the use of CAL in dentistry (Chapter 1).

5.4.3 Lessons Learned in the pilot study

The pilot study indicates that the two programs facilitated the learning process in different ways. The hypermedia program, aimed at novices, tries to provide opportunities for students to control what they learn by choosing their own routes through the material. In the event students chose to follow the narrative approach, as in a book. In contrast, the linear structure of the computerised case study clearly provides students with a narrative experience of the details of a real-life case.

The main lesson from the pilot study is the difficulty in getting meaningful data to analyse. Observing individual students runs the risk of watching them passively read information from the screen. Although introspective interviews or think-aloud protocols could have been used during the main study as an alternative means of getting information about interactivity, both protocols face the problem that at the point where "the penny drops" other studies have found that students tend to go quiet, as if the mental activity required by students to actually work out a solution does not provide any '... spare capacity for a meta-level account' (Laurillard, 2002, p.42).

With the hypertext program the MCQ questions at the end of the program are aimed at helping novices to recall factual information rather than developing an awareness of how to apply skills to solve a particular problem within that domain. The hypermedia approach has been chosen because it gives students the freedom to follow their own paths through the program they wanted. The plan was to see what paths through the hypertext package would be adopted by individual students and why. However as both students work through the program in a linear fashion, there is a real possibility that J-year students at the start of the academic year would be even more likely to opt for a linear route through the program, making the additional flexibility redundant as far as this study is concerned. Furthermore, despite the use of talkback interviews, the combination of hypermedia (with factual questions separated from the main body of material) and the linear approach adopted by the students makes it difficult to record and transcribe data in a way that can be used to analyse and draw conclusions about any differences in interactivity taking place whilst different students use computers to learn about orthodontics.

In contrast, the linear structure of the orthodontic case study makes it simpler to record and compare data from different students. The problem of passivity is alleviated by observing students as they work through the program in tutor groups. Although more difficult to transcribe interactivity when more than one person is recorded, there is the benefit of being able to observe and record students working together as they negotiate over answers to the CAL questions. Additionally discourse analysis, incorporating a 'conversational framework', becomes a viable proposition for drawing together key points from the data analysis to model the interactivity that occurred. Recording observations using all the students in one year, rather than a smaller sample of the students, means the main study would be less likely to miss something significant. Finally, the M-year, as a cohort of students who are no longer novices but who have not yet mastered orthodontics, also provide opportunity for research in the area of advanced, post-introductory learning. As a result the main study concentrates on an in-depth study of the M-year as they work through their first complete computerised case study in their tutor groups.

With the case study, two points have been identified that can provide focus for the main study. The main study concentrates resources on studying interactivity when students used the computerised case study, rather than the e-book, as this was felt both to offer the best opportunities for analysing interactivity and for collating a variety of different types of data, including observation, audio and video recordings, post-session interviews and questionnaire data. In the main study these data have been combined to provide a rich, quantitative and qualitative description of the role of interactivity (Laurillard, 2002) when students use computers to learn about orthodontics at the advanced (post-introductory) stage of learning..

5.5 Chapter summary

This chapter reviewed both the pilot study and the preparatory work undertaken to develop the CAL programs used in the pilot. Because of their usefulness in explaining the interactivity that occurred in both the pilot and the main study, the chapter started by defining two different methods for tooth identification before describing the background and development of the CAL programs used in the study. The main findings of the pilot study indicated that the orthodontic case study JB should be used in the main study both to investigate the interactivity that occurred when students encountered the unexpected and to find out more about how students familiarised themselves with specialist orthodontic terminology.

Chapter 6: The Case Assessment

Chapter 6: The Case Assessment

6.1 Introduction

The purpose of this chapter is to analyse the interactivity that occurs when students work through a series of computerised questions classifying and assessing orthodontic case records presented on the screen. Quantitative data are used, where appropriate, to anchor and underpin the qualitative data collected from the students. The chapter starts by reviewing the quantitative data derived from log-files and the outcome of end-of-year examinations. Using activity theory as a framework, the chapter examines the interactivity observed whilst the students work through the case assessment section of the program, drawing inferences where possible about students' underlying conceptions of orthodontics that might underpin their activity in response to the questions presented by the program.

6.2 Getting started with the main study

6.2.1 Statistical analysis of the quantitative data

An analysis of the questionnaire data reveals no significant difference in computer skills or attitudes to IT when compared with any of the four previous cohorts of students at the dental school. Within the cohort itself there is a significant difference ($p<0.001$, Appendix D, Table D2) between males and females, with females expressing less confidence over all uses of the computer than males, which is consistent with earlier studies of Bristol dental students (Grigg and Stephens, 1999; Grigg, Stephens and Davis, 1998) and research in other areas (Brosnan, 1998). On individual IT activities, e.g., word processing, there is no significant difference between males and females ($p>0.05$, Appendix D, Table D2), except in using databases, ($p<0.05$, Appendix D, Table D2), where males again self-assess themselves as more confident than females.

A chi-squared test on the results of the end-of-year orthodontic examinations reveals no significant difference between male and female students in their overall results

(Appendix D, Table D4a). Similarly a correlation test comparing the combined results of end of M- and S-year examinations with confidence levels in using IT collected in the questionnaire survey shows no correlation between level of confidence and overall orthodontic exam outcome ($r = -0.00065$, Appendix D, Table D4b). This correlation suggests that even if there is a difference in computer confidence levels between males and females, students either find alternative means to cover what needed to be learnt for the examinations, or lack of confidence in their IT skills does not prevent them from using the computer to learn. As the focus of this study is on interactivity rather than attitudes, investigating the relationship between confidence levels and using computers has been left for future research.

Another difference between students comes from an analysis of the S-year orthodontic exam results. These results are compared to see what differences there might be depending on whether students choose to work on their own or in pairs. Again the small number of students involved in the study means that the following results should be treated with caution, however the results can be used heuristically to point towards the social nature of learning that other researchers have highlighted. The results (Appendix D) show that when students are ranked on the basis of their performance in the final orthodontic exams at the end of the S year, only 1 individual student comes in the top 10 students in the year (the next two individual students are tied at 14th. A Mann-Whitney-U test on the top half of the year (Table D3), finds that students in the main study who choose to work in pairs are more likely (at exactly the 5% level) to end up in the top half of the year than students who choose to work on their own.

The problem with interpreting this result is that although students are free to work either individually or in pairs during the CAL exercise, there is no way of knowing whether students continued to work in this way when they returned to their tutor groups. Neither is there any way of knowing whether students did better because they worked in pairs or whether other factors might explain the result. It does indicate that social interaction may play a significant part in learning and therefore highlights the importance of trying to include this type of conversational mode of learning into any computerized system that is going to be delivered to students who are likely to be using it on their own.

6.2.2 The impact of previous experience

The second research question asks what can be inferred about students' underlying conceptions of orthodontics that can explain why particular patterns of interactivity were observed. The use of activity theory makes possible an exploration of how students' previous experiences of orthodontics (e.g., as patients) might influence both their attitude towards orthodontics and how they answer the questions. For example James' experience of orthodontic treatment seems to have a devastating impact on his attitude towards orthodontics. In the post-session interview, James describes what happened:

> **James:** … I didn't used to like going to the dentist and having all my 4s taken out was not … a pleasant experience … But I think … I was a terrible ortho patient, personally … I'd eat fizzy chewits and pull the molar bands off, and … where the wires had protruded out the back … I hated it – so …I got wire cutters and cut them off myself. … Every three weeks I was in having bits bonded back on.

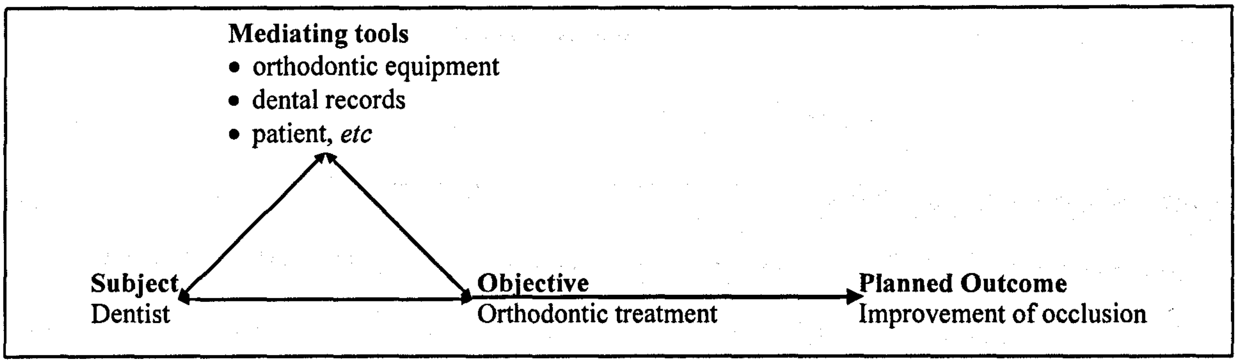
Undoubtedly flavoured by this experience, James highlights his understanding of orthodontics in a broader context, showing how decisions relating to orthodontic treatment might be influenced by external socio-cultural factors outside the domain of dentistry:

> **James:** Yes, I think ortho's good, but … when you look at the justification for it, there are very, very few clinical justifications on health grounds for doing ortho. And that seems funny when … 99% of the ortho is NHS in the UK … In America, … if you're going to pay $5,000 for your ortho then … you can have it for purely aesthetic reasons, but … it seems odd in the UK. … I think orthodontists must be very good at persuading the government's advisory bodies that orthodontics is necessary and should be funded.

Although it is interesting to speculate to what extent James' previous experience of orthodontics had coloured his judgement on NHS orthodontics, a discussion of socio-cultural factors such as economics and dental health priorities as such lay outside the remit of this study. This negative experience is highlighted here because of its motivational impact – from what he said it seems unlikely that James would be interested in orthodontics after graduating. So although he is the only student to express such a negative opinion of orthodontics, James' comments have been included because they illustrate the importance of previous experience on how students learn.

Using activity theory allows this negative experience to be considered the focus of activity in an activity system involving the dentist/orthodontist as the subject of the activity network, the outcome being an improvement in the patient's occlusion, with the student as a patient acting as a mediating tool in the process (Figure 6.2.2a).

Figure 6.2.2a: An activity system for previous orthodontic treatment

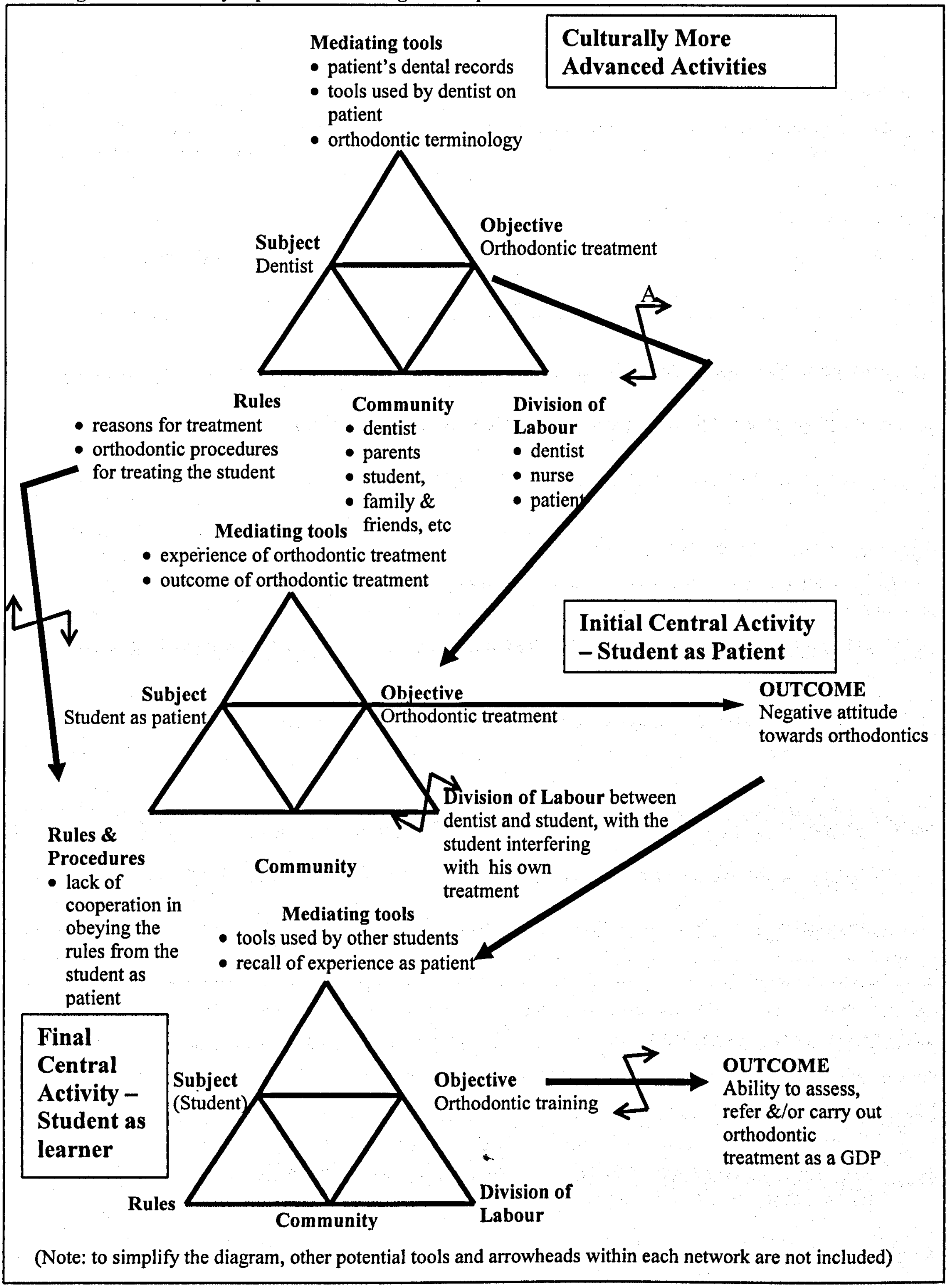


The difficulty with this analysis is that although it is fairly obvious that the patient would be learning about orthodontics through experiencing treatment, the orthodontist would be the one in charge of the activity – although James is, perhaps, more active than others in participating in his treatment! An alternative approach might account for the emotional impact of past experience (Figure 6.2.2b). By using the definition of a tertiary level contradiction as that '*between* the object/motive of the dominant form of the central activity and the object/motive of a culturally more advanced form of the central activity' (Engeström, 1987, p.33), James' attitude could arise from a conflict between what he wanted and what the dentist and, by inference, James' parents, expected from treatment.

> **James**: I had my first assessment aged 12, 13, and basically they had a look and ... said "We think you should have braces" and I was like, "Why?" ... And I just sat there... They said "Oh... it'll make cleaning your teeth easier" which I'm sure it will... But I wasn't ... unhappy with my appearance or my occlusion. I didn't think I had buck teeth and ... I'd never really been teased about it ... and ... I thought "Surely I'm going to get teased more for having the braces" .... Because I don't think there was anything wrong with [my teeth].

The lightning arrows show how the contradiction fell between the division of labour and the central activity – the objective of the central activity is seen differently by James and his dentist, hence each individual's actions result in a "tug of war" over the expected outcome of the case.

Figure 6.2.2b: Early experiences as a negative impact on how students learn about orthodontics



In contrast, other students seem to draw more positively on their experiences of orthodontic treatment to help them gain a better understanding of how to go about assessing and treating an orthodontic patient. For example, Belinda uses her memory of her own orthodontic treatment to help Anne work out the angulation of the lower right canine:

Anne: … when … it's distal, do they mean it's like that? **Belinda**: They mean it's a bit like that, you see = ***[also uses hand to illustrate point, but holds hand in such a position that cameras can't pick up exact movement]*** = when my own teeth were straightened, they moved from there to there, so distal's there, and mesial's there…

6.2.3 To prereview or not?

Returning to the first research question, which is to describe how students interact with a CAL program, each other and their tutor, the main study observes and records the students at a stage in their training where, having attended a series of introductory lectures on orthodontics, they are expected to put theory into practice using records from a real patient for the first time:

To gain a better understanding of the clinical presentation of the case students need to go through the examination in its entirety, as these summaries do not include negative findings that could help to place the case into context. Following an outline of the patient's history the first activity the program asks students to consider is how to assess the patient's records displayed on the screen by choosing relevant images to answer a series of classification questions leading to a case diagnosis.

Using Anderson's *et. al.* (2001) taxonomy of educational objectives (Chapter 2), this classification activity can be described as one that asked students to remember and understand how to draw on factual and conceptual knowledge to assess the various features of the case (Appendix A, Tables A1 and A2). The classification section asks students to assess the case by carrying out an extra-oral, intra-oral and radiographic examination of JB's dental records. The following examples illustrate those points in the program which are particularly effective in getting students to talk, thereby encouraging a more active and discursive approach to learning.

At the start of the session the noise level is relatively high both because students enter the CAL room at slightly different times and because of the general bustle of settling down and asking questions about what is happening. This background noise makes it difficult to transcribe the recordings, however computer generated log-files reveal that most students spend less than one minute on the history before moving to the first question. Three pairs (David and Edward, Olga and Peter and Sophie and Tina) are recorded spending time reviewing the case. Although difficult to hear on the transcript, the occasional words picked up during the twenty minutes before they answer the first question suggests Jennifer and Kate also spend time previewing the case.

6.2.4 Seeking help

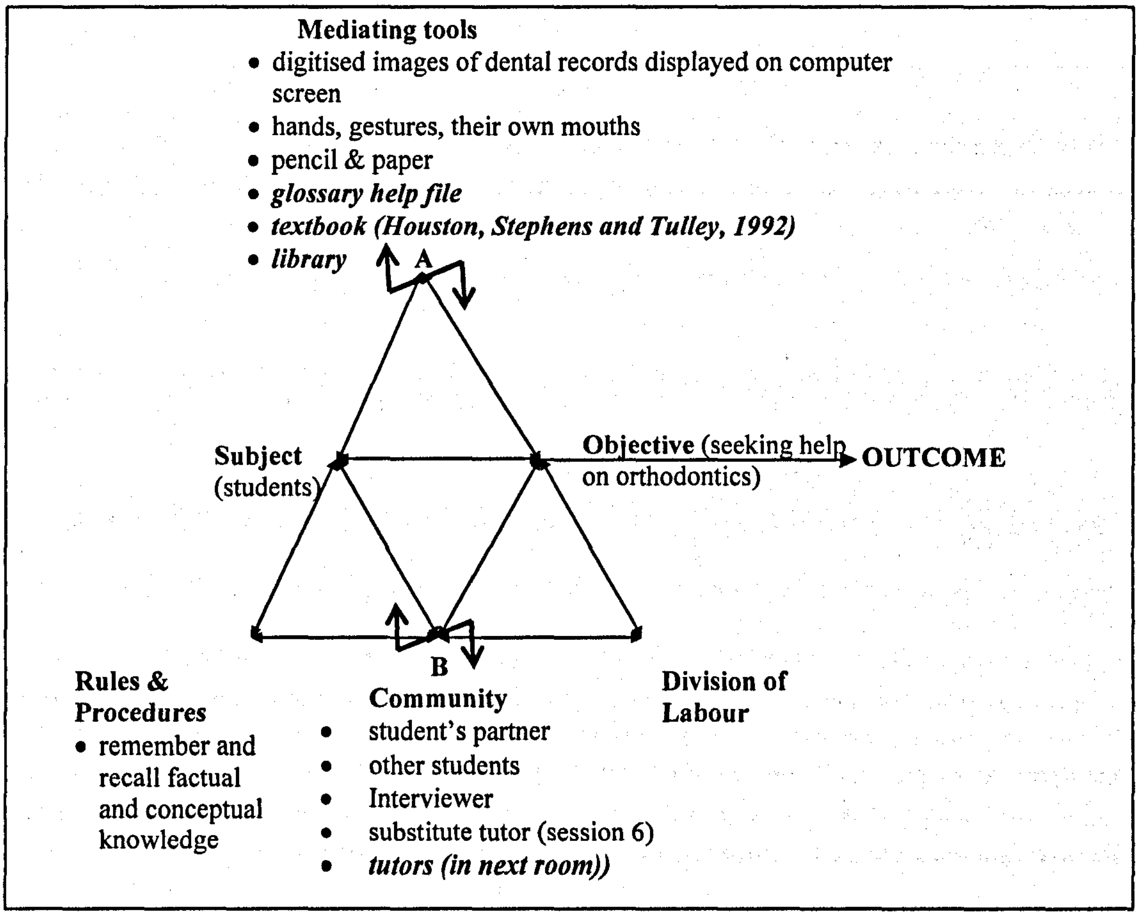
An activity system illustrating potential sources of help is shown in Figure 6.6. One of these sources is a computerised glossary help file containing orthodontic theory that students could open from within the program. This file uses a similar format to the introductory e-book developed for the pilot study (Chapter 5). All students are told how to access the file and use the search facility, as part of the briefing at the start of each session. The log-files show that just 11 sets opened the glossary files:

- Four individuals (Debbie, Xenie, Xavier and Victoria) look at the file before starting the session (but do not return to it during the session).
- Twelve students open the glossary file at least once during the case assessment section – Adam and Bill Quentin; Pamela (to check for skeletal relationships, question 2); Anne, Belinda and Christine; Henry and Laura; Leonard and Mary; Winifred (to check for tooth notification, question 6).

None of the remaining 32 students (14 students working in pairs, 4 working as individuals) make any attempt whatsoever to use the glossary file. Although the introductory e-book is also made available for the M-year students in the main study to access if they want to look up further information on the computer, the log-files show that none of the students tried to access this file. A χ^2 test comparing the number of individuals who opened the glossary file with the corresponding number of pairs showed a significant difference at the less than 2% level, with individuals significantly more likely to open the file than pairs (Appendix D, Table D6 (p=0.0123, df=1).

The two arrows (A – within the mediating tools; B – within the community) show constituencies where students make little or no use of a particular element available to the students within that constituency. The words emboldened in ***italics*** highlight the elements within each constituency that are not used by the students – within mediating tools the glossary help file, the orthodontic textbook or the library, within community, the tutors who sat waiting in the next room.

Figure 6.2.4: Activity system for seeking help about the computerised case study



For example, in the post-session interview, Kate and Jennifer describe how they used a piece of paper to work out how to use the FDI notation to answer question 6, and, when asked whether or not the section on tooth identification in the glossary file might have helped, comment:

> **Jennifer**: Oh, well, we didn't think =
> **Kate:** = we didn't think to use that, no *[both laugh]* I suppose we could have, but no, we were able to sit down and work it out from memory.

Although the log-files record that 11 sets open the glossary file during the case assessment section of the program, despite their consternation in the treatment planning section (see Chapter 7), students make no attempt to use either the glossary file or the introductory e-book to find out more about the extractions. Indeed so few students attempt to look at the glossary file that it is impossible to say whether this lack of interest is due to a problem with the glossary file itself or with students' reluctance to "step outside the program".

Later Brian comments on a similar behaviour "pattern of forgetfulness of other sources of information" that he had noticed when using video conferencing with students

Brian: ... I've noticed this before, when we did our video conferencing trial ... that if you sit there and observe and keep quiet, they ... forget that you are there. You can always interject and answer questions they cannot answer themselves. And they got better at it ... [and] began to realize you are there and ... started using you as a "reference/glossary"...

Another avenue that the students could use, but did not, is to visit either the next-door library or their tutor waiting in the adjoining room. Even when reminded by the Interviewer none of the students leave the CAL room to speak to a tutor about the case, for example when Adam and Bill, having tried to include the partially erupted canine in the upper right buccal segment, ask the Interviewer for help with question 15. Once the Interviewer moves on, Adam and Bill choose to continue with the questions, rather than seeking further help. Students are, though, prepared to turn to other students for help. A more in-depth analysis and discussion of these "outside the pair" interactions, when they occur and what can be inferred about why students interact in this way can be found in the relevant sections below.

In session 6 a substitute tutor, Gareth, agrees to be present in the CAL room itself rather than sitting next door, to see what difference his presence makes on how students respond to the program. The impact of his presence will also be discussed further in the relevant sections below, and a detailed transcript of his conversations, particularly with those students who choose to work as individuals, can be found on the resources CD.

6.3 The extra-oral examination

This section consists of five MCQ format questions which students use to classify the patient's extra-oral features using both the Face and Cephalometric image (Ceph). Students usually refer to the Cephalometric image in one of three ways: the 'Ceph', the 'lateral skull' or the 'lateral skull tracing'. Occasionally a student refers to the image as the Cephalometric, or Cephalomets, rather than one of the other terms above. When discussing students' use of this image in the text that follows, the term 'Ceph' has been used for the sake of consistency as it is the term most often used by the students when referring to the Cephalometric diagram.

Throughout this section of the program transcribing the students' responses has been still quite difficult, mainly due to the high level of background noise particularly from students late entering the CAL room. Although the session has already started, the noise from these late arrivals comes as they settle down, asking questions about what to do and generally catching up on the latest gossip and what other students had been doing since their last meeting.

Although the label 'extra-oral examination' is included at the top of each screen as a reminder of what they are trying to achieve, Brian explains that, without a real patient or a photograph of the patient in profile in front of them students will have to use the Ceph and Facial images to work out both the percentage of the lower face to upper face height and the maxillary-mandibular plane angle. However:

Brian: ... in JB none of these values are significantly away from average anyway...

Having opted to start answering questions without spending much time reviewing the case some students, for example Adam and Bill, need to familiarise themselves with operating the program whilst simultaneously trying to make decisions about how to assess the extra-oral features. Most students appear comfortable with the way the orthodontic terminology is used in the extra-oral examination, although occasionally students seem to choose the correct response by accident with no indication, post-feedback, that they understand why that particular answer is correct. For example Sophie and Tina, having decided that the lips are mildly incompetent, habitually apart, apparently click on the wrong box:

> **Sophie**: ... ***[chooses 'Mildly incompetent Habitually together']*** THEY'RE NOT, THOUGH, LOOK!!! ***[laughs]***
> **Tina**: Ok. Mildly incompetent. Habitually together. Ok. Well, we got it right, accidentally!

Although some students seem to have difficulty remembering the actual numbers, others have little problem assessing the vertical skeletal relationship. For example, Anne, Belinda, Christine, and Charles and Debbie all turn to the Ceph, with Charles and Debbie turning first to each other and then to Christine before answering the question.

As well as dental records, other tools used by students to answer the extra-oral examination questions include attempting to remember what they'd been taught, asking other students what they could remember, or just guessing at the answer and learning from the feedback when unable to find the answer any other way. Like Anne, Belinda and Christine, the video recordings of Elizabeth and Felicity, Jennifer and Kate show examples of students using their hands and the Ceph to answer question 2.

Anne, Belinda and Christine do not use the Ceph to assess lip competency (question 4), probably because it is easier to associate the Ceph (with its relationship to measurements taken from a lateral skull radiograph) with the underlying skeletal relationship but not with soft tissues such as the lips. They seem unable to make the connection even after reading the feedback:

> **Christine**: ... The answer's incorrect. They're not together! ***[suggests she believes the lips are together, and not apart]***
> **Belinda**: Well, you can't tell if they're together if it's just a picture!
> **Christine**: That's silly ***[gestures towards image on screen]*** 'cause when you take a photograph, you don't put your lips together anyway ***[touches own lips]***
> **Belinda**: ... Exactly

In contrast, Adam, Bill, Jennifer and Kate, having commented on the difficulties of assessing lip competency from a photograph, realise how to use the Ceph after reading the feedback from the program displayed on the screen:

> **Bill**: ... ***[reads]*** This has to be inferred, since although the lips are apart in the Facial view, they are together in the lateral skull – oh, that's what you use the Ceph for!

Adam: ... Ohhh! I see.
Kate: ***[reads]*** ... they are together on the lateral skull tracing. **Jennifer**: Ah-HAhh! ***[although Kate had criticised the photograph, Jennifer's "Ah-HAhh!" suggests she realises from feedback they should use the Ceph]***

Others look at the Ceph before answering the question, e.g. when Henry suggests to Laura that they need to look at the Ceph. Despite Laura's uncertainty, they manage to find the correct answer:

Laura: Yep. We probably got that wrong. **Henry**: What do we call the lateral skull – Ceph? ***[...] [chooses 'Ceph', then chooses 'Mildly incompetent, habitually together']*** No, we got it right!

Brian explains that the students need to assess whether the case deviated sufficiently from the ideal to be considered an extreme in either direction, rather than whether or not there are any minor deviations, because:

Brian: ... You are concerned about the fact that the teeth .. seem to have a limited eruptive potential to grow across a space [between the jaws]. Thus... you're only concerned with extremes in either direction, very large face heights and very small face heights. So ... they are arguing about a case where really it's within normal limits...

Activity theory has been used to find out more about why this pattern of interactivity is observed. The activity system for the extra-oral part of the case assessment offers a visual representation of the tools used to classify the case and the potential contradictions in the system that might be causing students problems with their assessment (Figure 6.3).

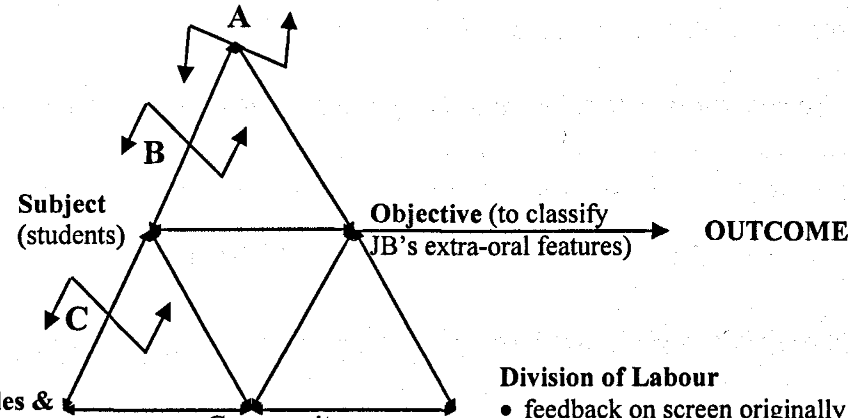
Most of the problems in judging extra-oral features of the case can be described as arising from a primary contradiction (A) within the "tools" constituency of the system – choosing the right tool for the activity and secondary contradictions (B and C) in understanding the procedures and how to use those tools/terminology. The contradictions appear to be due more to students' lack of familiarity with the procedures for using the terminology (C) than to their lack of understanding of the terminology itself (B). In particular a primary contradiction (A) within a constituent component of the central activity can be identified for the question on lip competency (question 4). This contradiction arises because several students do not realise that the lateral skull tracing (Ceph) has to be used when either the patient or a profile photograph is not available.

Supporting evidence that increasing familiarity comes with experience can be inferred from the pilot study (Chapter 5), where students did not have difficulties answering these questions. In nearly every case, feedback from the program proved sufficient to help students understand what is required, acting to restore equilibrium within the system.

Figure 6.3: Activity system for extra-oral assessment

Mediating tools

- orthodontic terminology
- links to digitised ('Face' and 'Ceph')
- MCQ format options provided by CAL program
- hands and fingers
- pen and paper
- memories of experiences as students and patients
- glossary help file
- feedback from CAL program



Division of Labour

- feedback on screen originally provided by orthodontic specialist who developed the questions for the CAL template

Rules & Procedures

- students' understanding of previously taught procedures
- remember and recall factual and conceptual knowledge

Community

- student's partner
- other students
- tutors
- Interviewer
- patients
- friends
- family etc

6.4 The intra-oral examination

The intra-oral section is divided into 4 sub-sections:

1. Identification of any absent teeth
2. Classification of the angulation, rotation and crowding of the teeth in the lower jaw
3. Same questions as (2), relating to the upper jaw
4. Classification of how teeth fit together, under the heading of teeth in occlusion

Students are provided with four digitised images of intra-oral views of a model of the teeth, accessed by clicking on one of the buttons at the bottom of the screen. These views are digitized images of photographs taken from the right ('Right'), left ('Left') and front of the model ('Labial') and with the model open – the occlusal view ('Occl').

6.4.1 Absent teeth

Question 6 asks students to use FDI notation, a specific symbol system used by orthodontists for tooth identification (Section 5.2). Using this notation students have to identify any teeth absent from the mouth.

When assessing a real patient for missing teeth, students will be able to look into the mouth, rather than an image of a plaster model. With a patient, Brian explains: "it would be patently obvious whether the tooth is through or not". However because the gum and tooth on the plaster model available for this case are the same colour, any partially erupted teeth are less easy to identify. Therefore the use of images of the plaster model does make this assessment marginally more difficult in the CAL program than would be the case if using a real patient.

However it is doubtful that a suitable patient would be available for students to examine at the right time in their training (Chapter 1). Providing images of a model of the patient's teeth is preferable to not having access to any records at all.

Although all students are introduced to FDI notation in their lectures it is not a symbol system with which they are particularly familiar at this stage in their studies. Brian explains that FDI notation was used originally to enter tooth notation onto a computer in the early days of IT. However although FDI notation is used regularly on the continent, it is not commonly in use on clinics in the UK. The danger with using FDI notation is that it can be relatively easy to key in the wrong tooth, e.g., 21 instead of 12, which in a worse case scenario may end up with the wrong tooth being extracted by mistake. One way around this would be:

Brian: … to give the notation in at least two different forms to avoid that possibility.

An overview of students' responses can be found in Table 6.4.1. As well as working out an answer, students have to remember both what the system is and how to use it – i.e. to remember and recall both factual and conceptual orthodontic knowledge relating to the case. One method that students use to recall this notation is to draw a diagram, for example when James and Kate use a pen and paper to draw a cross (a sign) to represent the four quadrants (what is signified by the sign):

Ian: What's the form of the FDI notation? **James**: … I'm just going to scribble something down on paper. ***[draws a cross '+'on a piece of paper]*** … It's the FDI notation. I've never used it and I'm just going to remind myself of it. Let's just do the upper level 1 2 3 4 type of thing. OK. I don't think I can remember it otherwise …
Kate: Oh, I can't do this now, so I can't quite remember how to do FDI notation, we don't use it a lot! ***[reaches to get pen and paper out of her bag, draws a cross '+'and writes the relevant numbers into each quadrant]***

Table 6.4.1: Students' choices for teeth absent from the mouth

Sets	Answer given	Comments
Debbie	18283848	Correct response, but may have overheard other students. Debbie works with Charles and enters her response after reading feedback on his machine
Henry & Laura		
Quentin		
Xavier		
Anne, Belinda & Christine	1817283848	Most frequently chosen response. Correctly enter the FDI notation, but include the upper right second molar (17) as well as all the 8s.
Adam & Bill		
Charles		
Frank & Gita		
Leonard & Mary		
Olga & Peter		
Pamela		
Rachel & Queenie		
Ralph		
Sophie & Tina		
Steve & Terry		
Ulysses & Victor		
Una & Wayne		
Victoria		
Winifred		
Xenie		
Helen & Isabel	1718283848	These two sets choose to include 17, but enter the FDI notation in the wrong order, either at the start or as an afterthought.
George		
Elizabeth & Felicity	1828384817	
Nigel & Oscar	Given response: 272625242322211111213141516~ 4746454443424131323334353637 Possible translation by quadrant: 27262524232221 | 111213141516 47464544434241 | 31323334353637	This response suggests that teeth present, rather than missing teeth, have been entered. Note FDI notation in the wrong order, starting with the 2s rather than the 1s. Response indicates 17 and all the 8s identified as missing teeth.
Kate & Jennifer	181713283848	FDI entered correctly, but include partially erupted 13 as well as 17
Kevin		
Ian & James	1317	Use FDI notation correctly. Include 13 as well as 17, but discount 8s, which are not expected in a patient of this age
David & Edward	Given response: 585753676878778788 Possible translation by quadrant **right** 585753 | 6768 **left** 7877 | 8788	Do not use recognised FDI format, possibly because they believe numbers 1 to 4 belong to the quadrants when they contain milk rather than the permanent teeth. Their answer suggests they include the upper right canine (as 53), all the 7s and all the 8s as absent from the mouth.
Michael & Natalie	7377	Do not use FDI notation correctly. Transcript indicates they opt to include the upper right canine and upper right second molar as absent from the mouth. Do not include the 8s in their answer.

Unusually for the students, Ulysses picks up a hard copy of the glossary file and uses it to recall the format of FDI notation. This paper-based version of the file is made available to students in sessions 5 and 6 to see if having a physical copy makes any difference to whether or not students make use of the file. Despite the availability of the hard copy, Ulysses's preference still seems to be to discuss and reflect with Victor on possible answers to each question, rather than look at either version of the glossary file. The video recordings focus on Ulysses and Victor, and do now show any other students in session 6 making use of the hard copy of the file.

The most commonly observed method of recalling how to use FDI notation is to rely on a partner to remember which side of the mouth is which. For example, having already chosen and typed in all the 8s, Adam and Bill need to decide whether the upper right second molar is on the right (17) or the left (27) side of the mouth:

Bill: So do you think it's left or right? So what is it? 17?
Adam: Yeah, 17.
Bill: *[types '17']* No.
Adam: ... it's not fully erupted, so I don't think you can count it as being erupted.

Having worked out how to use the FDI notation, nearly every student correctly observes that all the 8s are missing. Three sets (Ian and James, Nigel and Oscar, Michael and Natalie) fail to enter this information into the computer, probably because they do not expect to find the 8s (the third molars) in a 10-year-old patient, as James observes after reading the feedback:

James: ... so all the 8s. No. So I suppose for their age they wouldn't be expecting them.
Ian: No...

Just 4 sets (3 individuals, Debbie, Quentin and Xavier, plus Henry and Laura) correctly identify the 8s only as absent from the mouth. The analysis of the transcripts reveals that even students who work as individuals turn to each other for help on this question both to remember the form of FDI notation and to decide which teeth might be absent. It could be they are relying on a collective framework to provide memoy cues to influence both exactly what to remember and the way in which that previous experience is recalled, as suggested elsewhere by Wertsch (2001).

Like Ian and James, Debbie refers to JB's chronological age to help her decide that canines would not normally be expected before the age of 11, apparently forgetting that, on the previous screen, JB is described as being dentally advanced for her age:

Debbie: ... What about that? Is that going to come through? Is that erupted? ***[points to 17]***
Charles: I don't think that that 3 is going to ... ***[points to 13]***
Debbie: I don't think so, no. Because to be fair as well you don't get that there until 11...

The remaining 25 sets all consider 17 (the upper right second molar) to be absent.

Unlike the questions in the extra-oral section, where students tend to restrict themselves to the 'Face' rather than access other records available on the screen, several students in this section immediately examine the 'OPT' before checking the 'Occl':

Christine: Has that erupted? I'm not convinced it's come through. Because to be fair and square. But isn't this the intra-oral exam? ***[points to the top of the screen]*** You need the occlusal.

Having switched to the 'Occl', Anne, Belinda and Christine spend some time looking at the second molars (7s), trying to decide exactly what might be meant by the phrase 'have not erupted sufficiently to be present in the mouth' before including 17 as well as the 8s in their answer. Laura, too, realises that they should look at the intra-oral models after prompting by the Interviewer:

Interviewer: You're looking at the x-ray, rather than the intra-oral view. Why? ...
Laura: Oh, yeah.
Henry: What, the models need to be up?
Laura: No, It's the intra-oral exams, you do not need x-ray to pass the teeth...

By switching to the 'Occl' they are able to work out that only the 8s are absent:

Henry: OHhh! 7s are up. ... so we're only missing the 8s. All right. So the 7s are up.
Laura: The 7s are up ...
Henry: Well, the 7s... are up ... I don't think they're up yet. ***['they're' is an indexical expression indicating that Henry is pointing at the 8s]***
Laura: No.... All 8s, not the 7s. ***[enters '18283848']***

Despite entering the right answer, the transcript shows Laura realises from the feedback provided by the computer referring to the upper right second molar as '17' that they have confused the left and right hand sides of the occlusal image:

Laura: |Oh|, look, it's the right 7. The one reduced on the right hand side. ***[directs Henry's attention to 17, uses feedback to discover the correct way to use FDI notation]***

Henry: Uh?
Laura: Is 1 starting on the left or the right?
Henry: Left.
Laura: No, but it says the 17 is not erupted there, and the 17 is on the right…

Olga and Peter do not look at the 'Occl' but use the 'OPT' to answer the question. Like Ian and James, they refer to JB's age, mentioning that she has an adult dentition – perhaps picked up when they prereview the case (Section 6.2.3):

Olga: … Here are her adults… all the 8s and 17. ***[lists teeth she believes are absent]*** Yeah.
Peter: Yeah. And the 8s... Shall we check the Ceph?
Olga: Yeah. ***[Peter chooses 'Ceph', then 'OPT']*** … What about that 3? That's there. Ok. Oh, what about the right 3? [raises a query about the upper right canine]
Peter: Oh yeah. That has |erupted|.
Olga: |That one| that has erupted there. Yeah. ***[both agree that 13 has erupted]*** Ok. Shall we look at our answer? Yeah, right... ***[Peter enters '1718283848']***

Brian explains that an orthodontist will only need to take an 'OPT' radiograph if a tooth or teeth cannot be seen in the mouth when it will be necessary to decide whether or not an absent tooth might cause problems orthodontically in the future:

Brian: … If you see any part of a tooth present in the mouth you don't have to take a radiograph for that tooth because you assume they aren't clinically absent. … The key is the dentist must always worry about the need for extractions, and so they need to know if a tooth is present…

Victor and Ulysses, having also included 17 as an absent tooth, reflect on the feedback from the program to help them understand that a partially erupted tooth would probably be counted as present by an orthodontist:

Ulysses: … Why is 17 wrong?
Victor: OHhh, it's only just there! ***[points to 17]*** Sufficiently! ***[points to question]*** Not insufficiently! ***[runs finger under question on screen, both laugh]***
Ulysses: OHHhh!

Five sets (Kevin, Kate and Jennifer, Ian and James, David and Edward and Michael and Natalie) go further, including 13 (the upper right canine), which has partially erupted, as well as 17 and the 8s as being absent from the mouth. Again the feedback seems to help, for example when Jennifer and Kate realise that partially erupted teeth will not be considered to be absent in orthodontics:

Jennifer: OK, so what's wrong with 17?
Kate: And thirteen?
Jennifer: I don't understand how we can look at – because they haven't erupted –
Kate: Well, they have erupted partially – they are just there ***[points to upper right segment]*** Type in those teeth which have not erupted sufficiently to be present in the mouth. Oh, ok. Present in the mouth.

An unusual form of notation is used by David and Edward and, from the computer-generated log-files, by Michael and Natalie. Assuming they start, as directed, in the upper right quadrant and ended in the lower right quadrant, David's and Edward's transcript together with their choice of 58 57 53 67 68 78 77 87 88 suggests they include all the 7s, all the 8s and the upper right canine as absent teeth:

David: … Five. That's the upper right and fives, five seven, and that one's not erupted. Five eight, five seven *[types '5857']*
Edward: Um.
David: Five three... Let's go for the sevens and the eights…
Edward: Ok.
David: And that, that's only… partially erupted anyway. *[types '53']* So let's say those aren't erupted…
Edward: Ok.
David: Seven eight, seven eight, seven seven ... *[types '67687877]* And the lowers? …
David: All sevens and eights. Yeah?...
Edward: Ok. Just the sevens and the eights. The rest are all erupted
David: Hm.... *[types '8786', presses <enter>]*

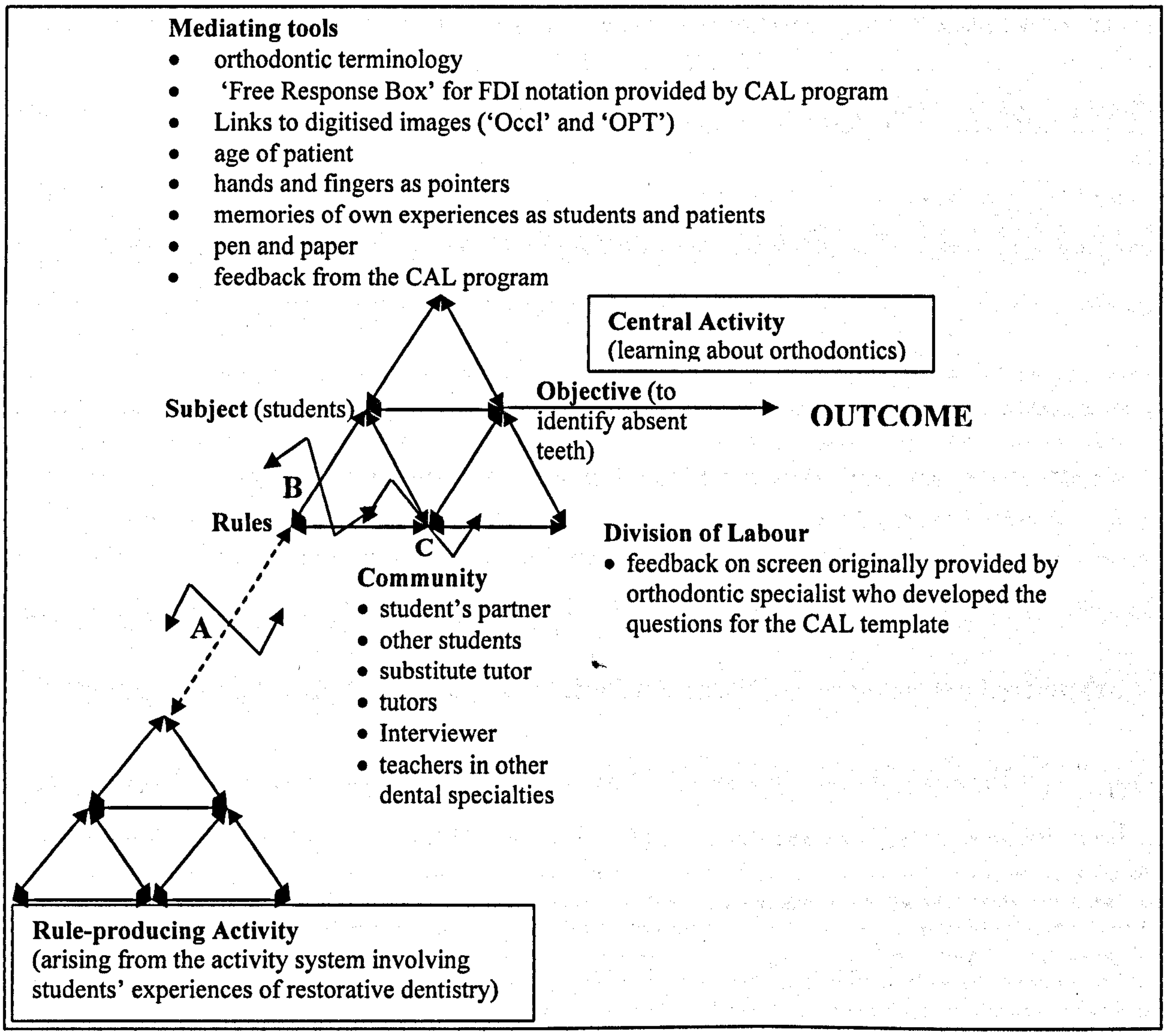
Michael and Natalie seem to adopt a similar approach, identifying 73 and 77 as the missing teeth. From their exchange it appears that Michael made the initial suggestion for FDI notation, which Natalie agrees to enter into the computer:

Michael: Ok. FDI. Have you done that? Is it that? … ***[on paper indicates what he thinks FDI notation looks like. Natalie agrees to use the notation and see if the computer accepts it]***
Natalie Oh, I'll put that down, and see if that does it.
Michael: Is the upper, upper =
Natalie = seven. And this one? ***[points to 13?]***
Michael: Um, 7. *[pause 1s]* Yeah. *[Natalie types '7377', presses <enter>]* Really? Ri-ight.

With regards to why these students choose this form of notation, a possible explanation is that they believe that the numbers 1 to 4, when used in the preceding number in each pair, referred to the primary dentition leaving the numbers 5 to 8 to refer to the permanent dentition. Unlike David and Edward, Michael and Natalie do not bother with the 8s probably because, like Ian and James, 8s are not expected at this age. As neither pair have a problem using the correct dentition later in the case, it suggests that David, Edward, Michael and Natalie receive sufficient information in the feedback from the program, which refers to the upper second molar as '17', to be able to correct their understanding of FDI terminology.

The majority of students' insistence on including the upper right second molar (17) in the mouth, coupled with those who also want to include the partially erupted upper right canine (13) suggests there is an underlying 'misconception' in the students' understanding of what is required to judge whether a tooth is present in the dentition. Activity theory provides a model for understanding what happened (Figure 6.4.1). The cause of this 'misconception' seems to be a contradiction with what they'd been taught elsewhere, *i.e.* there is a quaternary contradiction (A) between a rule-producing activity in a neighbouring activity (conservative dentistry – a tooth should be functionally present) and the central activity (orthodontics – a tooth is present even if just the cusp (the tip) had erupted) leading to a primary/secondary (B) contradiction in the rules-producing constituency of the central activity system for deciding on absent teeth. So the question whether teeth are absent suggests conflict between specialties disciplines regarding the exact definition of dental terminology.

Figure 6.4.1: Source of contradictions and tensions from outside the specific activity system that interfered with students' understanding of what was required to identify absent teeth



This contradiction arises because students have been taught in conservative dentistry that a tooth needs to be functionally present in the mouth to be counted as present, as Kevin (who chooses both 17 and 13) elaborates in the post-session interview:

Kevin: I assumed present mean functionally present =
Interviewer: Right.
Kevin: = and answered it accordingly. And so therefore these teeth I considered partially erupted, 'cos up on Cons ***[Conservative dentistry]*** we have unerupted, absent [and] partially erupted ... I suppose it depends on your definition of present... And my definition of present is functional, and these teeth aren't anywhere near in occlusion yet...

Brian explains that in reality GDPs will check the patient to see whether or not the teeth are present. Being able to examine a patient is easier if only because the white of the tooth contrasts clearly with the pink of the overlying gum rather than being white against white as in the plaster model. Even if only part of a tooth can be seen it is be safe to assume that that tooth is present in the mouth:

Brian: The trouble is they spend so much time in Conservation doing restorative dentistry where it is an adult mouth with all the teeth fully erupted, and ... they get an idea that present means it's fully in the mouth and absent means that it's extracted... It's unfortunate that that gets so embedded into their consciousness...

Another potential conflict might be within the community (C). The actual number of students who gave the correct answer is too small to allow any definite conclusions to be drawn (if only because they may have overheard other students discussing the feedback before answering the question). It is noticeable that 3 of these 4 sets are individuals (Table 6.4.1) making it possible that, on this occasion, the presence of a partner acts as a source of contradiction within the constituency of the community because the analysis reveals that several students in pairs seem to divide the task (division of labour), using their partner to try and remember how to use the terminology.

Most students express surprise at the feedback that 17 is just present in the mouth. The analysis using QSR/N6 implies this contradiction has a strong discursive impact on student understanding of orthodontics. Once students are familiar with this contradiction it is expected that they will be less confused in the future. Evidence for this assumption can be seen in the pilot study where students, observed at the end of the M-year, showed no problem identifying absent teeth, even though they, too, commented on their lack of familiarity with FDI notation (Section 5.4.1).

6.4.2 Angulation, rotation and crowding, lower and upper arches

After identifying teeth absent from the mouth the program presents students with 10 questions relating to the angulation, rotation and crowding of teeth in the lower and upper arches. For each arch this classification is divided into 3 sections covering the incisor, canine and buccal segments. The order of the questions (lower first then upper) is deliberate because good practice when doing an orthodontic assessment dictates that dentists should consider what is required in the lower arch first even if, as in this case, the most pressing problem is in the upper arch. The lower should be examined first because:

> 'in most cases the size and form of the lower arch has to be accepted because teeth are in a position of balance between the labial and lingual musculature… This zone of soft tissue balance appears to be narrow and hence changes in lower arch form produced by orthodontic treatment are very liable to relapse.' (Houston, Stephens and Tulley, 1992, p.145).

This section deals with students' reactions to these questions, apart from the question relating to the partially erupted upper right canine which will be dealt with in the following section. Table 6.4.2a shows the number of sets choosing the correct option at their first attempt. For comparison purposes (because not every set answered all the sub-questions in this section) Figure 6.4.2 gives a graphical overview of the average percentage of sets correctly answering each question.

The QSR/N6 analysis picks up an interesting discursive exchange between Laura and Henry over the answer to the degree of crowding in question 7 illustrating how, despite the recognition that it is difficult for computers themselves to be adaptive to students' perceptions of a situation (Laurillard, 2002), in this study due to the nature of the material within the program, adaptivity is observed. This adaptivity is between student and student rather than between student and computer or student and teacher, with each student adapting their response in the light of what the other student is saying:

Laura: How do you know that? ***[asks how to measure the crowding]***
Henry: With contacts. You've got one there, one there, 2, 3, 4, so another there. ***[declaration, offering an explanation, using specialist terminology]***
Laura: It says millimetres – how do you measure the crowding? ***["How do you do this in practice?"]***

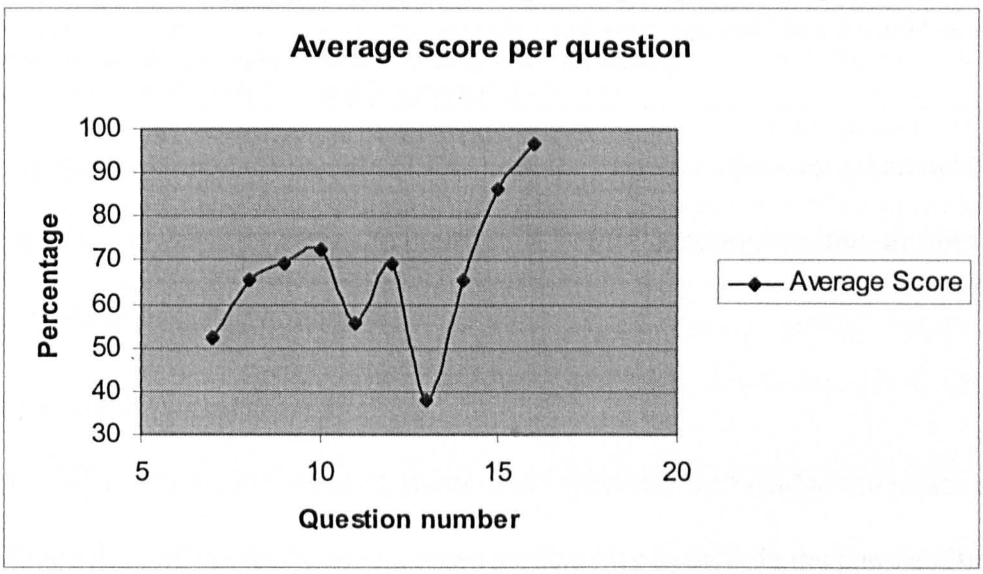
Henry: *[expands]* One millimetre plus the contact.
Laura: How is that? 2 to 3? Hm? ***[suggests the crowding is moderate]***
Henry: 2, mild? ***[argues that it is in fact mild]***
Laura: But if that contact is best, then it's one and two. ***[adapts her response, but still feels there's moderate crowding]*** Yeah.
Henry: But that's a slipped contact, there. ***['that' and 'there' point to the 'slipped contact']***
Laura: Yeah, 1, and then there.
Henry: Yeah, but I call that, and that ... ***[both negotiate over the answer, Laura agrees her suggestion is 'too much' and the crowding is really only mild]***
Laura: No... that's too much. I see...

Table 6.4.2: Number of sets correctly answering each part of these questions

Question	No. responding (out of 29)	Angulation (% correct)	Rotation (% correct)	Crowding (% correct)	Average Score across all 3 parts of each question (% correct)
7	28	6 (21)	14 (50)	24 (86)	(52.4)
8	28	12 (43)	27 (96)	16 (57)	(65.5)
9	28	19 (68)	26 (93)	15 (46)	(69.1)
10	29		22 (76)	20 (69)	(72.4)
11	26		14 (54)	15 (58)	(55.8)
12	27	22 (81)	16 (41)	23 (85)	(69.1)
13	27	10 (37)	7 (26)	14 (52)	(38.3)
14	27	17 (63)	26 (96)	10 (37)	(65.4)
15	29		26 (90)	24 (83)	(86.2)
16	29		28 (97)	28 (97)	(96.6)
Correlation r = 0.48		**Average – stdev = 50.6**		**Average = 66.1**	

Correlation without question 13 rises to r = 0.76. Stdev = standard deviation.
The maximum number of logs was 29, but students did not always log an answer to every question – usually when individuals came together to work on just one computer, rather than because they skipped a question. See also Appendix D, Table D7 for an overview of percentages of correct responses for all questions in the program.

Figure 6.4.2a: Graph of percentage of average score per question for questions 7-16



Several students are observed trying to remember how to use the terminology to answer these questions, sometimes choosing an answer and using the feedback from the computer to see whether they are right, for example in this exchange between Ulysses and Victor over the angulation of the lower incisors:

> **Ulysses:** I can't remember what we did. I can't remember. What actually happens if we try average? ***[uses left hand to pull at lower lip]*** Shall we try average? ***[Victor nods, Ulysses chooses 'Average']*** Yes...

Quantitative evidence that supports this improvement can be seen in the general improvement in percentage of correct responses between question 7 and question 16 in Figure 6.4.2a (discounting the problems over the upper right canine in question 13, see below). Similarly Adam and Bill's whispers increase in volume as they get closer to finding the correct answer for the angulation of the lower right canine:

> **Bill:** ... It's fucking difficult to tell that ***[last sentence said very quietly]***
> **Adam:** ***[again very, very quietly]*** Upright, I think. ***[chooses 'Upright', then slightly louder]*** OK, let's try mesial. ***[chooses 'Mesial', louder again]*** Try distal ...

Once again, despite the provision of background material in the glossary file, students make little attempt to open the file to find out more. The video recordings do identify a number of students using their hands to help remember the difference between distal and mesial. For example like Belinda, Kate uses her hand to indicate the angle of the tooth when deciding whether the lower right canine is mesially or distally inclined:

> **Jennifer:** I think ... upright? ***[chooses upright]*** No.
> **Kate:** No, that's not right. It must be distal. ***[raises right hand, palm flat, and tilts it towards the library end of the room to indicate the angle, palm facing away from the library]***
> **Jennifer:** ***[chooses distal, nods her head in agreement]*** Uh- huh...

Slightly less than half the sets (13/28) opt for upright as their initial answer for the angulation of the lower right canine in question 8, before guessing whether or not the canine is mesially or distally inclined.

Defining the labial/buccal segments

One difficulty for the students, particularly when trying to judge the rotation or degree of crowding of the teeth, occurs when students try to include the canine either in the labial or the buccal segment rather than dealing with it separately. For example, Adam and Bill turn to the interviewer for help in question 11, eventually realizing that perhaps the canine does not count in the buccal segment:

Adam: Just here = ***['here' points to crowding around the lower left canine]*** = ... a couple of sections back, it ... asks us if there was crowding here, in the lower segment, and we said ...there was, and it said that yeah ... = ***[having returned to question 9, 'it' refers to the CAL program]*** = there was a lack of space here for the canine. ***[points to the buccal segment and lower left canine]*** ...
Bill: Yes ... it's just ... that before it said there was crowding, and now it says that there is no crowding... ***[suggesst he is thinking along the same lines as Adam]*** ...
Interviewer: And ... if we return to the buccal segment?
Adam: Yeah, the buccal segment ... it should be from there to there, unless – it has ... taken ... the buccal segment and the canine by itself ... ***['unless' suggest he begins to realise the canine is considered separately and may not be part of the buccal segment]***

In question 12 Adam and Bill start to wonder if perhaps the canine is considered separately rather than as part of the labial segment:

Adam: ... The upper right canine ... is present.
Bill: But the canine doesn't count. ...
Adam: This is true. I thought maybe =
Bill: = maybe ... we always do the canine by itself. ***[wonders if they should be considering the canine in the labial segment, because they get asked separate questions on the canine]*** Don't we? So maybe we shouldn't do it.
Adam: Ok.

Having found that rotations are not present, Anne, Belinda and Christine also discuss whether or not to include the canine in the labial segment in question 12:

Christine: Why? ***[asks for explanation]***
Belinda: Because it's not rotated...
Christine: But surely that is, isn't it? ***[points to upper right canine]*** ...
Belinda: Yeah but ... – canines aren't part of the labial segment. ***[points out that canines aren't included in the labial segment]***
Anne: ***[points to to upper right canine then to the labial segment]*** But surely that is, there?
Belinda: Why then do they include the canines separately there?! ***[refers to the CAL program as 'they']***...

In question 15 Belinda and Christine decide that the canine should not be included in the buccal segment but should indeed be dealt with separately, despite overhearing Adam's comments to the Interviewer:

Belinda: You think it is, then? ***[turns to look at Christine, 'it' refers to upper right canine]***
Christine: Yeah, well, because Adam suggests the canine should be included.
Belinda: Yeah, well, we've done that one. ***[points to upper right canine, declares they have already covered the tooth in question 13]***
Christine: Oh, I see, when we did the 1s and the 2s, we did the canine. ***[agrees, referring to 1s (central incisors) and 2s (lateral incisors)]***
Belinda: I don't think that's meant to be in there, ***[points to 13, then to upper right buccal segment]***
Christine: No, well, with the 1s and the 2s.
Belinda: ... Yeah, yes.

Having found they are correct, Anne, Belinda and Christine have no problems with the upper left buccal segment, correctly choosing 'None' and 'None' as the answer.

In session 6 Victoria and Winifred are able to turn to Gareth for help on defining the labial and buccal occlusions, e.g.:

Victoria: I think we've found a problem here.
Gareth: No ... you've included the canine in the buccal segment, when it shouldn't be.
Victoria: Oh, so we've included that together ***[points to upper left canine and upper left buccal segment]***, when we shouldn't have have. It goes from |there to there – | ***[points to upper left buccal segment]***
Gareth: |And there to there|. ***[also points to upper left buccal segment]*** ...
Victoria: Oh, that makes sense.
Xavier: Oh yeah, it does...

Winifred: But I don't understand, because I got it wrong the first time.
Gareth: Oh, because you've included the canine here. The buccal segment goes from there to there.
Winifred: So it doesn't include the canine?
Gareth: No...

Other students do not seem to have a problem dealing with the canine separately from the labial or buccal segments, with Kate and Rachel in question 10 and Mary in question 11 all declaring to their partners that the canine is not included in the buccal segment.

Repetition of questions

Most students seem to find the repetition of question types useful, for example when Leonard comments in question 16:

Leonard: This is good ... for getting ... the feel of the thing, don't you think? Doing it again and again?
Mary: Yeah. Maybe... Ok.

Kate and Jennifer make a similar point in the post-session interview:

Kate: ... I found it helpful to have a "second chance" to practice....
Jennifer: ...because even when the questions didn't make any difference to the actual treatment being planned, they might in another case ...

In the post-session talk-back interview Kevin also mentions that the feedback to earlier questions has been beneficial because he could used it as a guide for answering similar questions later in the program:

Kevin: ... Earlier you had ... the class of the canine on the right hand side, before going onto the left. I didn't really know what the class was on the canine ... [in] the first question, applied it to the second one and got it, it was ½ a unit...

Kevin returns to this point when going through his responses to the general appliance design questions:

Kevin: ... we went through all these questions: What's the first step in designing appliances and what you would use, and this was all – not straightforward, but understandable. But then we got onto second thing.
Interviewer: Appliance design two?
Kevin: Yep, and I could answer this one, then - 'cos I just used the [previous] questions ...

There are several occasions when students refer to previous questions in this way, for example in question 12, when Anne, Belinda and Christine reflect back on the question on angulation for the labial segment in the lower arch to work out what the classification might be in the upper:-

Belinda: But … that's not average is it? **Christine**: But it was average last time, wasn't it? … **Anne**: Is it average? **Christine**: |Yes| **Belinda**: |Yes| I think it's average. ***[chooses 'Average']*** Yes!

Similarly Ian and James are able to work out that the canine should not be included in the buccal segment in later questions following the feedback that there is no crowding in the lower right buccal segment in question 10:

Ian: … Well, it's not the canine then? **James**: That's not the buccal segment. ***[pause 2s]*** Well, that's not the buccal segment. You know that's the labial segment – canine segment. You're just basically looking from the 4s backwards.

However not everyone was happy, and some students do find repeated questions puzzling. For example in question 8 Peter wonders what treatment might be required if the lower right canine is distally inclined:

Peter: What does that mean, if you need treatment distally? **Olga**: It means that you treat it from there.

Una and Wayne are also uncertain, raising the issue in later questions and again in the post-session interview:

Question 7 **Una**: ***[chooses 'Absent']*** Yeah. Ok. I don't believe they're average. I don't know. **Wayne**: No, but there's something wrong.
Question 11 **Una**: Why are they asking these questions? **Wayne**: Yeah. I don't know.
Una: Well, it was good, but I found some of the questions puzzling. **Interviewer**: Why was that? **Una**: Well, they didn't seem to be really relevant to this particular case, and we thought there might be more to it than it really was. **Wayne**: Yes, it was confusing to be asked questions that we'd already gone over, when they didn't seem to be applicable in this case.

Although they might be happy about the case assessment questions, some students query the repetition of the general appliance design questions, for instance in question 56 when Victor and Ulysses wonder:

Victor: Is this all correct, or is this meant to catch us out?

Ulysses: It's meant to catch us out. Didn't we just do this in the last appliance?
Victor: Posterior retention.
Ulysses: Yeah.
Victor: *[chooses 'Posterior retention']* Yeah.
Ulysses: Perhaps the last appliance was a clue.

The case assessment questions are included in the orthodontic template not because they are particularly relevant to the case but because by the time students qualified they are expected to check all these features to decide what is wrong with a case, rather than focus on one problem to the detriment of others which might be equally important in deciding whether orthodontic treatment is desirable or even possible.

Overall, though, most students seem to like using the program, finding it useful to have a series of "drill & practice" questions that can support them as they developed experience of carrying out orthodontic assessments:

Kate: ... If we'd been thrown in at the deep end, and just given the case, well, it would have been a real struggle.
Jennifer: I wouldn't have known where to start, to be honest, ... it would have been confusing.
Kate: Yeah.

The repeated questions give students the opportunity to have:

Helen: ... a "second shot" at some of them.
Isabel: Yes, they were fine. I liked it and it was good to be able to see what happened at the end.

The problem facing the students can be described by understanding that the choice of pedagogy itself (in this case being asked the question) suggests a particular conception of the learning process to the student – i.e. the medium chosen for a particular learning task, and how it is presented, will carry its own message to the learner that will influence his/her underlying assumptions about what is expected, whether or not this is intended (Hillman, Williams and Gunawardena, 1994; Bruner, 1996; Fosnot, 1984; Norton, 1992).

The likelihood is that, because this is the first time the students go through a study like this, there is an expectation on their part that only questions relevant to the particular case will be asked. Hence, as Gita implies in question 8, students are looking for anything that might provide an answer:

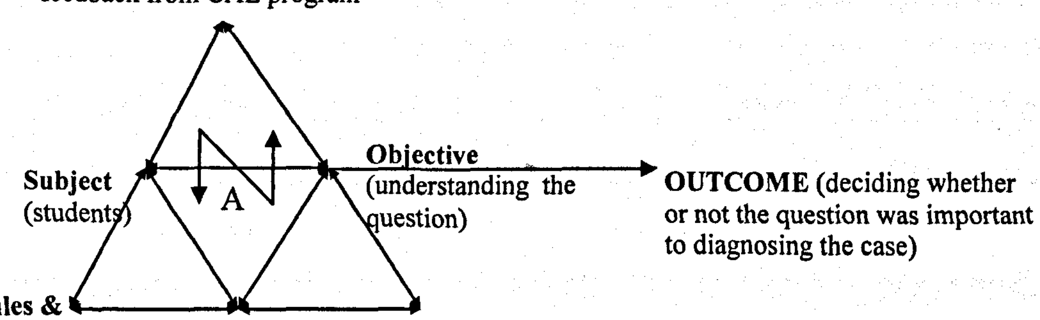
Gita: Lower arch, lower right canine. Is the angulation mesial, upright or distal. I'm sorry, but why are you treating that? ***[Gita's comment on 'Why are we looking at this?' indicates that at this point she expects to see only questions relevant to this particular case]***

Frank: Why not?
Gita: I would say it was fair enough. [...]

Figure 6.4.2b shows an activity system where the contradiction lay in a difference between what a student understands of what is expected – i.e. the outcome of the activity – a secondary contradiction (A) between two of the constituents of the activity system arising from the students' expectations, and hence understanding of the program, that all the questions would be relevant to the case. Another way of describing the contradiction is that it can be considered a tertiary contradiction between the expectations of the tutor and those of the students. In the focus of this study the actual description of the contradiction does not have to be precise; what is important is that activity theory has acted as a heuristic device to highlight a potential contradiction which can then be used as a focal point for discussing the problem and identifying potential solutions. As will be seen, during the interactivity that occurs in the rest of the program most students are able to use the implicit feedback from the program to come to terms with the fact that not every question will have an answer immediately relevant to Case JB – i.e. the feedback is again acting to restore equilibrium in the system.

Figure 6.4.2b: Contradiction in the activity system arising from students' expectations that questions would be relevant to the case and would therefore require treatment

Mediating tools
- MCQ format options provided by CAL program
- links to digitised images of dental records ('Occl', 'Right' & 'OPT')
- hands and fingers as pointers to focus attention
- memory of orthodontic definitions
- feedback from CAL program



Rules & Procedures

Community
- student's partner
- other students
- substitute tutor (Gareth)
- Interviewer
- tutors (in next room)

Division of Labour
- feedback on screen originally provided by orthodontic specialist who developed the questions for the CAL template

One of the possible drivers behind students' thinking there is a problem when one does not exist could be because they are being asked to identify features which require treatment rather than features with minor deviations from the ideal. Students in the pilot study had few problems answering these questions, suggesting that the students in the main study will also understand how to answer the questions in due course. This accustomisation is certainly the case for Gita who, by question 20, appears comfortable with the fact that there may not actually be a problem with the case just because the question is asked:

Gita: ***[reads]*** Where the facial photograph doesn't allow this, estimate the relationship. ***[pause 2 s]*** Well, it's correct and correct, isn't it?

Classifying the partially erupted upper right canine (question 13)

Unlike other questions in this section, classifying the partially erupted upper right canine causes problems for most of the students, with only 10/27 sets correctly identifying the angulation as mesial. The average percentage score across all three parts of the question drops from just under 70% of sets correctly classifying the upper incisors to just 38% of sets for the upper right canine, going back up to 65% of sets correctly classifying the fully erupted upper left canine in the next questions (Figure 6.4.2a).

Students are fairly evenly split between the two most popular choices for the angulation, with 12 sets choosing upright and 10 sets mesial, suggesting the possibility that most guess the answer. Further evidence that most students "guessed" the angulation came from the QSR/N6 analysis of the transcripts showing that even when students correctly answer the question, their "success" is frequently due to a lucky guess:

Edward: I can't quite see, let's make it mesial. **David**: Yeah, you can't tell, because it's not erupted.
Olga: ... How can we tell with the upper right? **Peter**: Upper right. I don't know which it is. ***['which it is' refers to which answer to choose]*** ... Let's just try here ***[chooses 'Mesial']***

Although most students appear happy to guess, Laura disagrees when Henry adopts this approach in question 13 (there is a similar argument between Frank and Gita when trying to answer the next question):

Laura: What are you doing? Henry? Are you doing? Henry? ***[laughs]*** What are you doing?! WHAT ARE YOU DOING? It's distal!!
Henry: Well, I tell you, I've pressed every one except that, to get that! Ooops!

Two sets (Mary and Leonard, Ian and James) do adopt a more methodical approach to answering the question. Having made one attempt at the question, Mary uses the 'OPT' to discover she can work out the direction of the tooth from the angle of the root:

Mary: ***[chooses 'OPT']*** Oh, but it's going back that way! ***[represents root position by bending her right elbow, hand level with nose, tilting right arm to the left across her body, face turned towards Leonard]***
Leonard: Yeah, the root's going back that way ***joins in arm tilting, but with arm pointing towards back of room]***
Mary: The root's tipping that way? ***[points hand down to lower left corner]*** The root's tipping distally so bringing it upright then? ***[brings arm to upright position, then brings hand down in 'windscreen wiper' movement]***
Leonard: Yeah.

Ian asks James to open up the 'OPT' before choosing an option, with James's confidently expressed "Mesially inclined" and Ian's agreement suggesting they are able to work out how to judge the angulation of the tooth from the direction of the root without further discussion or explanation:

James: ***[chooses 'Occl' then 'Right']*** The upper right canine. Right. Um. I don't know – what do you think?
Ian: That's good one.
James: You can't really tell, can you.
Ian: Can you get the OPT up?
James: ***[chooses 'OPT']*** Mesially inclined.
Ian: Yeah.

At the start of the M-year students will not be familiar with dealing with a partially erupted tooth. It is possible that because students are asked about the intra-oral examination they feel confined to using different views of the models rather than accessing the radiograph as an additional check when unable to tell angulation from the models alone. Brian explains that looking at a radiograph is essential when dealing with an unerupted or partially erupted tooth, because looking at the root is the only way to judge the angulation. In the case of JB:

Brian: ... the root's tilting distally, so the tooth is mesially inclined... A mesially inclined tooth means that the crown is further mesial than the root, not that the root is more mesial than the crown...

Students in the pilot study did not have a problem classifying the angulation of a partially erupted tooth. This finding suggests that increasing familiarity and experience of working with orthodontic cases over the course of the M-year would enable the students in the study understand how to classify a partially erupted tooth.

Student interactivity when classifying the angulation, rotation and crowding of teeth

The difficulty for students seems to be partly due to their lack of familiarity in applying definitions in reality. Students also need to make the connection between the angulation and number of rotations and the impact these factors might have on the assessment of crowding. For example a tipped tooth requires more space and, once aligned, space becomes available for other teeth. Conversely a rotated tooth, such as an incisor, would generally be rotated because it is short of space and usually cannot be aligned unless space is provided. What the student has to do is to imagine what space is required for all the teeth in the segment to be aligned (Stephens, 2004).

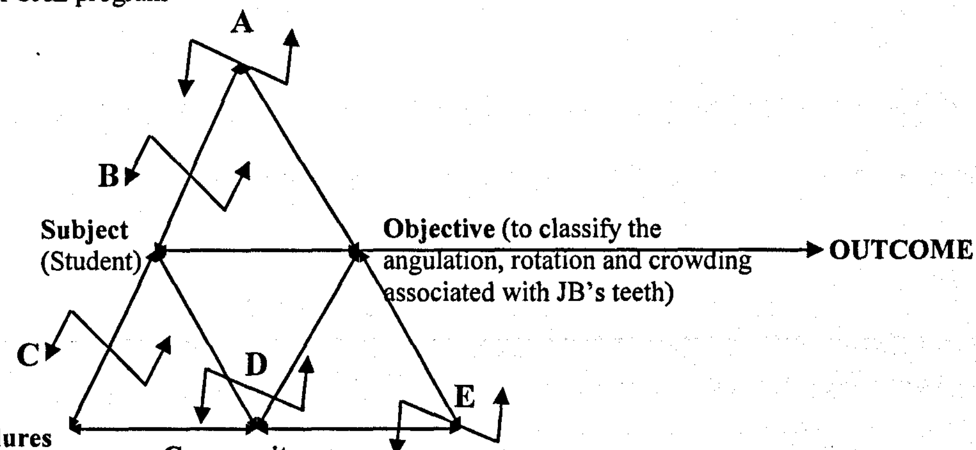
Activity theory suggests a primary/secondary contradiction between students and their understanding of the terminology (A, B) and a secondary contradiction in their understanding of procedures needed to use that terminology, particularly in relation to working out the angulation of the partially erupted upper right canine (C) (Figure 6.4.2c).

For 4 students (Henry, Laura, Frank and Gita) there are noticeable secondary level contradictions between the constituencies of rules and procedures (C), community (D) and division of labour (E) and what they need to do to achieve the required objective, with the two male students trying to guess at the answer without waiting for agreement on this approach from their female partners.

Another primary level contradiction within the system also occurs at the level of division of labour (E), for example when Mary becomes confused by Leonard's attempts to take on the role of 'expert' to explain what is happening. More successful within the constituency of the division of labour are Henry and Laura's "adaptive" reflections which help them to identify the lower labial crowding as mild. In this particular instance, feedback from the program alone is not sufficient to help most students understand how to judge the angulation of partially erupted teeth.

Figure 6.4.2c: Activity system for questions on angulation, rotation and crowding

Mediating tools
- MCQ format options provided by CAL program used to classify all JB's teeth
- orthodontic terminology, particularly definitions of angulations, rotations and degrees of crowding
- links to digitised images of patient's records ('Occl', 'Left', 'Right' and 'OPT')
- hands and fingers acting as focus of attention
- memory of own experiences as students and patients
- textbook
- feedback from CAL program



Rules & Procedures
- intra-oral examination, therefore do not consider looking at the 'OPT' to see if the angle of the root can help them judge the angulation of the partially erupted tooth
- remember and recall of factual and conceptual knowledge

Community
- students' partner
- other students
- substitute tutor (Gareth)
- Interviewer
- tutors (in next room)

Division of Labour
- when one person in a pair acts as an 'expert/teacher' to explain what was happening to another'
- when students turn to the Interviewer or Gareth for help
- when individuals come together to work on a question
- feedback on screen originally provided by orthodontic specialist who developed the questions for the CAL template

6.4.3 Teeth in occlusion

The remaining ten questions in the intra-oral section related to classifying how the teeth came together (the occlusion), as laid out in Table 6.4.3.

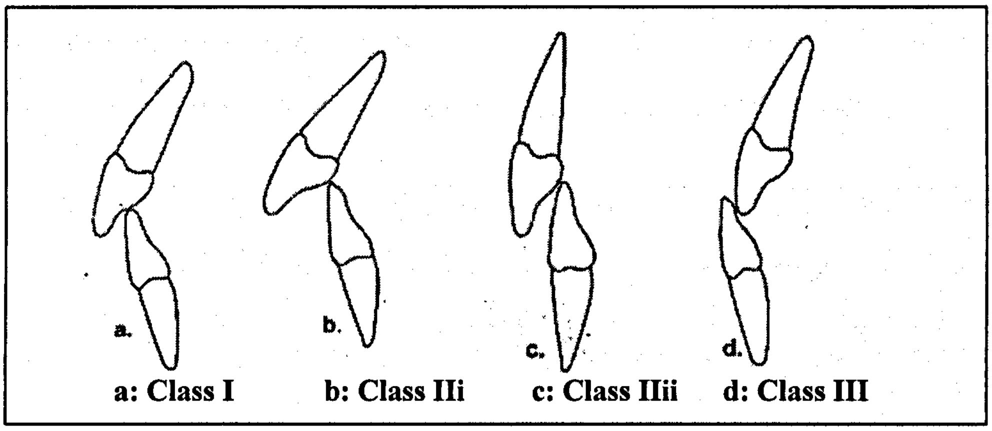
Table 6.4.3: Questions relating to teeth in Occlusion

Question	Relationship	Correct response
17	Incisors	Class I
18	Overbite	1/3 - 2/3 (average)
19	Overjet	Average
20	Upper and Lower Centrelines	Correct and Correct
21	Incisor crossbite	There is no crossbite
22	Right Side Canines	½ unit Class II
23	Left Side Canines	½ unit Class II
24	Right Side Molars	½ unit Class II
25	Left Side Molars	Class I
26	Buccal Crossbite	There is no crossbite

Classifying the incisor relationships

Figure 6.4.3a shows examples of the different types of classification for how the incisors might come together. In this particular orthodontic case the incisors are in a Class I occlusion, which students could check against the Ceph.

Figure 6.4.3a: Incisor classifications



Although each screen is labelled 'intra-oral examination' it should be remembered that students are free to examine the other records on the screen (and particularly the Ceph) to answer the question.

Brian explains that students need to use the Ceph to check the patient's profile to classify the incisor relationship – relying solely on the models would nearly always lead to an incorrect classification.

The majority of students (21/29 sets) are able to classify the incisor occlusion as Class I, although nearly a quarter (7 sets) initially opt for either Class II division I or division II, possibly because they answered the question solely from the view of the models from the 'Left'. For example, having chosen both the Class II options before finding the correct answer, Leonard uses his hands and the information on the screen to explain the different types of occlusion to Mary:

Leonard: ... ***[chooses 'Right', then 'Left']*** Do you reckon it's Class II ... division 1***? [Mary nods. Leonard chooses 'Class II div 1', then 'Class II div 2', then 'Class I']*** Because they're not – ***[points to screen with second finger of left hand]*** If they were that side, they would be in align, ok?
Mary: Oh = ***[leans back in chair, out of view of camera]*** = so, if it's Class II, then they should be like this, but Class III is like this, and Class I like this, then? ***[Mary's words indicate that she's using her hands to represent different occlusions of the teeth, actual moves not picked up on recording]***
Leonard: That's what I said.

An example of students checking their response against the Ceph (and the danger of relying on the 'Left' and 'Right' views of the model) occurs when, having initially decided on a Class II orientation for the incisors from the images of the model, Victor suggests:

Victor: Can we see the Ceph? ***[points to Ceph button, Ulysses chooses 'Ceph']*** Class II would be back = ***[represents classification by tilting his left hand to the left and back, then tilting his hand to the right and back upright]*** = Class III like that, and Class I like that. **Ulysses**: ... I would say it's class I. ***[chooses 'Left', 'Right', 'Left']*** **Victor**: ***[points to screen with left hand]*** From the left it looks like Class II, but from the right and the Ceph, I'd say one. **Ulysses**: Ok, Class I. ***[chooses 'Class I']*** Yes.

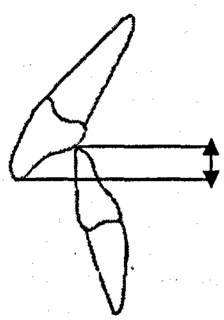
Most students are observed using their hands as tools to help remember and assess how the teeth came together, as when Ian and James point to where the incisal edges meet on the right side view:

James: ... it's Class I there – the incisal edge of the lower incisor occludes with the palatal cingulum of the upper. ***[points to where the lower incisor teeth meet the upper on the 'Right', confirming that he believes the incisors are in a Class I occlusion]*** **Ian**: Yeah.

Overbite

Figure 6.4.3b illustrates the overbite to illustrate what exactly the students are trying to judge.

Figure 6.4.3b: Illustration of the overbite (vertical overlap)



Overbite:
The 'vertical overlap of the upper over the lower teeth' (British Orthodontics Society, 2000)

When assessing the overbite for JB, nearly every set (27/29) opts for '0 to 1/3rd coverage of the lower incisors' rather than the correct (average value) of '1/3rd to 2/3rds coverage of the lower incisors'. Because students do not express surprise at the feedback, the reasons behind their understanding of how to classify an overbite are not picked up during observation, although Kevin mentions in his post-session talkback interview that the feedback is sufficient to help him understand how to answer the question.

Brian suggests it is possible that students, relying solely on the models, are mislead by the reduced overbite on the two lateral incisors. However they would have found the correct answer if they check their answer against the Ceph, as Helen suggests to Isabel post-feedback:

Isabel: ... *[chooses '0-1/3']* Ohhh? Why not?
Helen: Look at the ceph. *[Isabel chooses 'Ceph']* If you look there, you see that the incisor comes to there, and to there. *[Helen points first to upper incisors, then to lower incisors]*

Furthermore in reality students will be able to manipulate the models themselves to carry out an assessment of the overbite on clinic, rather than have to rely on examining images of the models, allowing them to:

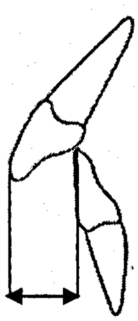
Brian: ... actually look from the other side of the models. You'd turn the models round, and look up the hole where the tongue is, to see what the vertical overlap was.

Overjet

For comparison purposes the overbite is illustrated in Figure 6.4.3c. Most students (24/29 sets) work out that the overjet in question 19 is average either from the side views of the models (e.g. Sophie and Tina) or, as Ian and James demonstrate, by examining the Ceph and taking into account what they'd already found out about the case:

James: Is the overjet reversed/reduced/average/increased/greatly increased? *[chooses 'Ceph'] [pause 2s]* Average?
Ian: Hmm.
James: If she's Class I occlusal, I can't see how she can have a massive overjet.
Ian: No. *[James chooses 'Average']*

Figure 6.4.3c: Illustration of the overjet (horizontal overlap)



Overjet:
The 'horizontal overlap of the upper teeth over the lower teeth' (British Orthodontics Society, 2000)

Centrelines

Students are next asked to decide whether the upper and lower centrelines (the lines between the central incisors) are properly aligned relative to the face. Again this question is included not because JB has a centreline discrepancy but because students should always check for this feature when carrying out an orthodontic assessment. If GDPs encounter patients with either centreline discrepancies or crossbites they will need to be referred to a specialist for treatment as complex cases. Most students do not have a problem with the centrelines, with 26/29 sets working out that the upper centreline is in alignment, and, following feedback about the upper centreline, all the sets are able to work out that the lower centreline is in alignment.

Incisor crossbite

A crossbite is defined as a malocclusion that occurs when the upper teeth bite inside the lower, reversing the normal relationship between the teeth (Hardy, 1994). In this question most students (23/28 sets) are able to work out that they are being asked a question when JB did not have an incisor crossbite although Helen and Isabel use the feedback to test whether JB has a 'shallow' crossbite on the left lateral incisors (22):

Isabel: Incisor crossbite.
Helen: I don't know ***[laughs]***
Isabel: Affecting one tooth?
Helen: I think they're on 22 there, but they're so shallow. What do you reckon?
Isabel: ***[chooses 'Affecting one tooth']*** No. ***[chooses 'There is no crossbite']***

When assessing the incisor relationships, the reality of the case means that students are being asked to make judgements about a patient with an average occlusion. By now most students seem comfortable with the idea that they might be answering questions about aspects of the case that do not require treatment, suggesting that in time all the students would become familiar with the idea of carrying out a "pre-flight" check on any potential orthodontic patients.

Classifying the canine and molar relationships

The final four questions in the intra-oral section of the program ask students to classify both the canine and molar occlusions (relationships) on first the right then the left. Although a definition of each occlusion is available in both the glossary help file and the introductory e-book, the students nearly all prefer to use other means to answer this question, including memory, hand movements, and different views of the digitised records. The log-files reveal that only Adam and Bill checked the glossary file to find out more about how to judge a buccal occlusion.

The first two questions ask students to assess the relationship of the right and left canines. As in question 13 the partially erupted canine causes problems in assessing the right side relationship:

Belinda: ... Well, how are we supposed to answer that?
Christine: No idea. Half a unit class III?
Belinda: ***[chooses '½ unit Class III']*** No. No...

Although the order of checking the teeth in the CAL template, to maintain consistency of approach, is to start with the incisors and work outwards rather than for any technical reason in this case students may have found it easier to answer the question if they first check the buccal occlusion, because:

Brian: ... the buccal occlusion is half unit Class II, so the chances are the canine is half unit Class II...

Just under half the sets (13/27) correctly choose '½ unit Class II' on their first attempt, with 6 of the remaining sets opting for Class I, 6 for '½ unit Class III' and 1 set each opting for a 'full unit Class II' or 'full unit Class III'. Students are more successful on the left, with 21/27 sets opting for the correct answer of '½ unit Class II'.

The three sets who preview the case (David and Edward, Olga and Peter and Sophie and Tina – Section 6.5) all correctly identify the relationship as '½ unit Class II'. It may be that their prior observations enable them to use their understanding of the buccal occlusion on the right to suggest the correct answer for the canine relationship. Similarly Wayne points to the image of the 'Right' view of the model to explain to Una that because the buccal (molar) relationship falls 'between a Class I and a Class II' relationship, then it is likely that the canine relationship would be similar:

Una: Ok. ***[Wayne chooses '½ unit Class II']*** Why is this?
Wayne: Well, because you can see it's there. ***[points to the molar region, suggesting he is using the relationship of the molars to work out the probable relationship of the canines]*** It falls between a Class I and a Class II, doesn't it?
Una: Oh! Ok.

Several students use their hands to identify the possible occlusion, for example Ian brings his hands together to illustrate a Class I relationship, from which he and James come to agree that the tooth is slightly more 'forward' than would be expected if it is Class I:

Ian: ... Class I's where distal incisal edge and this one would give the top one distal to the lower. ***[points to right side canines, then moves hands together]*** That's Class I, so if that were like that, that would be Class I.
James: Yeah.
Ian: Do you think it's that, or do you think it's slightly forward? I think it looks a bit forward.
James: I'd say ½ unit II.
Ian: Hmm. What do you reckon? Let's give it a go. ***[chooses '½ unit Class II']*** YESSS!!

Sometimes students use their own canine relationships to help identify the occlusion, as in the following exchange between Ulysses and Victor, in which they negotiate over whether or not the teeth are in a Class I or a ½ unit Class II relationship:

Ulysses: ***[chooses 'Right']*** ... It looks like it might be ½ unit Class II.
Victor: Ok. But aren't the canines supposed to meet like that, canine to canine?
Ulysses: Well, they aren't class I. ***[reaches inside his own mouth with his left hand]*** Why do you think they're class I?
Victor: Because the centre's meeting there ***[points to canines on 'Right']***
Ulysses: I don't think so. I don't think they're that far out ***[still feeling his own right side canines]***
Victor: So you think it's class II.
Ulysses: Not that far. ½ unit class II. ***[Victor nods, Ulysses chooses '½ unit Class II']*** ...

After Christine suggests guessing the answer, following their first attempt of '½ unit Class III', Belinda tries to work out where the canine might occlude, using Anne's mouth as a model of how the canine might come together. From this activity, Belinda and Christine are able to identify that the canines are in a '½ unit Class II relationship:

Belinda: ... Where's it meant to occlude?
Anne: Where's it meant to occlude? Is it meant to occlude there? ***[points to lower right canine]***
Belinda: So you reckon it's a half unit class II then? ***[turns to Anne]*** Smile at me. ***[looks in Anne's mouth, points to the canines]*** Yes, it's meant to occlude on the 1, 2, 3 distal, I think.
Christine: Yes, 1, 2.
Belinda: 1, 2. ***[chooses '½ unit Class II']*** Correct.

Adam and Bill also discuss how the canines might come together. As Adam and Bill take turns to finish the sentence, discourse analysis suggests the two are thinking along the same lines to come to a common understanding and agreement about the answer:

Bill: What is the canine relationship on the right? ... Is it that? ***[points to '½ unit Class II' option]***
Adam: Yeah, 'cos ... it should be just about here. ***[points to right side molars]*** So it's gone slightly behind the cross-tip.
Bill: Should be there ... |there, should be...| =
Adam: |yeah, yeah| = should be the tip of the upper one should be just =
Bill: = in the distal =
Adam: = should be just ... there. It should be more ... medial, but it's not ... it's ... too distal... It should be like =
Adam: = it should be like that.
Bill: What, tip to tip?
Adam: Yeah, the upper should be slightly ahead, I think.
Bill: Alright, I've got it. ***[Adam chooses '½ unit Class II']***

Brian suggests that although some of the students are classifying the right canine relationship correctly, as with the definition of teeth present in the mouth (Section 6.4.1) there may be an underlying contradiction with the way teeth are referred to restorative dentistry:

Brian: Yes, they're getting confused with ... canine disclusion and series of occlusion, which unfortunately restorative dentists get into... They tend to forget they're talking about artificial reconstructions, not the actual dentition...

Not surprisingly, with both teeth fully erupted, and having worked out how to classify the canines, students experience far fewer problems working out the classification of the canines on the left, with 22/28 sets correctly identifying the relationship as '½ unit Class II'. However Kate and Jennifer still appear confused over the classification, and although the log-files indicate they correctly identify the relationship on the screen, the transcripts suggest that like Sophie and Tina in the extra-oral examination (Section 6.3) they do so by mis-entering their original choice of Class I:

Kate: The left canine = ***[chooses 'Left', then '½ unit Class II', rather than 'Class I']*** = oh, I answered the wrong one. ½ unit Class II, rather than class I. But it's right!

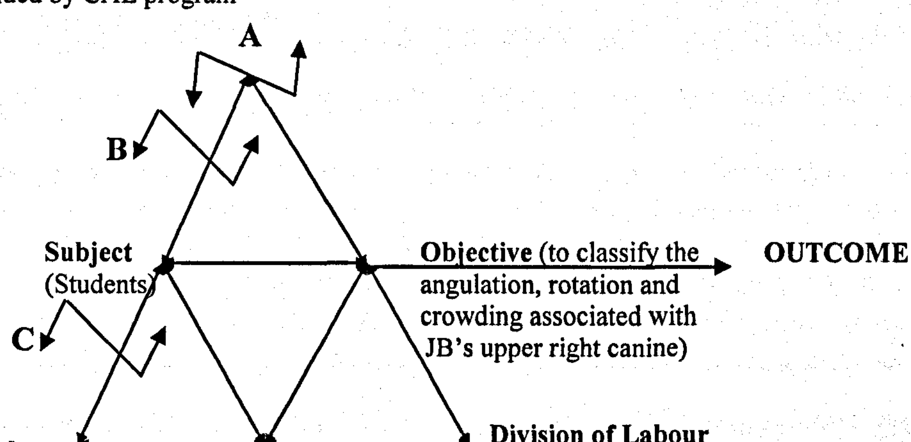
By far the most common response is to go for the same choice as the right side For example having discussed the canine relationship classifications in the previous question James and Ian feel no need to discuss it any further on the left:

James: On the left hand. ***[chooses 'Left']*** Same again.
Ian: Yeah.

The problems with dealing with the canine suggest a primary contradiction between what students have been taught and the reality of the case (Figure 6.4.3d). The situation is similar to that when the students are asked to assess the angulation, rotation and degree of crowding of the upper right canine. The problems with classifying the right side canine relationship again suggest the existence of a primary contradiction (A) in choosing the best mediating tool for the activity (*i.e.* looking at the buccal occlusion to judge the potential canine relationship) and two secondary contradictions (B & C) both in understanding how to use that tool and in adapting their understanding of the taught classification rule to make a judgement about the relationship. Note that due to unfamiliarity with procedure, feedback from the CAL program does not help in restoring the system.

Figure 6.4.3d: Confusion over classifying teeth when dealing with a partially erupted canine

Mediating tools
- MCQ format options provided by CAL question
- orthodontic terminology
- links to digitised images of patient's records ('Occl', 'Left', 'Right' and 'OPT')
- mental model of orthodontic procedures
- students' own canine occlusions
- hands and fingers as pointers to focus attention
- hands and fingers to illustrate occlusal patterns
- feedback provided by CAL program



Rules & Procedures
- need to guess occlusion based on other relationships that can be assessed (e.g. buccal occlusion)
- remember and recall factual and conceptual knowledge

Community
- students' partner
- other students
- substitute tutor (Gareth)
- Interviewer
- tutors (in next room)

Division of Labour
- when one person in a pair acts as an 'expert/teacher' to explain what was happening to another'
- feedback on screen originally provided by orthodontic specialist who developed the questions for the CAL template

Prior to the study session students have only had to classify occlusal relationships of fully erupted teeth, whereas in reality they are now being asked to classify a relationship involving partially erupted teeth. Once again it is suggested that increasing experience of judging orthodontic patients will help students learn how to judge the occlusion of partially erupted teeth, if only because as GDPs they should not be surprised by the presence of partially erupted teeth in a patient that might be suitable for orthodontic treatment!

Classifying the buccal (molar) relationships

Having spent time during the preclinical and J-years covering buccal occlusions, students are not expected to have problems assessing the buccal occlusions:

> **Brian**: It's a pretty easy one on buccal occlusion – I mean they really ought to get it right... They have been hammered about this... – they ought to get molar occlusion right.

The QSR/N6 analysis shows students talking about ways in which the molar teeth can be classified; with 23/29 sets correctly identify the molar relationship on the right as '½ unit Class II'. For example, some students talk about how the buccal cusps will fit into the lower molars, as when Adam and Bill refer to the position of the upper jaw when trying to decide whether the molars are Class I or ½ unit Class II on the right:

> **Bill**: ... So if it was class II, then that = ***[points to lower jaw]*** = ... would be further forward.
> **Adam**: No, class III would be further forward... Class I is normal. Class III is when you get the whole lower jaw... further forward, and class II is when – ...
> **Bill**: Yeah ... ½ unit? ...
> **Adam**: There. This is supposed to be in there ***[points to where molars touch each other]*** Isn't it?
> **Bill**: ... Yeah.
> **Adam**: ½ unit Class II? ... ***[chooses '½ unit Class II']***

Helen and Isabel make sense of how to classify the teeth post-feedback:

> **Isabel**: ... Wait a minute, though. If that upper canine there and that's there ***[points to canines on 'Left']***
> **Helen**: Yeah, but you can tell it's not going to ... fit in that gap there ***[points to gap between lower canine and premolar]***
> **Isabel**: Oh, yeah, I suppose so. So it is definitely Class I!

Although the buccal occlusion on the right causes little problem, on the left the MCQ format for assessment provided students with tools (units of measurement) that do not provide them with the choice of an MCQ option that exactly matches the reality of the case. The problem arises because the format is trying to use discrete units to make judgements about a real patient:

> **Brian**: ... the right is ½ unit Class II, and I suppose some of them might say, "Oh, well, the left's the same', when in fact it isn't...'It's really a ¼ unit Class II ...

Only 1 student (Victoria) identifies the case as a Class I molar relationship on the left. The QSR/N6 analysis reveals that she does this after Gareth explained that the relationship does not need to be precise, but can be estimated to give an approximate answer that can be used to plan future treatment:

> **Victoria**: So is that a ½ unit Class II as well? ***[points to the right buccal occlusion]***
> **Gareth**: ... It's just short of ½ – ... It's useful to predict because it tells you how much space you need for the treatment. But you ... can be too particular and if it is just short of this = ***[points to a full unit option]*** = you can say 5/6th or ... just roughly ½ a unit...

Adam and Bill have a conversation about the position of the cusps when deciding on the molar relationship on the left, trying to relate what they can see back to the incisor relationship before going on to choose '½ unit Class II' as their answer:

> **Adam**: This bit of mesio-buccal cusp should be in the buccal groove.
> **Bill**: ... So shifting backwards should be the same as what happened with the canine – the canine should be forward ... and it's not.
> **Adam**: If it's shifting back ... Shall we make it Class II? ... [if you] take a tip from the incisors = ***[refers back to the incisor relationship]*** = Class I is where you've got the cingulum on the inside, where you can't even ... see them...

Reading the feedback on the screen Adam and Bill return to reflect on the previous question to make sense of the feedback provided by the program:

> **Adam**: ***[reads]*** ... the correct answer is that the left buccal segment is |Class I.|
> **Bill**: |Class I.| So it's not quite right... So shall we just go back to the question before and just check?
> **Adam**: ***[returns to question 24]*** Oh, it's absolutely fine, ok. So if it's shifted straight forward, it should be just a buccal occlusion. So if the mesio-buccal cusp of the upper goes in the lower buccal groove –
> **Bill**: Yeah.
> **Adam**: So this = ***[points to upper right molars]*** = is shifted slightly further forward.

Ulysses and Victor initially opt for a Class III occlusion before finding '½ unit Class II' for the right, using their fingers to point at molars on the screen. More cautious on the left, they use their own mouths and the answer to the previous question to debate whether or not the molars might be in a Class I or a ½ unit Class II relationship:

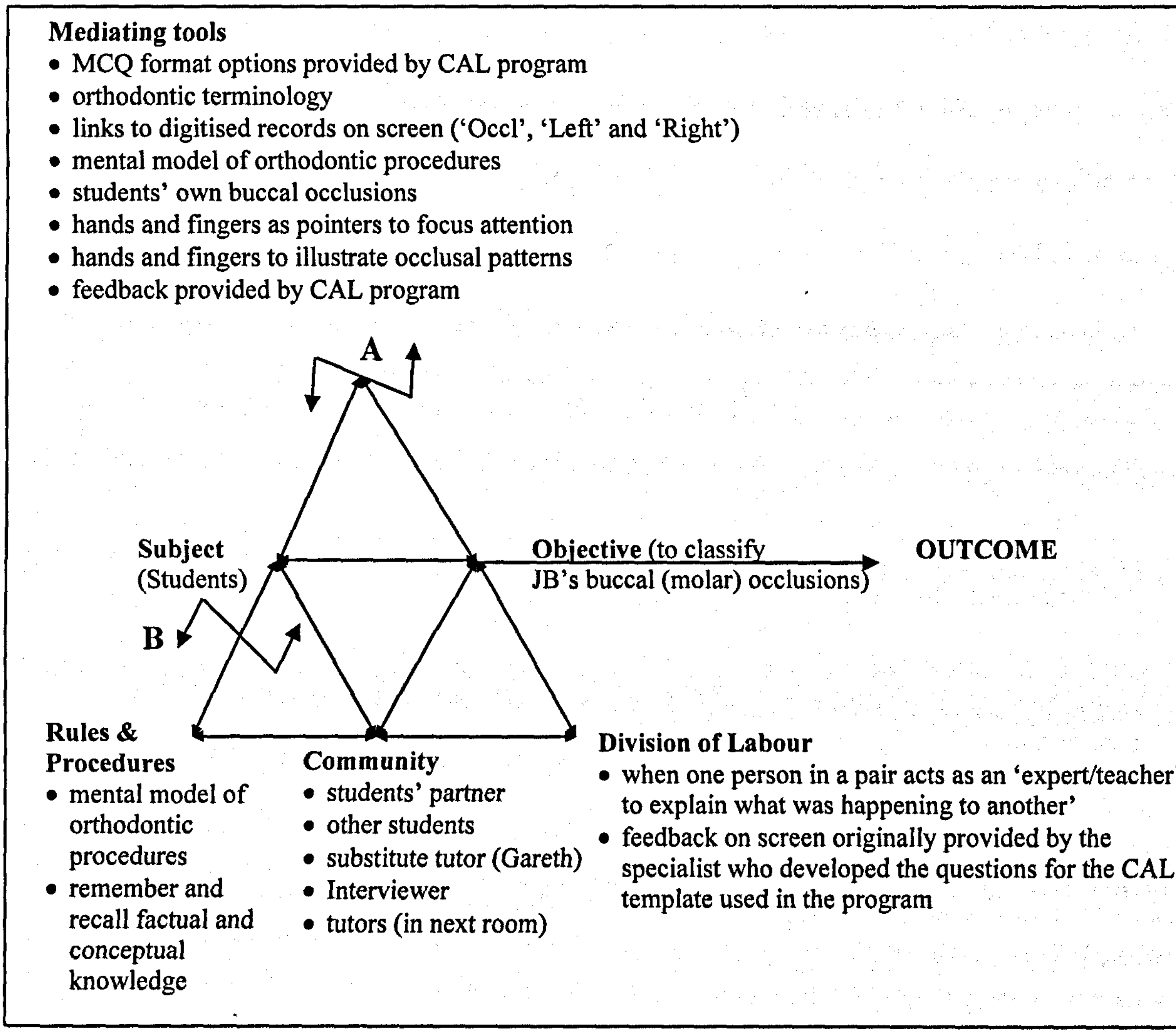
> **Victor**: ***[runs right thumb between upper and lower molars on screen]*** They're meeting here and here ***[places thumb on right side of his own cheek, first finger on left cheek, other three fingers folded under, feeling his own molar relationship?]***
> **Ulysses**: ***[chooses 'Right']*** So that's ½ unit Class II ***[chooses 'Left']*** So is it Class I? ...
> **Victor**: I'm not sure. ***[shakes head]*** It may be Class I ***[points to molar region with little finger of right hand]*** It's definitely meeting there. ***[Ulysses chooses 'Right', Victor runs right thumb over molar meeting points]*** I thought it was Class III, not Class II. Oh, yeah, I see, because it's meeting there, and not there = ***[points to two adjacent spots on lower first molar]*** = so it must be Class II. ***[Ulysses chooses 'Left'] [pause 2s]*** Yeah, it's ½ unit Class II. ***[Ulysses chooses '½ unit Class II']*** ...

Finally some students choose ½ unit Class II on the left because they seem to assume they should choose the same option as that on the right, for example:

Elizabeth: Left molar relationship?***[chooses 'Left']*** ½ unit Class II again, do you think?
Felicity: Yes. ***[Elizabeth chooses '½ unit Class II']*** …

Activity theory suggests the presence of primary and secondary contradictions in the system (Figure 6.4.3e).

Figure 6.4.3e: Activity system for answering intra-oral questions relating to buccal occlusion



A primary contradiction (A) arises because the MCQ format for assessment provides students with tools (units of measurement) that do not provide an option that exactly matches the reality of the case. A secondary contradiction (B) arises from difficulties in understanding how to use that tool to assess the case. In this case, it seems that a lack of precision in measuring instrument (classification option) combined with an expectation that there has to be a problem with the relationship, possibly compounded by their memories of the molar relationship on the right, appears to be the cause of the problem. Using the feedback, students do learn to adjust their answer to fit the options available to them based on an estimated measurement that is sufficient for treatment planning purposes rather than making an exact measurement of the occlusion.

Buccal crossbite

When it comes to assessing the crossbite the majority of students (23/29) agrees there is no buccal crossbite. In 2 sets (Anne, Belinda and Christine; Ulysses and Victor) that decide there is a buccal crossbite the transcripts reveals this is not a unanimous decision but a unilateral one taken by the student operating the computer seemingly being convinced that a crossbite exists. For example Belinda is adamant there is a local crossbite possibly because she wants to include the upper canine in the buccal segment:

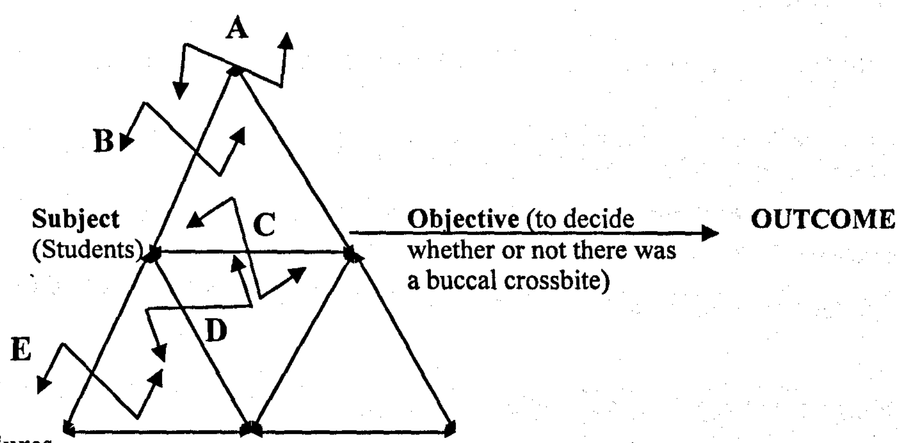
Belinda: Is the buccal crossbite bilateral, unilateral on the right? It's local, surely?
Christine: I can't see any crossbite.
Belinda: Yes.
Christine: ***[points to upper right canine]*** Is that tooth going to go in there?
Belinda: No. It's a local crossbite on the right! ***[declaration, chooses 'Local crossbite on the right']*** ...

Where there is a problem, activity theory suggests the presence of primary and secondary contradictions in the system (Figure 6.4.3f). In this case difficulties in judging whether or not there is a buccal crossbite arise from a primary contradiction (A) due to the existence of a question on the buccal crossbite and a secondary contradictions (B) because students believe it requires an answer, leading to another secondary contradiction (C) in understanding the objective of the question. These primary/secondary contradictions arise because the MCQ format for assessment provides the students with options that make them believe there is a problem that does not actually exist.

As with the question on the molar relationship, even here a few students again try to answer a question when, because the question has been asked, they feel there is a problem needing treatment – hence there is a tension in the system (C) between students and their understanding of the objective of the question. Another possible secondary tension (D) can be identified between students and their partners about whether or not a crossbite actually existed. A secondary tension (E) may also arise because some students might still be including the upper right canine in the buccal segment. As it is not raised in any of the post-session interviews, it is probable that the feedback helps all the students understand that not every question will automatically indicate a problem for JB.

Figure 6.8.3f: Activity system for deciding on the presence of a buccal crossbite

Mediating tools
- MCQ format options provided by CAL
- links to digitised images of patient's records ('Occl', 'Left' and 'Right')
- mental model of orthodontic procedures
- students' own buccal occlusions
- hands and fingers as pointers
- hands and fingers to illustrate occlusal patterns
- feedback provided by CAL program



Rules & Procedures
- question asked to encourage students to consider this detail in future cases
- canine is dealt with separately, not part of buccal segment
- remember and recall other factual and conceptual knowledge

Community
- students' partner
- other students
- substitute tutor (Gareth)
- Interviewer
- tutors (in next room)

Division of Labour
- when one person in a pair acts as an 'expert/teacher' to explain what was happening to another'
- feedback on screen originally provided by specialist who developed the questions for the CAL template used in the program

6.5 The radiographic examination

The final part of the case assessment asks students to look at a panoramic radiograph (OPT or X-ray) of the teeth and jaws and answer three questions relating to: how many teeth are present on the radiograph, whether any of these teeth are sufficiently carious to need treating and whether their underlying roots and bones are healthy. The reason for these checks is to encourage students to think about these factors automatically when carrying out an orthodontic assessment rather than because JB has any problems in this area.

Orthodontic treatment will almost certainly have an adverse impact on any underlying untreated caries or periodontal disease because of the difficulty facing patients in maintaining oral hygiene unless these problems are dealt with prior to treatment. Any bad oral hygiene habits will need to be corrected at the same time, to prevent problems from reoccurring. As the questions ask students to identify any problematic teeth by FDI notation or enter 'None' if none of the teeth had problems; the CAL program provides students with free response boxes for their answers.

The first question asks students to check the 'OPT' to see if any teeth (including the 8s) are missing. Having already answered a similar question in the intra-oral section (Question 6, Section 6.4.1), most of the students (26/28 sets) have no problems identifying 'None' as the answer. Of the remaining sets, the QSR/N6 anslysis reveals that Helen and Isabel do not bother answering the question, moving straight to question 28 whilst Winifred, Michael and Natalie all choose 'None' but pressed the <enter> key without typing anything into the free response box. The transcripts also show several students counting the teeth on the X-ray before choosing their answer, for example:

Henry: Type in those teeth which are missing on the x-ray. ***[Laura yawns]*** None. [...] Let's just check a minute. 1, 2 , 3, 4, 5, 6,7,8. 1, 1, 2, 3, 4, 5, 6,7,8. 2,3,4,5, 6,7,8. 1,2,3, 4, 5, 6,7,8. None. ***[Laura nods, Henry enters 'None']***

Others look at the 'OPT', then say 'None', a response accepted by their partner without further comment, for example:

Leonard: … ***[chooses 'OPT']*** I reckon none. What do you reckon?
Mary: Ok. None.
Leonard: None. ***[enters 'None']***

The second radiographic question asks students to identify any teeth with caries that might require treatment – an essential pre-requisite prior to orthodontic treatment. One clue that is missed by several students is that they have been informed earlier in the program (before entering the intra-oral section) that JB's oral hygiene is good and her caries experience low. Although not made explicit, students are expected to check shadows on the 'OPT' that might indicate the presence of a carious tooth against the views of the models to see if there is a problem that required treatment, as Kevin notes in the post-session interview:

Kevin: This area. ***[referring to the lower right lateral incisor and lower right canine]*** I thought that was carious, but I suppose … I should have checked the models, yeah, and the models look fine, don't they? Can't see anything wrong with the models…

Kevin is not the only student who misunderstands what is required – a significant proportion (9/27 sets) enter an answer other than 'None'. The QSR/N6 analysis reveals that, after entering their answer, 2 sets (Elizabeth and Felicity, Henry and Laura) move onto the treatment planning section without further comment about why they are wrong. Other students do comment on their answer, usually realizing that filled teeth do not count after reading feedback provided by the program:

Wayne: ***[Una enters '172747']*** That seven. Oh! They don't require treatment! **Una**: Oh! They don't require treatment. They've been treated. Ok.
Ulysses: … ***[enters '1727']*** Oh! **Victor**: Tsshphw. **Ulysses**: ***[enters 'None']*** Ok, so it doesn't count teeth that have been filled. **Victor**: No.

Some students check the models pre-feedback, for example Ian, who like Kevin suspected the lower right lateral incisor and canine as being carious, checks the 'Occl' before answering the question in response to James' query as to whether or not the shadows might just be 'marks' on the 'OPT':

Ian: … We're looking at 42 and 43 ***[types in 4243, but doesn't press <enter>]*** **James**: It's probably just a mark, actually. **Ian**: Hmm… What do they look like – in reality? That's the thing ***[chooses 'Occl']***- they don't look to have any humongous cavities in them, do they? Go for none. ***[deletes previous answer, enters 'None']*** Yeah.

Leonard and Mary have a similar conversation about the lower right lateral incisor and canine:

Leonard: ***[chooses 'OPT']*** Grossly carious. **Mary**: ***[points to lower right incisor region]*** There? **Leonard**: ***[chooses 'Labial']*** It doesn't look as if they're going to be a problem ***[declarational, chooses 'OPT']*** **Mary**: ***[points to lower incisors]*** No, they don't look a problem. **Leonard**: No. None. ***[enters 'None']***

In session 6 Gareth helps Xavier reach a similar conclusion about using the models, noting that in real life the quality of the 'OPT' displayed on the screen is:

Gareth: … as good as it normally gets. If you want to look at the x-rays, for an exam, what would you do?

... And when it comes to the metal filling?
Xavier: Yes.
Gareth: You really can't tell if it needs treatment there.
Xavier: Yeah.
Gareth: So what would you do?
Xavier: Well, I'd have to go back to the mouth, but it's not here. The models.
Gareth: ... That's right ...

Brian suggests that, in reality, after checking in the mouth for any caries on clinic, a dentist would next:

Brian: ... look at the OPT, and if you couldn't tell, you'd take a bitewing radiograph...

However he advises against taking the question out unless it is relevant, because:

Brian: But there are some cases where it's patently obvious [there are caries] on the OPT at least, and so once again you don't want to put that question in only where it's obvious otherwise they get the idea that the question is only asked where there's an affirmative...

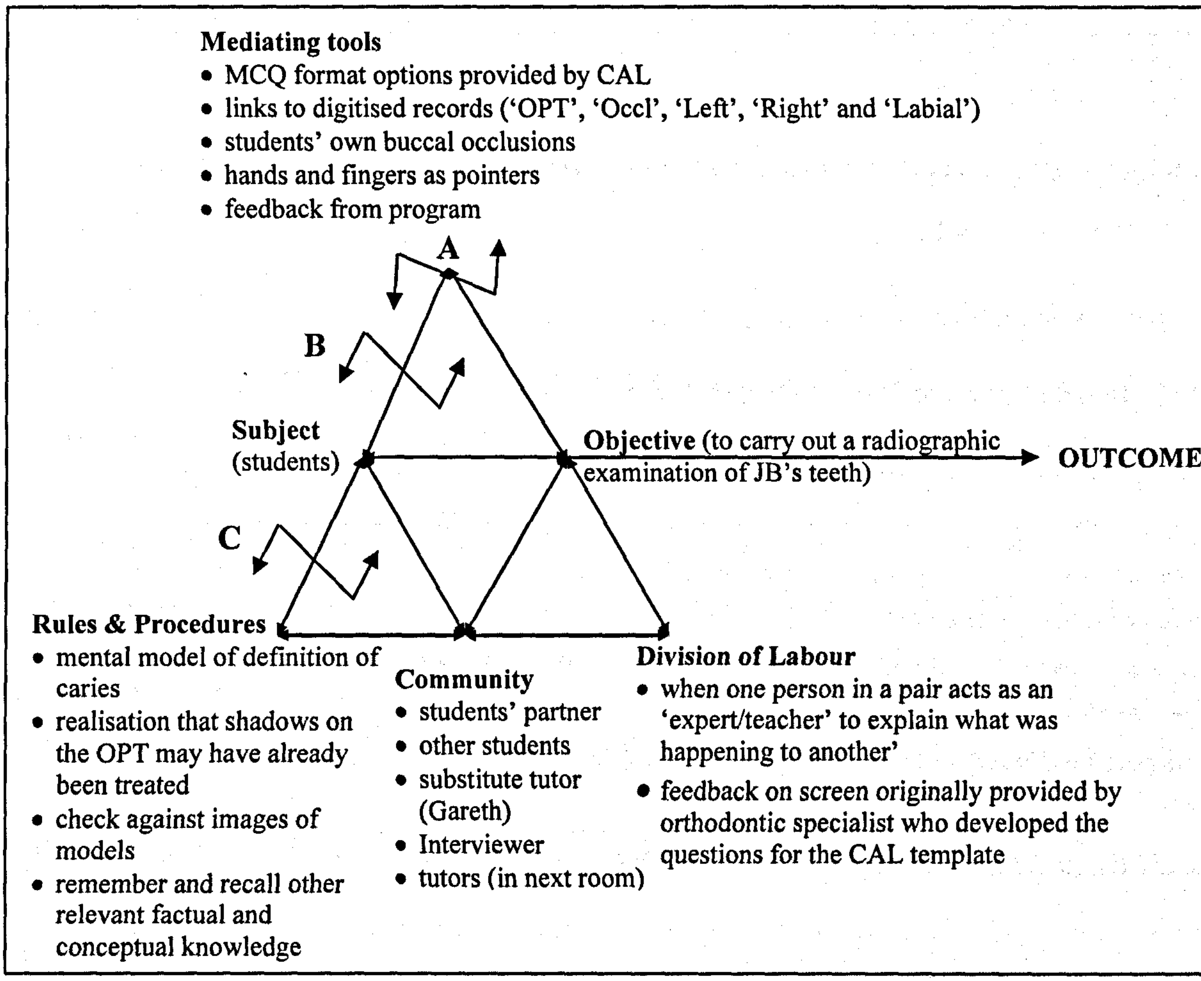
Students again seem to have a problem because they rely on just one record, the 'OPT' – perhaps because their attention is distracted by the sub-heading of "radiographic examination" displayed on the screen – rather than checking against the various digitised images of models. As a result they identify and select teeth that have already been filled.

Analysis of the transcripts suggests that for some students the nature of the activity (a radiographic examination) has resulted in a primary contradiction (A) within the constituency of the tools in choosing the correct records (the models as well as the 'OPT') and secondary contradictions (B and C) in understanding how to use these tools and the procedures they need to follow to judge whether carious teeth are present (Figure 6.5).

The majority of students (18 sets) do answer the question correctly and most of the remainder seem able to work out from the feedback and each other that they should use views of the model to check whether there is a caries problem associated with any of the shadows on the 'OPT'. Again this indicates that increasing familiarity with orthodontic assessment will help students understand how to answer these questions.

The final question in the radiographic section asks students to use FDI notation to identify any regions with pathology of the roots and surrounding bone. The QSR/N6 analysis shows that, like the radiographic question about absent teeth, students do not experience any real problem answering this question, with 27/29 sets correctly entering 'None', the other 2 sets again forgetting to type "None" before pressing <enter>.

Figure 6.5: Activity system for judging whether or not the case involved carious teeth



6.6 The case summary

The assessment section ends with a brief summary of the case, in which the importance of the stacking of the upper third molars is highlighted. As with the introductory 'e-book' in the pilot study, the level of interactivity between students changes during this part of the program. Students tend to sit quietly reading the text on the screen, providing far fewer opportunities to draw inferences about their conceptions of orthodontics.

Like Yvonne (Chapter 5) some students are recorded asking their partners or Gareth about 'upper molar stacking'. For example, although later events indicate that her comments are ignored, Anne raises a question about upper molar stacking as Belinda read out the case summary:

Belinda: ...Third molars are present on the radiograph and there is evidence of upper molar stacking. **Anne**: Upper molar stacking? I don't remember seeing anything about upper molar stacking...

Laura seems to ask a question about upper molar stacking at a similar point in the program. Finally Gareth spends time discussing the case diagnosis and summary with the individual students as they work through the case assessment summary. Recorded in the observation notes is the emphasis he places both on the crowding around the upper third molars in response to questions about the upper molar stacking and the importance of considering how that crowding might be relieved when deciding on a course of treatment:

Victoria: ... What, what's upper molar stacking? **Gareth**: From the crowding they're ... all coming together... That is stacking. Can you see? That's why they aren't level. **Victoria**: That's stacking? **Gareth**: Well, you see, it seems like they crashing together. **Victoria**: Oh, ok.
Winifred: ... What's upper molar stacking?... **Gareth**: It is exactly what it says ... when they're coming up underneath each other. ... They're stacking up. **Victoria**: Should you leave them alone? **Gareth**: You can, you can, but it's really not such a good idea... You can leave them. But if you want to relieve upper molar stacking, you need to take it into account in your treatment plan generally...

Not all students are confused by the term "upper molar stacking'. For example Kate suggests that the presence of upper molar stacking implies extractions will be required to make room for the 8s:

Kate: *[reads]* ...Third molars are present on the radiograph and there is evidence of upper molar stacking. Ah, the upper arch won't have enough space due to crowding to move this down ***[points to upper right canine]***...

By this stage in the program students seem confortable using FDI notation when referring to teeth. It is possible that the questions provided by the program relating to the occlusions, a fundamental part of orthodontics, have encouraged students to practise using the specialist terminology associated with the topic.

6.7 Chapter summary

This chapter started with an overview of the results of a statistical analysis of the quantitative data collected in the study before discussing the findings of the QSR/N6 analysis of the qualitative data obtained from the observation notes and transcripts of audio and video recordings.

After considering how previous experience of orthodontics might influence students' motivations and understanding of orthodontics, the chapter followed students as they worked through questions they need to consider when carrying out an orthodontic assessment, including some that were not necessarily relevant for treating JB. The students quickly got used to using and finding their way around the program, rarely mentioning the computer itself after question 6, possibly helped by the strong linear structure underpinning the narrative design of the program. Despite the potential "drill & practice" nature of the program, students made very little use of the extra material provided in hypermedia format in a separate glossary file, and none whatsoever of the introductory e-book.

Several students were observed adopting a "trial and error" approach to answering some of the questions and coming to terms with using specialist orthodontic terminology, using what they have discovered to answer similar questions later in the program. Within each sub-section activity theory was used as a framework to identify any contradictions within and between each constituency that might cause problems in assessing the case. As well as learning how to use the symbology specific to orthodontics and which records to use to answer each question, this was the first time that the majority of students had to deal with the complexity resulting from using records taken from a real patient. It was suggested that gaining familiarity with using programs based on the CAL template and increasing experience of assessing orthodontic cases could be expected to help students carry out orthodontic assessments as they gain experience and confidence in the topic.

Chapter 7: The Treatment Plan

Chapter 7: The Treatment Plan

7.1 Introduction

This chapter explores the interactivity that occurs as students answer questions designed to take them through a suitable plan of treatment for JB. In terms of Anderson's *et. al.* (2001) taxonomy of educational objectives this problem-solving activity can be described as asking students to use cognitive processes involving the remembering, understanding, analyzing and applying of procedural knowledge backed by a solid recall of factual and conceptual knowledge to arrive at a suitable treatment plan for the case (see Appendix A, Tables A1 and A2).

Using activity theory as a framework, this chapter discusses students' responses to each decision in turn, concentrating on what happens when students encounter the unexpected. Of particular interest are students' reactions to decision 4, extraction choices, which are described in detail because this is where the complexity of the case departs radically from students' expectations of what is required.

To find out more about the interactivity that occurs as students work through the treatment plan, each decision will now be examined in turn, concentrating on what students' interactivity reveal about their underlying conceptions of orthodontics that might be influencing their responses to the questions.

7.2 Decisions 1 and 2: timing and outcome of treatment

7.2.1 Timing of treatment

The first decision presented to the students is "Should this case be treated?" Although it could be argued that this question might be redundant in a computerised case study designed to support students as they learn about orthodontics, it has been kept as it is a question that dentists need to consider every time they make an orthodontic assessment. In mild cases the risks and social inconveniences may outweigh the benefits of treatment.

The second part of this question asks whether treatment should be instituted at once or delayed.

Most students seem distracted from considering the whole case by the presence of the partially erupted upper right canine (13). Most (22/29 sets – 15 opting for a delay of 6 months, and 7 for a year or more) opt to wait before starting treatment even though the tooth is effectively prevented from erupting any further. For example:

Tina: ... I'd want to wait for that tooth ***[points to 13]*** **Sophie:** What do you reckon? Wait for that tooth to erupt? **Tina:** Yeah. I'd wait. Maybe a year or more? **Sophie:** Ok. ***[chooses 'Treat in a year or more']***

Table 7.2.1a lists the reasons given by students as recorded in the transcripts for wanting to wait before starting treatment.

Table 7.2.1 Reasons for chosen responses for timing of treatment

	Option chosen			
	Treat now	**Wait for treatment**	**No treatment required**	
Total Sets	6	23	1	
Set	**Wait for**	**Comments on why students wanted to wait, taken from transcripts**		
Anne, Belinda & Christine	6 mths	Christine suggests treating now, overruled by Belinda who wants to wait for the canine		
Elizabeth & Felicity	6 mths	Elizabeth initially suggests treat now, then decides that maybe they should wait for the canine		
Kevin	6 mths	Kevin says he wants to wait for the canine to erupt		
Ian & James	6 mths	James suggests wait for canine, Ian agrees		
Michael & Natalie	6 mths	Michael suggests wait for canine, Natalie agrees		
Olga & Peter	6 mths	Peter suggests wait for canine, Olga agrees		
Queenie & Rachel	6 mths	Rachel suggests wait for canine, Queenie agrees		
Ulysses & Victor	6 mths	Ulysses suggests wait for canine, Victor agrees		
Una & Wayne	6 mths	Wayne suggests wait for canine, Una agrees		
Adam & Bill	12 mths +	Adam suggests waiting, Bill agrees		
David & Edward	12 mths +	Edward suggests wait for canine, David agrees		
Jennifer & Kate	12 mths +	Jennifer suggests wait for canine, Kate agrees		
Nigel & Oscar	12 mths +	Nigel suggests waiting, Oscar agrees		
Sophie & Tina	12 mths +	Tina suggests wait for canine, Sophie agrees		

This reaction may be understandable as the students have been taught that it is:

Brian: ... a general orthodontic principle, you wait until canines have erupted before deciding on treatment, so I understand why they are saying this.

However as the upper left canine has erupted fully students should be asking:

> **Brian**: why … the canine is fully erupted on the other side of the mouth … and only partially erupted on the right.

Furthermore students are expected to use the information provided at the start of the intra-oral part of the program (Section 6.4), where they are given the information that the patient is dentally advanced for her age. In question 6 nearly all the students note that at least three of the 7s are present in the mouth (Table 6.4.1), something that would not normally be expected before the age of twelve. Students are therefore expected to realise that they have in front of them records from:

> **Brian**: … a patient who's dentally approaching twelve, and if you haven't got a canine down when they're dentally approaching twelve, then there's something wrong,

The only student who mentions that JB is dentally advanced for her age (suggesting that she should be treated now) allows himself to be over-ruled by his partner, eventually agreeing to leave the case untreated:

> **Henry**: Well, she's quite mature dentally … so I think treat now. What do you think?
> **Laura**: I agree with no treatment.
> **Henry**: Left untreated?
> **Laura**: Uh-hn.
> **Henry**: Oh, we'll have yours. ***[chooses 'Left untreated']***

Other students mentioned JB's age but do not seem to notice that she is dentally advanced for her age. For example when Victor asked about JB's age, Ulysses suggests waiting until the canines are fully through, with Victor picking up from the feedback that treatment could start immediately because more space was required for the 13:

> **Ulysses**: ***[chooses 'Face', 'Labial', 'Occl']*** I think we should wait until that's there. ***[points to upper right canine]***
> **Victor**: How old is she?
> **Ulysses**: 10 years
> **Victor**: Wait 6 months? […]
> **Ulysses**: Well, yes, the canines aren't fully through. I think we should wait until the canines are through, don't you?
> **Victor**: Yes, we need to wait for the canines … Well, it says that the sooner space is made available for the upper right canine the better, and that makes sense, so yes, treat immediately.

Several times students working in pairs agree with a partner's suggestion to wait for the canine to erupt, even if they initially propose immediate treatment. For example like Henry Belinda overrode Anne's suggestion of 'Treat now' because:

> **Belinda**: ... that there canine's not fully erupted. ***[points to 13]***
> **Christine**: True. What is it you want to say.
> **Belinda**: What is it YOU want to say ***[chuckles]*** Six months? ***[chooses 'Treat in six months']*** In fact there's every reason to begin treatment at once. ***[to Anne]*** Sorry.

Elizabeth and Felicity also decide against immediate treatment:

> **Elizabeth**: Well, we might as well treat it now. We don't want to – Unless you wait ... for that to come through ***[leans forward, points to 13, then leans back in the chair and folds her arms]***. Treat in a year, or =
> **Felicity**: = six months?
> **Elizabeth**: Yeah.
> **Felicity**: Oh, alright! ***[chooses 'Treat in the next six months']***

But waiting is unlikely to make a difference because the upper right canine cannot erupt unless space is made for it (Stephens, 2004). Furthermore:

> **Brian**: ... the longer they wait, the more the lower crowding's going to increase, until they get the 7s out, which will actually freeze the crowding where it is, which is acceptable. So if you'd waited for ... another year, I think that they would be into taking out 4s, 5s and upper and lower fixed. So that's why it should be treated NOW.

Some students use what they see in the digitized records on the screen to reflect on how they might actually treat the case when trying to decide when to start treatment:

> **James**: ... if you let that erupt = ***[points to 13]*** ... = and put a removable in just to tip these into place, I think you'd find – there's hardly any crowding, is there?
> **Ian**: No. |Would you –?|
> **James**: |What do| you reckon? Treat in six months? ***[door opens & closes]*** ...
> **Ian**: Uh huh.
> **James**: ***[chooses 'Treated in six months]*** Ok.

Later Ian and James offer more explanation about their choice, showing how they adjust their reasoning having read the feedback on the screen:

> **Interviewer**: You opted to wait for six months on the extractions. Can you explain why? ...
> **James**: Didn't we want the 3 to erupt |a bit more?|
> **Ian**: |... wanted the 3| to erupt more then, yeah. Because it was barely erupted, wasn't it? I mean, there was just a tip of it showing...

At this point Ian mentions he thinks that 13 might be stuck because:

> **Ian**: ... I suppose looking at the OPT... it was probably quite submerged, wasn't it, and locked in by ... maybe it wouldn't have erupted more...
> **James**: Yes...

Having suggested immediate treatment Peter also allows himself to be overruled when Olga suggests waiting, agreeing that they should indeed wait for 13 to erupt fully before starting treatment. They are able to use feedback from the program to work out that they do not need to wait for the canines to erupt fully before starting treatment:

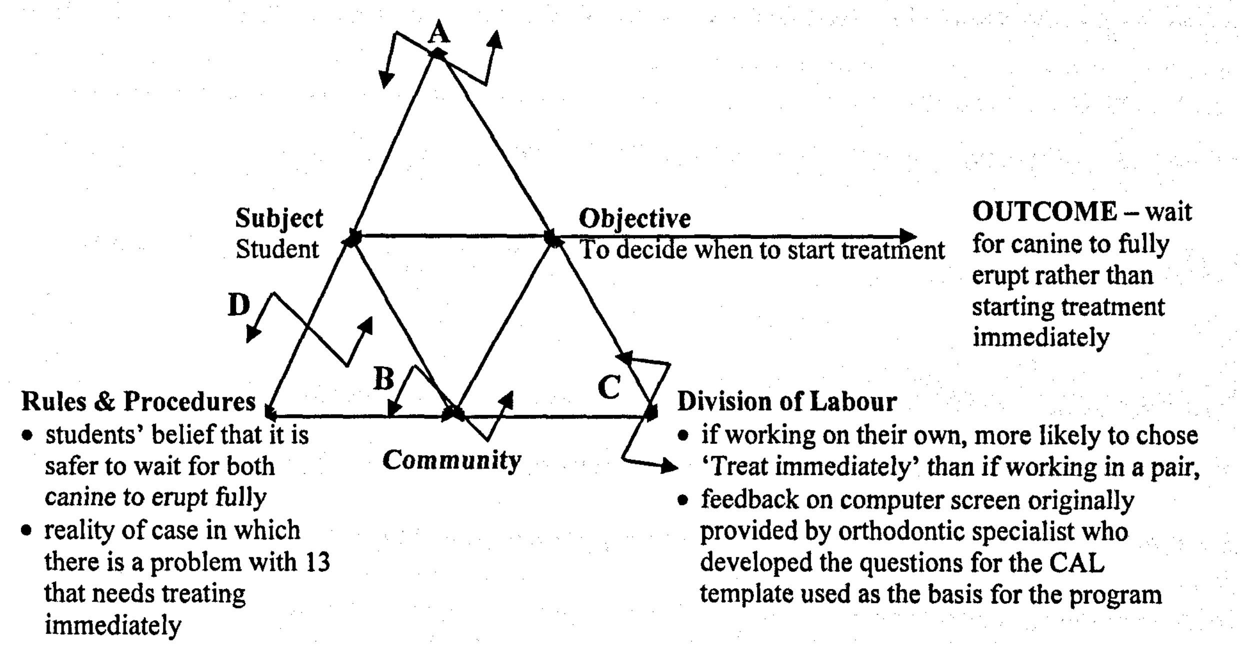
Peter: Let's treat now then...
Olga: ***[points to 'Treat in the next six months']*** That one.
Peter: That's got to make space for the upper. ***[points to 13 on the 'Occl', chooses 'Treat in the next six months']***
Olga: How do you know that that cusp must come up?
Peter: I suppose you haven't got to wait for it to erupt. ***[points to 13, both laugh]***

Figure 7.2.1 shows the activity system that represents the potential source of contradictions in students' understanding about the timing of treatment arising from primary and secondary contradictions within the system.

Figure 7.2.1: Activity system for deciding on timing of treatment

Mediating tools

- MCQ format options provided by CAL question on timing of treatment
- orthodontic terminology & links to digitised images of patient's records ('Labial', 'Occl')
- hands and fingers as pointers to focus attention
- feedback provided by CAL program
- actual age versus dental age of patient
- Presence of 7s – not usually seen before the age of 12



The main difficulty for the students appears to come from the problems they have in identifying and using other information about the case that lie outside the immediate focus on the partially erupted 13. Students seem to have trouble recognising that the presence of 7s and a fully erupted upper left canine supports the statement that the patient is dentally advanced for her age.

The activity system suggests that one primary contradiction (A) arises in the constituency of the mediating tools in understanding the implications of having to deal with a case in which there is one partially and one fully erupted canine in the upper arch.

Another primary contradiction arises within the constituency of the community due to presence of partner student as (B) leading students to make a decision to wait for the canine to erupt fully. A third primary contradiction occurs in the constituency of the division of labour due to presence of partner student – suggesting that pairs adopt a 'safer' approach of waiting for the canine to erupt before beginning treatment (C) compared to students working as individuals. Finally there is a secondary contradiction between students and the consitutency of rules and procedures in understanding which procedure they should be rely on to decide when to start treatment (D).

A χ^2-test comparing option choices on treatment timing supports this finding, showing that individuals are significantly more likely to chose 'treat now' than those working in pairs ($p<0.01$, $df = 1$, Appendix D, Table D9a). Although the small sample size means this result should be treated with caution it is possible that students in pairs allowed themselves to be overruled by a partner.

Once again feedback from the program and talking to their partners seems to help most students realise why JB needs to have immediate treatment.

7.2.2 Outcome of treatment

In decision 2 students decide whether they should aim for an ideal or a compromise outcome. All the students in this study agree that an ideal outcome is required, with little discussion even between pairs on this question.

7.3 Decisions 3 and 4: deciding on extractions

For decisions 3 and 4 the program asks students to answer four questions relating to extractions in first the lower and then the upper arch. The first two questions ask if extractions are necessary (Decision 3), the next two ask students to use FDI notation to identify sites for extractions (Decision 4). As discussed previously (Section 6.4.2), the order is important, particularly at this stage of planning a course of orthodontic treatment. Students sometimes discuss which teeth they feel should be extracted whilst deciding whether or not extractions are required; carrying these discussions over into the questions associated with Decision 4. For example, when reflecting on the upper arch, Ian comments:

Ian: Having regards to the degree of crowding and the patient's profile ... upper extractions ... gotta be. Gotta make space. You've got to make space for this - you've got to do it. ***[points to 13]***
James: Whip those 4s out.
Ian: Yep. ***[chooses yes]***

Just over half the sets (16/29) opt for no extractions in the lower arch. Of the remainder, 10 sets feel extractions would be required, 3 that it is too early to say – perhaps unsure whether or not to wait for the upper right canine to erupt (Table 7.3a).

Table 7.3a: Deciding whether extractions were required

	Extractions required (No. of Sets)	No extractions required (No. of Sets)	Too early to say (No. of Sets)
Lower arch	10	16	3
Upper arch	20	5	3

Most students (20/28 sets) opt for extractions in the upper arch with 5 sets arguing extractions are not required and 3 sets wanting to wait. One reason recorded for opting for extractions is the belief that the partially erupted canine needs room to erupt. Other students feel that extractions will be required because the upper arch is more crowded, having reflected on feedback about extractions being needed in the lower.

The QSR/N6 analysis indicate that students no longer have problems using FDI notation when it comes to entering their choice of extraction sites into the free response box displayed on the screen. Furthermore as they work through the program some students are observed switching between the two different systems for identifying teeth. For example, whilst reflecting on the lower arch extractions, Jennifer switches from discussing premolars to talking about 4s when discussing extractions in the lower arch:

Jennifer: ... First premolars, don't you think?
Kate: Yes, so what is it?
Jennifer: It's 4, 34 – 44 ***[Kate enters '3444']*** Oh! ...

This 'switching' of tooth identification terminology is first seen in the intra-oral section of the case assessment, for example in question 15 when Christine talks about the incisors and the canine:

Christine: ... Oh, I see, when we did the 1s and the 2s, we did the canine...

In comparison to the responses to question 6, the fact that students no longer show any difficulties using FDI notation suggests they are becoming more comfortable using the specialist symbology. When deciding which teeth should be chosen for extraction, the use of QSR/N6 facilitates the building of a phenomenological profile of the sets based on combining a qualitative analysis of the reasons suggested by students captured and transcribed from the video and audio recordings with the quantitative data contained in the computer log-files. According to Brian, students have previously been provided with a paper on extracting 7s as part of a reading list. Students can also refresh their memories of orthodontic extraction choices by reading (or re-reading) the relevant chapter on Treatment Planning in the orthodontic textbook (Chapter 8, Houston, Tulley and Stephens, 1992), again displayed as a recommended reading list on the introductory screen at the start of the program.

Brian points out that if students have read the textbook they will find that in this particular case the 7s should be chosen for extraction in order:

> **Brian:** ***[looking in Houston textbook]*** ... "To relieve impaction of lower third molars." So we've got one reason. "To relieve minimal lower incisor crowding" ... "To prevent lower incisor crowding"... So it's that, that ***[turns page]*** and that! They've actually got three out of the four possible reasons ...

The key issue is:

> **Brian:** ... that the lower arch is acceptable as it stands... But you don't want it to crowd anymore... So there's too little crowding to justify premolar extractions. And the two alternatives are 1: do nothing – in which case the crowding will almost certainly get worse. Or 2: take out the 7s where one knows the crowding will not get any worse, or at least if it gets worse it will be very marginal.

In Brian's view it is perfectly logical to take out 7s because the mild crowding at the front of the mouth means that a fixed appliance will be required to close the excess space following premolar extractions. Compared to the additional complexity of the treatment required if 4s have been extracted Brian explains that the only problem with extracting 7s is that:

> **Brian:** ... the third molars ...may not come into as good a position as the 7s were in. But it's better to think of that, because ... what it will mean is that you might have to tidy up the position of the third molars later on. But you have a better than 50% chance that you won't have to tidy up the 8s as they will come into a good position. As indeed they did in her case...

Students can refresh their memory of the case by clicking on one of the buttons at the bottom of each screen in the treatment planning section giving access both to the digital images of JB's dental records and to a copy of the case assessment summary provided at the end of the radiographic section of the program. As will be seen it is no exaggeration to say that the students appear stunned to discover that second molars, rather than the expected premolars, are chosen for extraction. The extraction sites proposed in the feedback from the program cause consternation amongst the students.

Nearly all the students in the main study (25/29 sets) opt to extract 4s in the lower arch (Table 7.3b). Only 2 sets (Debbie, Adam and Bill) choose 7s in the lower arch. Analysis of the transcripts reveals that Debbie chooses 7s having seen Charles answer the question:

Debbie: So, which extractions in the lower arch. The premolars?
Charles: Yes, the 4s. *[enters '3444']* Oh. 7s?
Debbie: 7s? I don't understand? Why the 7s?
Charles: I don't know. It doesn't make sense. [...]
Debbie: *[enters '3747']* Never mind...

Adam and Bill would have chosen 4s but enter 7s after overhearing Debbie and Charles discussing the case:

Adam: ... Yeah. Alright. I always remove 4s, but right.
Bill: *[turns to Debbie]* Did you say remove 7s?
Debbie: Yeah, we wanted to remove 4s, and they say 7s.
Adam: Ok, so we'll try for the 7s and see what they say. Lower arch.

And, even though Debbie, Adam and Bill have entered 7s in the lower arch following feedback from Charles, all four students continue to reflect on why these teeth were chosen post-feedback before opting for 4s in the upper arch:

Bill: Why are the first premolars inappropriate?
Debbie: I don't know. That's what we were talking about ... because they're always saying that they'd always be premolars.
Adam: Well, are we saying that it should be 5s, I mean, saying take out 5s?
Bill: Yes, if it was mild and ... proclined, take out 5s.
Debbie: Yeah
Charles: Well, why take out 5s? You'd need a fixed appliance.
Adam: Yes, but if you take out 7s you'd definitely need a fixed appliance.

A similar reaction was observed from both students in the pilot study (Chapter 5), suggesting that the reality of this case departs radically from students' expectations of the procedures they should follow for planning a course of orthodontic treatment. The source of this consternation seems to be the discovery that 7s are recommended for extraction.

Table 7.3b: Overview of extraction choices

Set	Lower arch		Upper arch		Group	Comment
	Suggest	Chosen	Suggest	Chosen		
Kevin	4s	14243444	7s	1727	3	Identifies both mild labial crowding & posterior crowding
Leonard & Mary	4s	3444	4s or 5s	1525	3	Recognise level of crowding, bringing together both posterior and anterior crowding in post-session interview,
Elizabeth & Felicity	4s	1424	4s	1424	3	Recognise posterior crowding, and include mild crowding after feedback and in post-session interview
Ian & James	4s	3444	7s	1727	2ii	Recognise balance and mild crowding
Henry & Laura	4s	3444	4s then 7s	1727	2ii	Recognise balance and posterior crowding.
Nigel & Oscar	4s	3444	7s	2717	2ii	Recognise balance and posterior crowding
Queenie & Rachel	4s	3444	4s then 7s	1727	2ii	Recognise balance and posterior crowding
Ulysses & Victor	5s	3545		1727	2ii	Recognise posterior crowding and balancing, opted for 7s. Do not consider labial crowding to be mild enough to justify 7s
Olga & Peter	5s or 4s	14243545	5s	1525	2ii	Recognise posterior crowding
Frank & Gita	4s	3444	4s/5s/7s	1525	2ii	Recognise balance and posterior crowding
Ralph	4s	3444	6s	1626	2ii	Recognises posterior crowding
Helen & Isabel	4s	3444	7s	1727	2i	Recognise need to balance
Pamela	5s	3545	7s	2717	2i	Recognises need to balance
Sophie & Tina	4s	3444	7s	3747	2i	Recognise need to balance, use wrong FDI notation. Would want a 2nd opinion as GDPs.
Charles	4s	3444	1424	1424	2i	Works with Debbie
Debbie	4s	3747	4s	1424	2i	Works with Charles. Recognises need to balance. On log-files enters 1727 after Charles chose 1424
David & Edward	4s	1424	4s	1424	2i	Recognise need to balance
Jennifer & Kate	4s	3444	4s	1424	2i	Recognise need to balance
Quentin	4s	3444	4s	1424	2i	Recognise need to balance
Steve & Terry	4s	3444	4s	1424	1	Mention balance and mild crowding, but do not make connection with 7s.
Anne, Belinda & Christine	4s or 5s	3444	1424	1424	1	Mention all 3 reasons separately without making connection with extracting 7s
Adam & Bill	4s or 5s (7s overheard)	3747	1424	1424	1	No idea why 7s are chosen, but return to reflect on extractions later in the tutorial.
Michael & Natalie	14	14	1424	1424	1	No idea, do not comment further
Una & Wayne	4s	3444	5s	1525	-	Turn to Gareth for help in recognizing balance. Recognise posterior crowding
Victoria	4s	3444		1727	-	Turns to Gareth for help
Xavier	4s	3444		1727	-	Turns to Gareth for help
Winifred	Tutor (7s)	3444		1727	-	Turns to Gareth for help
Xenie	4s	3444		1727	-	Turns to Gareth for help
George	4s	3444	4s	1424	-	Leaves CAL room early, reasons for choice not given, but does admit having worked on the case previously as a "board study"

The QSR/N6 analysis of the transcripts reveals that, post-feedback, students suggested one or more of three reasons why 7s were chosen:

1. The posterior crowding
2. The mildness of the incisor crowding

3. Extractions in the upper arch need to "balance" those in the lower arch.

However students using the term "balance" appear to do so imprecisely. In orthodontics a "balanced" extraction is the term reserved for when a tooth extracted on one side of an arch is balanced by a similar extraction on the other side of the arch to maintain the centreline of the dentition with respect to the face. An orthodontist, when referring to an extraction in the upper arch opposing one in the lower, should normally refer to it as a "compensating extraction" that is carried out to maintain the buccal occlusion:

> **Brian**: ... the trouble is [that students have] got this great hang-up about balancing... If you say: "Why do you balance?" ... And they say "to prevent centreline shift". "Yes. And when do you get centreline shift?" "When there's incisor crowding." "Is there incisor crowding here?" "Uhhh. No." So you don't have to balance....

Just one set in this study (Ulysses and Victor) refers to a compensating extraction in the same breath as talking about "balancing" extractions in the upper arch:

> **Ulysses**: I suppose you've got to be careful to balance the extractions here. You have to have compensating extractions, don't you.
> **Victor**: Hmm. I suppose.
> **Ulysses**: Take out the 7s? ***[shakes head]***
> **Victor**: I suppose you take out the 7s to compensate and make room for the 8s.
> **Ulysses**: ***[enters '1727', both read feedback]***

The term "balancing" has been retained in inverted commas where students were recorded as apparently referring to compensating extractions in their discussions amongst each other (however incorrectly), rather than using the more orthodontically correct term of "compensating extractions", because the focus of this thesis is on what can be inferred about students' understanding of orthodontic treatment planning and not the subject of orthodontics itself.

As with other phenomenological studies (Marton and Säljo, 1976a,b; Fransson, 1977; Entwistle, 1988a), although every student's reaction can be described as unique at one level, on another it is possible to identify three distinct groups of students by their level of understanding, particularly relating to why second molars are chosen for extraction (Table 7.3b). Having identified possible reasons suggested by students for extracting 7s, the sets are split into three groups (Table 7.3b). Group 1 consists of students who appear unable to draw conclusions as to why 7s are chosen. Group 2 students can come up with one or two reasons for extracting 7s, but not all the reasons.

As most students fell into the second group this group is sub-divided, with those at level 2i only able to identify the need to "balance" extractions whilst those at level 2ii are able to identify the degree of crowding (particularly around the 7s) and the need to "balance" extractions with those in the lower arch. Finally those in group 3 recognise both the posterior crowding and the mild incisor crowding as reasons why 7s are chosen for extraction. The criteria for each group are laid out in tabular form in Table 7.3c.

Table 7.3c: Descriptions of levels of student understanding of reasons for choice of extractions

Group	*Description*
1	Utter disbelief, stick rigidly to one procedural rule (always chose premolars). Focus on problem of 13. If students try to make sense of why 7s are chosen, may mention both mild incisor crowding and posterior crowding without connecting these reasons to the 7s
2i	After reflection on feedback students suggest extractions need to be "balanced" against those in the lower arch
2ii	Either chose 7s or, after reflection, suggest 7s for extraction in the upper arch either because of the posterior crowding or because of the mildness of the incisor crowding but not both
3	Despite expressing surprise to feedback seem to understand need for extractions for all 3 reasons, either immediately after receiving feedback in the lower arch or by end of session

The students excluded from this classification include George (who admits at the end of the session that he has worked on the case previously as a "board study") and Victoria, Xavier, Winifred, Xenie, Una and Wayne in session 6 who are recorded in the transcripts as receiving help from the tutor. Una and Wayne might have been able to identify posterior crowding as a reason without Gareth's help, because when discussing whether or not to extract teeth in the upper arch, Una feels it would be justified:

Una: ... because ... there's space for them to come in. ***[points to 8s on 'OPT'] ... [Wayne chooses 'Yes'] ...***

However before they could work through the feedback to the next question on their own, Gareth provides them with an answer:

Una: Which teeth should be extracted in the lower arch? Well, what do you reckon?
Wayne: The 4s? ***[enters '3444']***
Una: That's scary. It says the 7s here...
Wayne: Why should you take out the 7s?
Una: Why are you taking out the 7s?
Gareth: Because of these 8s sitting here...

The QSR/N6 analysis of the transcripts in session 6 gives no indication that either Ulysses or Victor, at the far end of the CAL room to Gareth, are consciously aware of what he is saying. As they are able to link the degree of posterior crowding with the need to "balance extractions" in the upper arch in their understanding of why 7s are chosen then, with the *proviso* that they might have been influenced by overhearing his words, Ulysses and Victor have been allocated to the 2ii sub-group of students.

7.3.1 Students in group 1

Just one set (Michael and Natalie) fail to come up with any conclusions as to why the program expected them to choose 7s for extraction. Although Michael suggests both the 4s, Natalie is so fixated on the upper arch problem that she seems determined to extract just the upper right first premolar (14) to make room for 13 – despite being asked by the program just for their choice of extractions in the lower arch. When the program goes on to ask for their choice of extractions in the upper arch, Natalie again refers to the canine when suggesting the 4s:

> **Natalie:** ... We want to let out the canine...
> **Michael:** That must mean here and here. ***[points first to the upper right first premolar, then the upper left first premolar]***
> **Natalie:** 14, 24 ***[enters '1424']*** The 7s?!!!

The mildness of the incisor crowding means the case could alternatively be treated by extracting:

> **Brian:** ... 7s on one side only... because you'd have to move the buccal segment back on one side to give the canine enough space. And then, in the lower arch, simply because having extracted in the upper arch, you carry out a compensatory extraction in the lower arch which allows the 8s to come forward together... So unilateral 7s would be entirely acceptable in this case, for people who thought "Well, I don't really want to risk having to upright two lower third molars, or on one side I could do it perhaps with a little local section appliance...

However this plan would require knowledge of a more advanced level than would be expected from undergraduates. In view of their lack of interactivity and reflectivity throughout the session it seems unlikely that either Michael or Natalie can be described as advanced orthodontically. Indeed despite expressing surprise that the 7s are chosen for extraction, Michael and Natalie move straight onto the next question without further discussion at that point, although they will eventually returned to the question of why 7s are chosen for extraction later in the program, when considering how they might design the removable appliances (Chapter 8).

Three sets (Adam and Bill; Anne, Belinda and Christine; Steve and Terry) are classified at the top of group 1, having mentioned either the posterior crowding or the mild incisor crowding without connecting these reasons to the extracted 7s. Adam and Bill believe the mild crowding indicated fixed appliance treatment will be required if 5s are extracted to move the 6s back into place apparently forgetting both the waiting 8s and without considering any possible need to "balance" the extractions:

Adam: Yes, but if you take out 7s you'd definitely need a fixed appliance.
Bill: ... The 7s are what they say

Whilst trying to decide whether or not lower arch extractions are required Christine mentions that the 8s were "stuck". This comment triggers reflective behaviour in all three students as they start to wonder, post-feedback, about their own 8s:

Christine: ... I think that those end ones there are stuck. ***[points to upper 8s on 'OPT']*** ...
Belinda: ... there's going to be inadequate room for the lower third molars –
Anne: I don't even know if I have any third molars or not. ***[feels inside her right cheek with her right hand]***
Christine: I don't know either – I might, but I don't think – neither do I.
Belinda: Mine's coming through, my upper one's coming down. ***[moves her cheeks speaking, feeling for the 8s with her tongue?]***

However when it comes to considering whether extractions are required in the upper arch Anne's earlier query about upper molar stacking is either forgotten or not taken up by the others. In the next question on extractions in the lower arch Anne, Belinda and Christine decide on the 4s because:

Belinda: ... We want it all done in the anterior segment, we don't want it done buccally, so if we take out the 5s, we don't have to bring = ***[brings hands towards body, palms facing the body, fingers pointing up]***
Christine: |Lower arch, lower arch|
Belinda:= |the teeth forward.| ... I reckon the 4s will need to come out.

Surprised at the feedback they still seem to have forgotten their previous comments about the lack of room for the 8s, apparently translating "7s are hardly ever extracted" as:

Belinda: ... you NEVER want to take out molars, surely?...
Christine: ... In that tutorial a couple of weeks ago they said that "You hardly ever take out 7s". Why are 4s wrong?...
Anne: Because if she's 10, then, no – she's too old to take out the Ds or Es, no.

Belinda goes on to suggest that she would prefer to extract 5s rather than 4s or 7s in the lower arch because:

Belinda: … that's not producing space up here ***[points to labial segment of 'Occl']*** **Christine**: No. That's what I said… **Anne**: = and … if you take the 4s out, the 4s out, the 5s and 6s will tend to move forward here ***[touches left hand side of 'Occl']***

Hence Belinda and Christine appear to agree with Adam and Bill that extracting the 7s is not the answer because:

Belinda: … If you did get rid of … the big 7s, the space = ***[touches lower arch of 'Occl']*** **Christine**: = would be too great, yeah.

Evidence that Anne, Belinda and Christine are ignoring the waiting 8s can be seen in their answer to the question on extractions in the upper arch, when Belinda comment that taking out the 7s would mean that:

Belinda: … you're going to have real problems with anchoring. You're going to have to bring all of these down ***[points to 6s with right hand]*** and all of these down.

Although a recording is not available for transcription purposes (Chapter 4), observation notes, together with the log-files, suggest that provisionally Steve and Terry can be categorised in group 1, having mentioned both the mild crowding around the incisors and the need to "balance" extractions in the lower arch with matching ones in the upper arch whilst apparently failing to make the connection between these features and the need to take out 7s rather than 4s.

Corresponding to students who adopt a surface approach to learning (Entwistle, 1988a), the 4 sets in the first group (group 1) seem to have little idea why they are being asked to extract 7s, and move on without attempting to probe any deeper. These students, particularly Michael and Natalie, seem to fit the model suggested elsewhere by Papert (1980) of students who do not link the procedure they are attempting to perform with their general store of knowledge, but merely change the answer when encountering an error without trying to examine in any detail, let alone change, their understanding of the underlying procedure.

In contrast to a layperson whose 'folklore' knowledge of the problems of crowded wisdom teeth might lead to ready acceptance of 7s for extraction, it seems that these students, following taught procedures, find it particularly difficult to overcome the training they have received. There is even evidence of a tendency to blank out information that does not fit the expected pattern – for example Belinda and Christine fail to recognise Anne's questions about upper molar stacking as possible clues as to why 7s are extracted.

7.3.2 Students in group 2

The bottom half of the middle group (level 2i) consists of 8 sets that all refer to the need to "balance" extractions in the lower arch with similar ones in the upper arch. Four of these sets (Charles, David and Edward, Jennifer and Kate, Quentin) choose 4s as "balancing" extractions in the upper arch, matching their earlier choice of 4s in the lower. For example Kate agrees without comment to Jennifer's suggestion of 4s to "balance the extractions" whilst David mentions after reading the feedback that he has forgotten that extractions in the upper arch would be opposite those in the lower. As Debbie again enters '1727' in the upper arch after reading the feedback on Charles' screen, she is counted as choosing '1424' for this question. The remaining 3 sets (Helen and Isabel, Pamela, Sophie and Tina) who mention just the need to "balance" extractions all switch to '1727' in the upper arch. For example, Helen justifies her choice of 7s to Isabel on the grounds that:

> **Helen**: Go for 7s this time... Because if you've taken the 7s out in the lower, then you = |need to balance | –
> **Isabel**: = |need to balance | = yes. ***[Helen enters '1727']***

In an example that illustrates Brian's concern about how easy it is to misidentify teeth for extraction (Section 6.4.1), Sophie realises that she has entered the FDI notation for teeth in the lower rather than the upper arch after agreeing with Tina's suggestion of extracting the 7s to "balance" the earlier ones:

> **Tina**: ... they need to balance.
> **Sophie**: Ok. Yeah. So you think the 7s?
> **Tina**: Yeah. I'm just telling you what it said earlier.
> Sophie: Ok. ***[enters '3747']***
> **Tina**: Ok. It was the 7s, but you've put them in for the lower arch ***both laugh]***
> Sophie: Oh, the upper arch. ALL RIGHT! OK! ***[Sophie re-enters '1727']*** Ok.

In the post-session interview Sophie and Tina express their unease at being asked to extract 7s not necessarily because they have misidentified teeth, but mainly due to their lack of practice. They are sufficiently concerned that they feel uncertain that they could:

Sophie: ... ever be prepared to extract 7s. Even if an orthodontic consultant was to ask me to do so as a GDP, I'd not be happy about it. **Tina**: I agree - I just don't feel very confident about extracting any teeth, certainly not at this stage in my training - I've just not had enough practice doing them...

Both are so convinced that 7s should "never" be extracted for orthodontic treatment alone that they insist they would:

Sophie: ... certainly want a second opinion = **Tina**: = yeah = **Sophie**: = yeah, and I'm not even sure I'd go ahead and take out the 7s, even then - I really just wouldn't be happy about it. **Tina**: True.

Their comments prompt the following reaction from Brian that can perhaps be considered typical of a consultant asked for a second opinion:

Brian: What incredible arrogance! ... "I wouldn't do what a consultant told me" – it is very odd... there are a lot of people [who] have this strange idea ... that somehow ... on the basis of incomplete knowledge and their own sort of straight reasoning in the absence of facts, [this] nevertheless entitles them to make decisions which overrule others who have more knowledge.

Belinda, Sophie and Tina are not the only ones to interpret "hardly ever" as "never", as Helen, Rachel and Queenie observe in their post-session interviews:

Helen: Yes, we didn't expect the 7s, we've been taught to take out 4s, or possibly 5s, but never the 7s.
Rachel: Yes, that was wrong, we've been taught to take out premolars. **Queenie**: Never the 7s. No. **Rachel**: No, it just didn't seem right...

The sets that are classified as meeting the criteria for the upper level of group 2 (level 2ii) do so because they are able to recognise either the posterior crowding (7 sets) or the mildness of the incisor crowding (1 set) as reasons why 7s are chosen for extraction in the upper arch. For example, having chosen 4s in the lower arch, Oscar uses the feedback to suggest that 7s might be extracted to relieve the molar crowding. In the upper arch he suggests the 7s to "balance" those in the lower. Oscar also refers to the need to "balance" extractions in the post-session interview:

Oscar: Well, I knew we had to balance the extractions, and if they really wanted the 7s to come out, ... then we had to go for the 7s again, but it felt strange...

Having initially typed '1424', but not pressed <enter>, Frank changes his mind, switching to '1525' to make more room for the 8s in the upper arch. After pressing <enter> he changes his response once more, this time to '1727', following Gita's suggestion that the upper arch extractions will need to "balance" those in the lower.Queenie and Rachel choose 4s in the lower arch and 7s in the upper. The transcripts show that when they first answer the questions they seem unsure why 7s will be extracted in the upper arch, apart from to "balance" those in the lower. However by the end of the program they are able to identify the need to let the 8s through as another possible reason for extracting 7s in the post-session interview:

Queenie: ... if the 7s have been taken out, then you need to take out the 7s in the upper to balance... And then... you have to extract the exact same upper molars in the upper arch. 'Cos you need to balance extractions... Because then you've got a good molar relationship on the 8s...
Rachel: The other reason may be to let the 8s through...

Olga and Peter, like Michael and Natalie, initially concentrate on the problem of the upper right canine, and end up misreading the question. Olga suggests that 5s should be chosen in the upper arch both to give 13 room to erupt and to provide more space for the upper molars:

Olga: I think the 5s should come out. I'd take out the 5s. Would you? What do you think? To give the upper molars room, and also to bring the canines back.

After Peter suggests extracting 4s rather than 5s in the upper arch they eventually settle on '14243545' for extraction, entering all four teeth (including the upper 4s) into the "Free Response Box" provided by the program for the lower arch extractions. Despite Olga's comments about the posterior crowding, they choose the second premolars (5s) in the upper arch, feeling that 7s are too drastic a choice for extraction. Either from the feedback, or from their reflections during the rest of the program, they are able to explain in the post-session interview that 7s may have been chosen:

Peter: ... because of those back ones
Olga: It looks as though it's relieving the back ones.
Peter: And they're more suitable, because you're making room for the canine.

Olga and Peter suggest that the source of their unease lay in the idea of extracting healthy teeth just to make room for the back teeth, echoing Yvonne's concerns in the pilot study (Chapter 5):

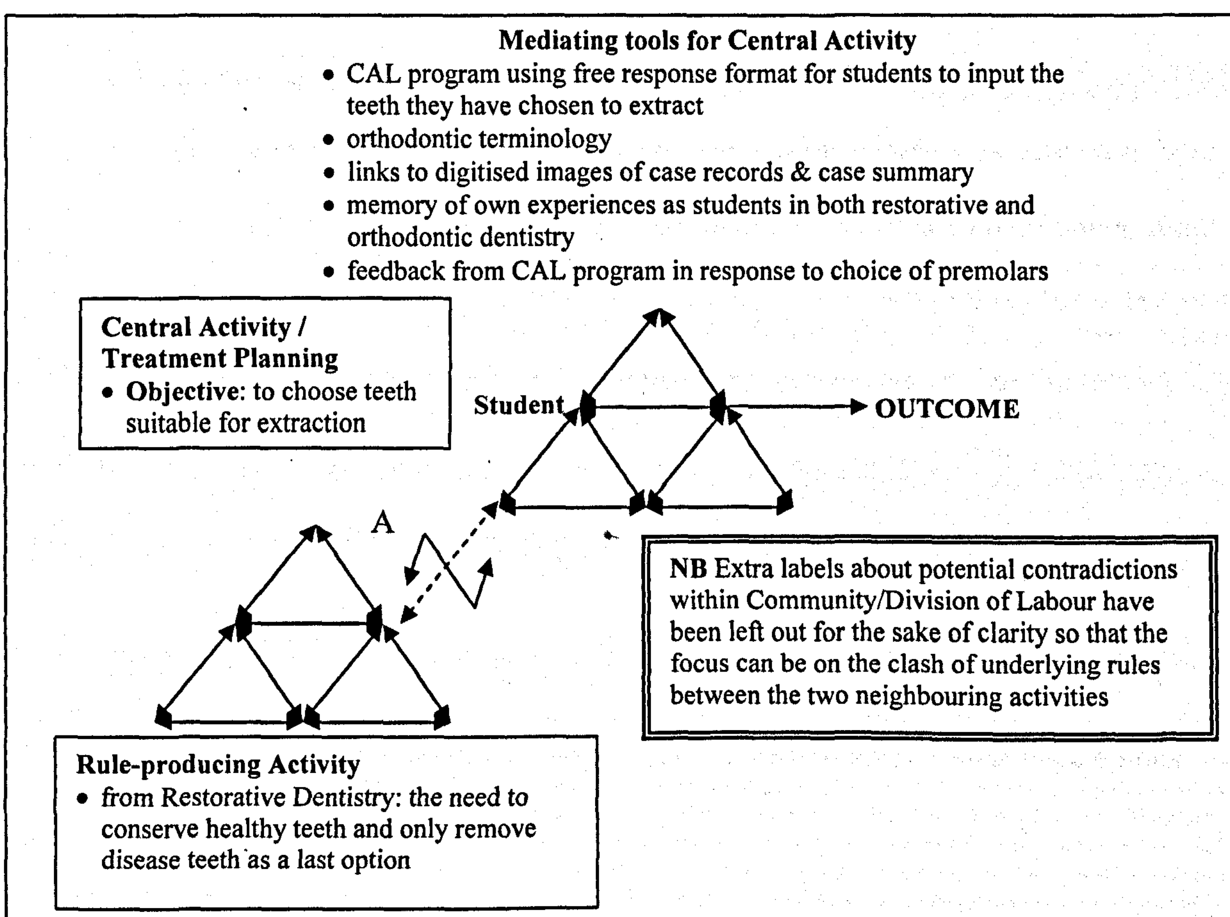
> **Olga**: ... You just assume that it would happen differently. That ... you don't take them out only if they're healthy. ... You take the bad ones out.
> **Peter**: You take the bad teeth out.
> **Olga**: Yeah, not if they're healthy... it just doesn't make sense to pull out healthy teeth. It goes against the grain for an orthodontist to pull out healthy teeth ... The thing is that if you take out the wrong tooth, then you can't really put it back in again.

James also raises this possibility as an issue in his post-session interview:

> **Interviewer**: How do you feel about having to take out healthy rather than diseased teeth?
> **James**: ... we've been taught that if the teeth are diseased, like 6s especially, because ... they are ... the first ... teeth to erupt, aren't they? And ... they're likely to be the ... first teeth that are likely to get restored in a child's mouth. And if you're going to take 6s out, then that's fine, if they're heavily restored...

Therefore one possibility for students' reluctance to extract 7s may be a potential quaternary contradiction (A) with a rule-producing activity in a neighbouring activity, in this case arising from restorative dental procedures (Figure 7.3.2) where students are encouraged to look on extractions as an "option of last resort".

Figure 7.3.2: A source of quaternary contradictions and tensions from nearby neighbouring activity that could interfere with students' understanding of what was required



Ulysses and Victor make their choice of 4s after debating whether the degree of crowding justifies the choice of 4s or 5s in the lower arch:

Victor: ... Don't you usually opt for 4s?
Ulysses: Yeah = ***[points to lower labial segment]*** = but there's not enough crowding to warrant taking the 4s out... So shall we take out the second premolars? ...
Victor: Yeah, ok.
Ulysses: ***[types '3545' hesitates]*** Are you sure?
Victor: Well, you usually take out the first premolars.
Ulysses: So should we go for the 4s?
Victor: Yeah, I think so.
Ulysses: ***[deletes previous entry, then enters '3444']*** Are you sure.
Victor: Ok.

From the feedback, Victor wonders if 7s are chosen for extraction to make room for the 8s:

Victor: It doesn't make sense. Why the 7s?
Ulysses: I don't know.
Victor: There's crowding at the front. So why should you take out 7s? For the 8s?

So as well as compensating extractions in the lower arch with similar ones in the upper, Victor seems to link one of the two key features in this case, which is the posterior crowding (the upper molar "stacking") with the need to extract 7s.

On a phenomenological level students in the higher level (2ii) can be identified as having a deeper approach to learning as they are able to identify more than one reason for extracting the 7s. Taking into consideration the underlying conceptions of orthodontics that students may be drawing on to answer these questions it is probable that those in the lower level (2i) are more heavily dependent on following set procedures whilst those in the higher group manage to gain a deeper understanding of the case through their reflections on the feedback from the records and the program. The two procedures taught to students that group 2(i) are relying on can be identified as:

1. Chose premolars for extraction
2. "Balance" premolar extractions in the lower arch with (compensating) extractions in the upper arch.

Further evidence that this difference between the two sub-groups is seen from a closer analysis of the transcripts relating to responses to question 35 **before** students receive feedback (Table 7.3.2) which shows 9/11 sets in groups 2(ii)/3 put forward one or more reasons relating to the crowding of the teeth after feedback on the lower arch extractions (with the other reasons listed in Table 7.3b arising from reflection **after** receiving feedback on the upper arch extractions). Four sets in group 2(i) suggest "balancing" extractions before receiving feedback, but seem to do so in an automatic fashion because they are following a taught procedure rather than because they have thought about the case. This analysis supports the view that students in group 2(i) rely on taught procedures to provide their answers whilst those in group 2(ii) seem prepared to reflect on the case following feedback in the lower arch before receiving feedback on the upper arch.

Table 7.3.2: Analysis of supporting reasons for extractions in the upper arch made pre-feedback

Group	Set	Analysis of suggestions made prior to feedback to question 35	UA Ext Choice
3	Kevin	Crowded 8s/mild labial crowding	1727
	Leonard & Mary	Crowded 8s/mild labial crowding	1525
	Elizabeth & Felicity	Labial segment more crowded	1424
2ii	Ulysses & Victor	Crowded 8s/"compensate"	1727
	Henry & Laura	Crowded 8s/"balance"	1727
	Nigel & Oscar	Crowded 8s/"balance"	2717
	Olga & Peter	Crowded 8s	1525
	Frank & Gita	Labial segment more crowded	1525
	Ralph	Crowded 8s	1626
	Ian & James	"Balance" (recognize crowding post-feedback)	1727
	Queenie & Rachel	"Balance" (recognize crowding post-feedback)	1727
2i	Helen & Isabel	"Balance"	1727
	Pamela	"Balance"	2717
	Sophie & Tina	"Balance"	3747
	Jennifer & Kate	"Balance"	1424
	Charles & Debbie	Automatic 4s (recognize "balance" post-feedback)	1424
	Quentin	Automatic 4s (recognize "balance" post-feedback)	1424
	David & Edward	Automatic 4s (recognize "balance" post-feedback)	1424
1	Steve & Terry	Automatic choice of 4s	1424
	Anne, Belinda, Christine	Automatic choice of 4s	1424
	Adam & Bill	Automatic choice of 4s	1424
	Michael & Natalie	Automatic choice of 4s	1424

7.3.3 Students in group 3

During the main study just 3 sets (Elizabeth and Felicity, Kevin, Leonard and Mary) recognise that 7s were chosen for extraction both because of the posterior crowding and the mildness of the crowding around the incisors. These students can be described as adopting a deep approach to learning both because they are able to identify all the reasons for extracting 7s and because they spend time reflecting on why these teeth are chosen. For example Elizabeth realises from feedback in the lower arch that extraction of premolars would leave a space that would need to be filled by moving:

> **Elizabeth:** … the front ones back and because the back ones are … quite crowded.
> **Felicity:** But surely you want to remove the 4s?
> **Elizabeth:** No, because that would leave too much room at the front, you need the room at the back, see?
> **Felicity:** … Ye-es … I suppose the third molars are in the way.
> **Elizabeth:** Yeah…

In the upper arch, although Felicity raises the possibility of "balancing" extractions, Elizabeth suggests that the increased crowding around the upper right canine will require the extra space created by extracting 4s rather than 7s:

> **Elizabeth:** It's more crowded here around that canine. ***[points to 13 on 'Occl']***
> **Felicity:** Yeah.
> **Elizabeth:** So I reckon we need the 4s. What do you reckon?
> **Felicity:** Well, it definitely needs something.
> **Elizabeth:** Because you get less room than from the 7s, if you remove the 4s, so I reckon the 4s.
> **Felicity:** Ok. ***[enters '1424']***

In the post-session interview Elizabeth sums the reasons for their surprise and explains why she thinks 7s are chosen for extraction:

> **Elizabeth:** … I can see why it needed to be done, because … if you didn't extract the 7s then you'd have too much space in the front, and not enough at the back….

Having chosen the 4s in the lower arch Leonard explains to Mary, post-feedback, why he believes 7s are chosen:

> **Leonard:** … you're only removing the lower 7s to relieve molar crowding. I think, that's it, yes, actually, that's it.
> **Mary:** Not the incisors then.
> **Leonard:** Yeah… not the incisors, yeah.

In the upper arch Leonard asks Mary to slow down to give him a chance to reflect and explains that 5s would be preferable to 4s because:

Leonard: ... we don't need that much space at the front, and again there's the third molars, they're still crowded there. ***[brings hands out wide and pushes them together]*** So I think it should be the 5s.
Mary: So what are you saying? That it should be the 5s again?
Leonard: Yes, 15 25

After finding that 7s are again the choice for extraction, Leonard's "you need to keep your extractions balanced" suggests he is referring to compensating extractions to maintain the buccal occlusion, something he alludes to earlier when reflecting on the right side buccal occlusion:

Leonard: Yes, but first this is obviously a class =
Mary: = one.
Leonard: You want to aim for Class I. Yeah, because she's already got a Class II you see.
Mary: Oh, so there's the canines.
Leonard: So you don't want to take the canines out even further. I would leave them where they are...

It is probable that recognising the upper labial incisors are slightly more crowded than the lower led Elizabeth, Felicity, Leonard and Mary to choose premolars in the upper arch despite their acknowledgement of the crowded posterior teeth.

Just one individual (Kevin) is able to identify both the posterior crowding and the mild incisor crowding and chose 7s in the upper arch. In the post-session talk-back interview he explains that, having chosen all the 4s to relieve the incisor crowding, he is able to use the feedback to identify 7s for the upper arch because he understands:

Kevin: ... that they mentioned the 8s are healthy, so if you take the 7s out that will make space for [the incisors] at the front, because [the crowding's] only mild, and then your 8s will have room to come through as well... And if you take the 4s out you'd probably generate too much space, you'd get spacing in the situation of mild crowding... But the 7s – you only need a little bit of space – if you take out the 7s, you've still got the 8s coming in and you relieve the mild crowding at the front...

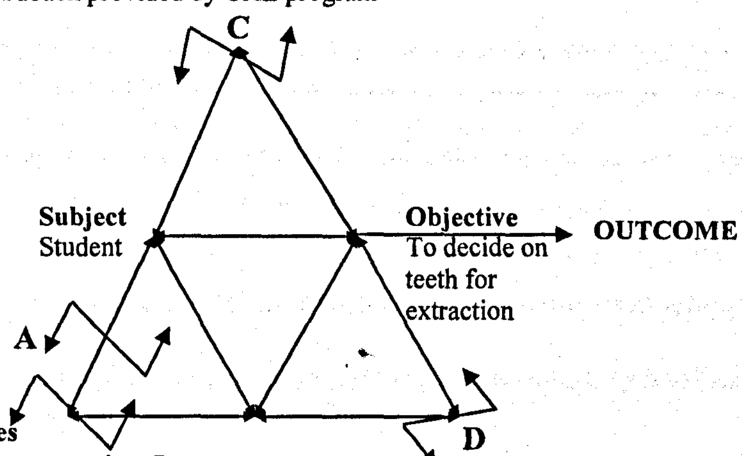
Quantitative evidence that students in groups 2ii and 3 have a deeper understanding of the case than students in groups 1 and 2i comes from comparing the extraction choices for the 2 groups. A χ^2-test on lower arch extraction choices reveals no significant difference, with nearly every set (21/23 sets) choosing premolars (18 sets choosing the 4s, 3 the 5s). In contrast in the upper arch the χ^2-test reveals a significant difference between the two combined groups at the 1% level ($p<0.01$, df=2, Appendix D, Table D9b), with 9 sets choosing 4s and 3 sets choosing 7s in groups 1 and 2i compared to just 1 set choosing 4s and 6 sets choosing 7 in groups 2ii and 3 (Table 7.3b).

This result suggests that students in groups 2ii and 3 take more notice of feedback from question about extractions in the lower arch and adjust their answers to match these extractions by opting to take out the 7s in the upper arch. Conversely students who rely solely on the procedure to "balance" extractions in the lower arch with ones in the upper, or who fail to look further than their belief that only premolars would be chosen for extraction, tended to chose extractions in the upper arch that matched their first choice of premolars, rather than the computer's suggestion of 7s. It should be noted that the sets were classified by group solely as a result of the QSR/N6 analysis of the transcripts – i.e. the analysis of their actual extraction choices in the upper arch has only been taken into account after the sets had been classified. Activity theory suggests that teeth are chosen for extraction based on (a) students' memories of the earlier questions in the case (b) their understanding of orthodontic treatment planning procedures and (c) the background reading on orthodontic extractions (Figure 7.3.3).

Figure 7.3.3: Activity system for deciding on extractions

Mediating tools

- CAL questions in MCQ and free response format
- orthodontic terminology, including FDI notation
- links to digitised images of patients' records ('Labial', 'Occl' & 'OPT')
- patient's chronological and dental age
- hands and fingers as pointers to focus attention
- feedback provided by CAL program



Rules & Procedures

- recall of specific reasons when 7s should be extracted
- belief that 7s are "never" chosen for extraction
- belief that taught procedure is premolars are always chosen for extraction
- recall and application of procedural, factual and conceptual knowledge

Community

- student's partner
- other students
- Gareth
- the Interviewer
- their tutors

Division of Labour

- Students' underlying beliefs too similar for any differences in perspectives that can help them assimilate and understand what is happening
- feedback on computer screen originally provided by orthodontic specialist

Students' difficulties in correctly identifying teeth for extraction seem to be due to primary and secondary contradictions (A and B) between the procedure required to deal with the complexity of the case and the simplistic procedures students had been taught in their lectures and primary contradictions. Another primary contradiction (C) lies in students' lack of recognition of the implications of the combination of posterior crowding and a mildly crowded labial segment in the digital records. Finally, students' underlying beliefs about premolar extractions appear to be too similar for any differences in perspectives that might help them assimilate and understand what is happening – a primary contradiction in the Division of Labour (D).

Using activity theory allows ways of learning about orthodontic treatment planning outside the computerised case study to be examined for the impact these alternatives might have on students' perceptions of the case. For example, the surprise about being asked to extract 7s may partly be explained by a secondary contradiction between students and their understanding of the basic rules about choosing extractions as well as a primary contradiction in choosing the right teeth (tools) to extract. This contradiction appears to relate to an oversimplification of what is needed at this point in the case, due to the students' prior experience of orthodontic teaching:

Brian: The problem is that you make it simple for them ...and you keep on reinforcing that. And perhaps to the extent that they just lose track of anything else...

It is noticeable that even in the upper arch this belief that premolars are chosen for extraction is strong enough for students to ignore the feedback in the lower arch in particular, leaving most students feeling confused and unsettled about being asked to extract the 7s. There is no apparent difference between individuals and pairs in their choice of premolars, suggesting that the presence of a partner neither helps nor hinders the students' understanding of why 7s are chosen. Furthermore some students seem so pre-occupied with the problem of 13 that they fail to read the question asking them to choose extractions in the lower arch and opt to list upper arch extractions first, again suggesting the existence of both primary and secondary contradiction in their understanding of the procedures and the required objective for the system.

The QSR/N6 analysis suggests that the order in which students appear to focus on relevant features of the case is to focus on the upper right canine first, then to take notice of the need to "balance" extractions. About half the sets are then able to identify the crowded 8s, with just four sets managing to identify the mildness of the incisor crowding as reasons why 7s are chosen for extraction. The main feature in the digitised records distracting the sets is the presence of that partially erupted canine, with some students apparently believing that the crowding around that canine and the incisors in the upper arch is severe enough to warrant extracting 4s or 5s. Another feature of the case that may have distracted the students is a belief that extracting the 7s will require more complex treatment (*i.e.*, using fixed, rather than removable, appliances) to move the front teeth back (implying that they either forget or do not realise the significance of the waiting 8s).

If any of the students later specialise in orthodontics they will probably need to learn how to:

> **Brian**: ... construct in your mind a three-dimensional model of what you've got with all the problems tagged onto it ... and ... you actually walk round and do an iterative procedure where you examine what's going to happen. If I do that, then that, then that, and, well that doesn't work, well, if I do that, then that, then that, then that will be a problem, so if I do that... They've got to construct a three-dimensional image... It does come in time.

Whether or not it is possible for a computer program to achieve this 'transformation' in student understanding is problematic; for Brian the best scenario was that computers can guide them through the relevant orthodontic processes:

> **Brian**: ... which will stimulate them in their mental development. It's like ... can you learn a language ... from a language laboratory? ...

7.4 Decisions 5-7: tooth movements, buccal occlusion and anchorage

Choice of mechanics

Decision five asks students to choose what type of mechanics they will use in first the lower and then the upper arch. Following extraction of the 7s in the lower arch no appliance will be required as it is expected that the remaining teeth will move into place without further intervention. However more than half the sets (15) opt for a fixed appliance in the lower arch, with just 10 sets choosing the correct answer of 'No appliance'. Unlike the students in the pilot study (both of whom also opted for fixed appliance treatment without commenting in the talkback session about their choice), students in the main study express surprise at finding out that 'No appliance' can be considered an appropriate form of treatment in the lower arch, for example:

> **Leonard**: *[chooses 'Fixed appliance']* No. No appliance. It's no appliance.
> **Mary**: Ok. But if it's no appliance, why ask the question?
> **Leonard**: *[laughs]* Good question, yeah.

Letting teeth move on their own after extractions have taken place, without further mechanical intervention, can be considered to be a form of mechanical movement in its own right (Houston, Stephens and Tulley, 1992). The problem is that students are:

> **Brian**: ... talking about using an appliance in the lower arch, when it's already said in the summary there's acceptable alignment in the lower arch. So they don't actually need to do any active treatment... They've forgotten they've said that...

The main reason students express for wanting to use a fixed appliance seems to be a belief that the 6s need to move back, as Adam and Bill illustrate, perhaps because they have forgotten about the waiting 8s:

> **Adam**: It's got to be a ... fixed appliance. Because if you try and move the 6s back, you'll need retention through the anchorage to get them back. *[chooses 'Fixed appliance']*

Queenie and Rachel, Ian and James, Una and Wayne also choose a 'fixed appliance' as their first choice of mechanics for the lower arch having talked about the need for other teeth to be moved back to fill the space left after the 7s have been extracted, despite Queenie's observation that maybe the teeth will drift into place. The other possible reason why students choose an appliance in the lower arch is that they believe that if the patient requires treatment then an appliance has to be used, as James suggests:

> **James**: ... No appliance? ... No, we're treating it, aren't we? So we've got to do something with it...

However students are able to work out from the feedback on the screen that perhaps an appliance would not be required because, as Anne notes post-feedback:

Anne: OHHh! It's the lower arch *[pause 1s]* So you might not need anything then? ***[cups right hand towards the screen]*** So if you've taken the 7s out, they might move into place? ***[points to 6s]***

Elizabeth makes a similar point before feedback after Felicity initially suggests that a fixed appliance will be required. This pair eventually opts for 'No appliance' in the lower arch:

Elizabeth: ... no appliance.
Felicity: Why do you say that?
Elizabeth: Because the teeth should move by themselves.
Felicity: Ok. ***[Elizabeth chooses 'No Appliance']***

Students are slightly more successful in the upper arch, with 11 sets opting for an active removable appliance as their first choice and just 7 for a fixed appliance. As with the lower arch, the most commonly stated reason for opting for a fixed appliance is the idea that 6s have to be pulled back, failing again to consider the waiting 8s. The extraction of 7s dominates the thoughts of several students, even when thinking about mechanics. For example Elizabeth refers to movement of the teeth when choosing a fixed appliance for the upper arch:

Elizabeth: I reckon fixed. Because you're not just tipping, because there's body movement of the upper teeth as well... ***[chooses 'Fixed Appliance']*** Oh. Can you not just tip the premolars? That helps, I suppose, unless they drift, but I don't think it's so good...

When trying to work out how an appliance might be retained in the upper arch Belinda and Christine turned first to Debbie and then to the Interviewer to see if they can help explain why 7s are chosen:

Belinda: ... So what are you going to use for retention on the right hand side? What is going to stop it from falling out? ***[truns to Debbie]*** ARE YOU ON THE PART WHERE THEY WANT YOU TO TAKE 7S OUT?
Christine: YEAH!
Debbie: YEAH. Why, I said 4s.
Belinda: Yeah...
Christine: ***[turning to Interviewer]*** We've just done the tutorial on which teeth to extract, right? And they said we can't take premolars... They say the 4s are wrong.
Anne: |They don't really explain to us –|
Christine: |And they don't really explain to us| why the 4s are wrong.
Anne: Yeah...

Anne suggests that perhaps extraction of 4s will leave too much space at the front of the mouth, but still does not make the connection that that is the reason why 7s are chosen for extraction:

Anne: I can see why the top ones are wrong =
Belinda: ***[turns to Anne]*** = |I can see it|
Anne: = |because you don't| need that much space. Because if you remove the 4s then you get too much =
Christine: = |space|
Anne: = |space.| But I still don't see why you should remove the 7s.
Christine: Yeah.
Anne: Or why you can't remove the 5s.

Ian and James also seem distracted by the extracted 7s when trying to decide what to do in the upper arch. Although they have previously discussed using a removable appliance when deciding when to start treatment, following their reflections on the feedback to their choice of extractions in the upper arch James suggests using 'Headgear', linking his choice to the need to:

James: … get distal movement, surely –
Ian: Aren't we just taking those 7s out?
James: Uh-hn ***[nods head]***
Ian: Just for the 8s. It seems odd to take 7s out just to make space for the 8s, doesn't it? ***[chooses Headgear']***

For Adam and Bill the focus of their attention seems to be what to do about the partially erupted canine:

Adam: You should retract the, um, upper right canine…
Bill: … The upper left canine is = |mesially inclined|.
Adam: = |mesially inclined|
Bill: Then you can upright that = ***[indicates the upper left canine]*** = and the upper right is slightly palatally misplaced, so if you pull that out ***[cups left hand, palm upwards fingers and thumb forming a 'flower' shape, moves hand backwards and forwards]*** …

Although Una, Wayne and Xavier ask Gareth to help them make more sense of what was happening in the upper arch, most other students say very little that indicate what they were thinking when deciding on mechanics. However Ulysses and Victor do not seem distracted by the extraction of the 7s when choosing an active removable appliance in the upper arch:

Victor: What are we going to do then?
Ulysses: ***[points to 7s]*** Take them out?
Victor: Take them out. ***[points to 7s]*** Yeah, take them out.
Ulysses: Active removable appliance. I think it's active removable.
Victor: ***[nods head in agreement]*** Active removable appliance.
Ulysses: ***[chooses 'Active removable appliance']*** YE-AH!

Buccal occlusion

The first part of decision 6 is to decide what buccal occlusion to aim for on the left and then the right side at the end of treatment. Having discovered that the buccal occlusion on the left was Class I and the right ½ unit Class II in the case assessment, nearly all the students manage to agree that they should be aiming for a Class I occlusion on both sides, 27/28 sets opting for Class I on the left (only Frank and Gita choose Class II on the left), and 23/26 sets for Class I on the right. For example Ian works out how a Class I occlusion can be achieved on the left by reflecting back on the buccal occlusion:

Ian: Buccal occlusion you are aiming for on the left side. The left side is the one they considered Class I, so if you take the 7s out and you pull these back in a little bit = ***[points to buccal segment on 'Left']*** = and it all moves back, I think it will just slot in perfectly as Class I. ***[chooses 'Class I']*** Yep. Next.

Similarly although Ian reminds himself that the occlusion on the left was ½ unit Class II, he is able to work out that a small amount of movement would be sufficient to bring the occlusion into a Class I relationship:

Ian: On the right side. Now this is the one that was ½ unit II ... **James**: Hmm ***[affirmative]*** **Ian**: Yeah, if you pull it back a little bit = ***[points to upper buccal segment]*** = you should get Class I, shouldn't you? ***[chooses 'Class I']*** Yep. Excellent. We've got this sorted.

On the left Peter, too, thinks about what might happen once the 7s are extracted, pointing to the upper left canine to suggest that the occlusion will remain pretty much unchanged:

Peter: What are you aiming for, on the left hand side? The 7s are gone from the buccal and that canine's – ***[points to upper left canine]*** **Olga**: Yeah **Peter**: So that, that's what I mean, Class I – **Olga**: ***[chooses 'Class I']*** Yeah! Class I.

In the remaining transcripts one student suggests Class I on the right and the other agrees without further comment. On the left, most students agree to go for the 'same again'.

Students now have to decide how to achieve these occlusions. On the left 14/28 sets correctly choose to move the upper molar distally. A third of the sets (9/28 sets) realise that the present occlusion should be maintained and as a result decide that treatment will not be required. Despite having been told that no treatment is required in the lower arch, 4 sets choose to move the lower molar mesially as well as the upper distally.

Having aimed for a Class I occlusion on both sides of the mouth Helen and Isabel seem to forget that no appliance is required in the lower arch, wanting to design an appliance to move the lower molar mesially on the left as well as the upper molars distally:

Isabel: ... Move upper molars distally, lower mesially?
Helen: Yeah, that's the one.
Isabel: That's the one.
Helen: Yes, as you've taken out the 7. ***[chooses 'Move upper molars distally/lower mesially']***

Having eventually found the correct response, Helen and Isabel decide to try the same option again on the right side of the mouth:

Isabel: How do you intend to achieve this on the right side? ...
Helen: Let's click the same again.
Isabel: What? Upper molars distally? ... ***[chooses 'Move upper molars distally]*** Ok.

On the right most sets (22/27) correctly opt to move the upper molars distally. Just 3 sets opt to maintain the present occlusion. For example, having previously reflected on what they could use when deciding what occlusion to aim for, Ian and James remember that as there was no appliance in the lower arch, then all they need to do is:

James: ... to move the upper molar distally, don't we? ***[chooses 'Move upper molars distally]*** Yep...

Having suggested moving the upper molars distally, Olga initially accepts Peter's argument that no treatment is necessary because:

Peter: We're already in Class I.
Olga: Ye-ah
Peter: We're not going to move anything, because it's going to be the same buccal occlusion. I can't understand – ***[chooses 'Maintain present occlusion']***

Now Peter is ready to accept Olga's suggestion of moving the upper molar distally. Again they are recorded taking time to review the feedback, reflecting on what active elements they might use to move the teeth distally:

Peter: So if ... we're going to move the upper molar distally, so that ... we're =
Olga: = going to move it back into occlusion.
Peter: So we've |move it back –|
Olga: |So we're moving| it back into the cusp, yeah.
Peter: Actually, that would sound quite reasonable, because it would be =
Olga: = with a spring?
Peter: Would it?
Olga: With a spring.

Peter: I thought that's that what we'd have ...

Adam and Bill also spend time discussing the case before choosing the correct answer on the left:

Bill: ***[chooses 'Left', points to the 7s]*** So if we have taken that out. **Adam**: So, yes, that's right, isn't it? ... ***[points to 27 on 'Left']*** The thing is, the ... 6 is in a Class I? **Bill**: Yeah. **Adam**: The other's ... ½ unit Class II, isn't it? **Bill**: Yeah, but how else can you do it? ... Oh, the other thing you can do is ... move the upper molar distally, and then the lower left ... – **Adam**: If you just move that distally, I think – On that side ***[points to 'Left']*** **Bill**: I'm sorry, yeah. [Just the] upper molar distally. **Adam**: Yeah ...

Although David seems to have forgotten no appliance is required in the lower arch, Edward uses the feedback to explain why only the upper molar needs to be moved:

Edward: Move the upper molar distally. **David**: ***[chooses 'Move upper molars distally']*** Oh! I would have said move the upper distally and the lower mesially. **Edward**: Really? **David**: Yeah. **Edward**: ***[points to feedback]*** Mandibular growth provides the necessary forward movement of the lower molar. See?!

Ulysses initially suggests maintaining the present occlusion on the left. However following Victor's recollection that the left side was ½ unit Class II, their reflections help them conclude that only the upper teeth needed to be moved:

Victor: If you just hang on for a sec, and think what is it you're going to do. Now what is it at the moment, a Class ...II isn't it? ... So that means that ... = **Ulysses**: = the upper is forward. **Victor**: So that means that the upper is forward, **Ulysses**: So move the upper molar distally and the lower mesially? Or ... is it just the upper distally? Because if you move the lower mesially? There's nothing wrong with the lower. **Victor**: Yeah ... **Ulysses**: You don't need to move the lower over. **Victor**: Yeah, so just the upper distally. **Ulysses**: ***[chooses 'Move upper molars distally']*** Yeah...

With half the students choosing the wrong type of mechanics it is useful to try to locate any potential underlying source for their misconceptions. The QSR/N6 analysis, combined with the log-files, make it possible to infer from the transcripts the reason why students make their choice on the left. These inferences, in combination with the computer log-files, again allow students to be classified into 3 groups (Table 7.4a and b).

Table 7.4a: Description of levels of understanding of treatment plan for the lower arch

Group	Option Chosen	No. of Sets	Description
1	Move upper molars distally/ lower molars mesially	5	With 7s extracted, 6s need moving back (forgetting both that no treatment is required in lower arch and the presence of the waiting 8s)
2	Maintain present occlusion	9	Buccal occlusion already class I, therefore no further treatment required (forgetting 7s are being extracted)
3	Move upper molars distally	14	Students remember that no treatment is required in the lower arch and that, as 7s have been extracted, some movement of upper buccal segment is required

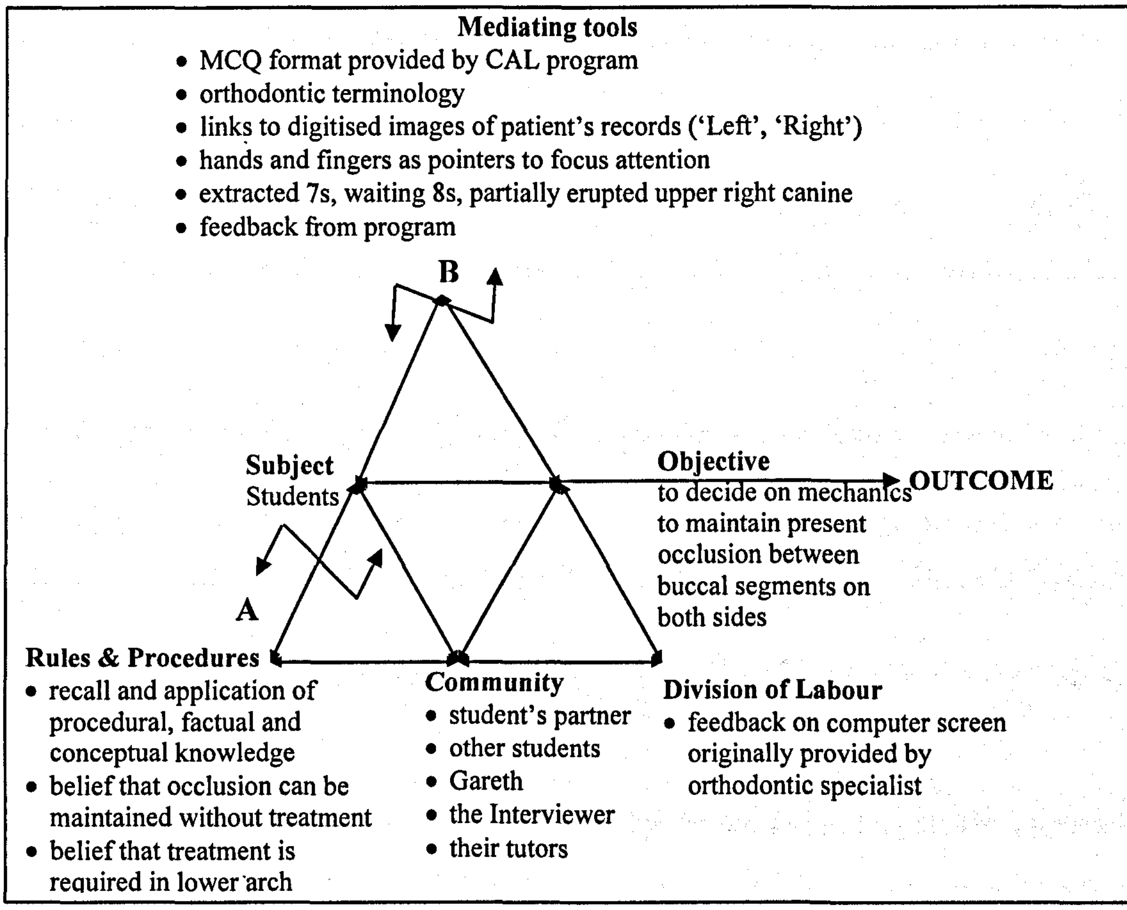
Table 7.4b: Overview of students' treatment plan for the lower arch

Group	Students	Comments from QSR/N6 analysis of transcripts
1	Frank & Gita	Frank suggests no appliance in lower arch in Q36
	Helen & Isabel	Isabel also suggests no appliance in lower arch in Q36
	Michael & Natalie	Michael suggests mesial movement of lower molars only
	Quentin	
	Victoria	
2	Anne, Belinda & Christine	Belinda's suggestion?
	Debbie	
	Charles	
	Nigel & Oscar	Oscar's suggestion?
	Olga & Peter	Olga suggests move UM distally, Peter maintain pres. occl.
	Pamela	
	Queenie & Rachel	Rachel's suggestion?
	Ralph	
	Winifred	
3	Adam & Bill	Discursive reflection to arrive at right answer
	Elizabeth & Felicity	Elizabeth's suggestion
	David & Edward	Edward suggests and explained why to David
	Jennifer & Kate	Jennifer suggest no treatment in lower arch
	George	
	Ian & James	Ian suggested no treatment in lower arch
	Kevin	
	Leonard & Mary	Mary suggested no treatment in lower arch
	Sophie & Tina	Sophie's suggestion
	Steve & Terry	
	Ulysses & Victor	Discursive reflection to arrive at right answer
	Una & Wayne	Wayne's suggestion
	Xavier	
	Xenie	

Activity theory suggests the source of their misconceptions is due to primary and secondary contradictions within and between the constituencies of the system (Figure 7.4a). Students' difficulty in deciding how to maintain the present occlusions seems to arise due to a secondary contradiction (A) in understanding the nature of the procedure required and a primary contradiction (B) in choosing the mediating tools (in this case that treatment was needed in the upper arch only).

It is interesting to compare student responses to the choice of mechanics on the left with decisions on the timing of treatment (Section 7.2.1) and the choice of extractions (Section 7.3). In Table 7.4c the orange background in the second column shows students who, according to the transcripts, spend little time discussing the case, or argue about how to answer the case rather than working together. Green is used to highlight students who spend time discussing/reflecting on the case, or who have been identified as reviewing the case before starting to answer any questions and white shows students working as individuals (Section 6.2.3).

Figure 7.4a: Activity system for choosing appropriate type of mechanics



In the fourth column, orange identifies students who can be classified as group 1, white indicates students who remain in group 2 and green shows students who move up one or more groups or who are already in the highest classification group (3). The interesting pattern is that students in the green group in the second column nearly all end up in the green group in the third column.

Students earlier classified as either Group 2(i) or 2(ii) seem to indicate a relationship between those who spend time reflecting on the case and those able to work out that mechanics would only be required to move the upper right molars distally. Interestingly nearly all the students who choose to work as individuals or those in pairs who do not discuss/reflect on the case either remain in the same group or drop into the lower classification group between choice of extractions and choice of mechanics on the left. The number of sets available for comparison purposes is too small to carry out any meaningful statistical analysis of this finding.

Table 7.4c Comparison of students answering all three questions on timing of treatment decisions, extractions and left side mechanics

Students	Degree of discursion/reflectivity picked up from transcripts	Timing of treatment	Group classifications (extractions → mechanics)
Michael & Natalie	Very little discussion at all – gave up on extractions without discussing	6 mths	1 = 1
Anne, Belinda & Christine	Plenty of discussion, look outside pair for help on extractions, Belinda overruled Christine on timing of treatment	6 mths	1 → 2
Adam, Bill	Plenty of discussion, look outside pair for help on extractions	12 mths	1 → 3
Debbie	Worked as individual – looked outside for help on extractions	6 mths	2i = 2
Charles	Worked as individual – looked outside for help on extractions	Now	2i = 2
David & Edward	Reviewed case before starting	12 mths	2i → 3
Helen & Isabel	Spend more time gossiping than reflecting whilst working on the case. Do not reflect on extractions	Now	2i → 1
Jennifer & Kate	Reviewed case before starting	12 mths	2i → 3
Sophie & Tina	Reviewed case before starting	12 mths	2i → 3
Una & Wayne	Spend time reflecting on extractions	6 mths	2ii → 3
Ulysses & Victor	Always looking for other clues	6 mths	2ii → 3
Frank & Gita	Always arguing, Gita seemed to spend more time reflecting, Frank guessing	6 mths	2ii → 1
Ian & James	Always looking for other clues	6 mths	2ii → 3
Kevin	Talk-back session suggested he spent time reflecting – liked repetition of questions	6 mths	3 = 3
Nigel & Oscar	Very little discussion at all, but suggest posterior crowding as reason for extractions	12 mths	2ii = 2 (guess)
Olga & Peter	Reviewed case before starting,	6 mths	2ii = 2
Queenie & Rachel	Very little discussion at all, but suggest posterior crowding as reason for extractions	6 mths	2ii = 2
Elizabeth & Felicity	Spend time reflecting on extractions	6 mths	3 = 3
Leonard & Mary	Spend time reflecting on extractions	Now	3 = 3

This pattern of learning being supported by the presence of a partner is reversed for the Timing of Treatment question, where a partner means students are significantly more likely to be influenced by the argument that they should be cautious and delay treatment to wait for the canine to erupt than students working as individuals (Section 7.2.1). Only 1 set, Leonard and Mary, manage to answer both the timing of treatment and the mechanics question correctly as well as identifying all three reasons for choosing to extract 7s. Table 7.4c is used as a starting point for a wider discussion of differences in interactivity between students in Chapter 9.

Sources of extra-oral anchorage

The final decision in the treatment planning question asks students to choose a source of anchorage. Once again several students turn to others to refamiliarise themselves with the terminology. For example, having asked if intermaxillary anchorage (using the teeth in one arch as anchorage for tooth movement being carried out in the opposing arch) can be used with a removable appliance, Felicity asks for help in remembering the difference between inter- and intramaxillary anchorage before suggesting the correct answer:

Felicity: … What's the difference between inter and intra?
Elizabeth: Intra is –
Felicity: Oh, intra's in the mouth, ***[brings right hand up to mouth and moves it from one side to the other and back again]*** and inter is =
Elizabeth: = inter is between the arch
Felicity: So shall we say intra? ***[Elizabeth chooses 'Intramaxillary']*** YEAH!

When Anne asks for help Belinda and Christine explain that intra was within the arch, whereas intermaxillary stretched between the upper and lower arches:

Anne: What is intramaxillary?
Belinda: |It's just something in the mouth…|
Christine: |Yeah, it's between there| and there ***[points to the roof and then the floor of her mouth]*** It's like, when you have elastics and such…

Several students end up guessing at the terminology, for example, having forgotten the difference between inter- and intra-, James asked if Ian could remember the difference before the pair worked through all the options, despite Ian's memory of having taken notes on the subject in the past. After discussing the terminology with Olga and also working through all the options, Peter turns to Natalie for help:

Peter: ***[turns to Natalie for help]*** What's the difference between inter and intramaxillary? Is it like that because it's crowding there?
Natalie: Well, intramaxillary is within the arch, so it would go say from there to there, ***[points from one side of upper arch to the other on 'Occl']*** whilst intermaxillary is between arches, so it would go from top to bottom, from there to there ***[points from upper arch to lower arch]***…

In session 6 this question generates both student-tutor and student-student interactivity as Gareth, in particular, adapts his response to students' understanding of the terminology in the following exchanges, eventually turning to the metaphor of international travel to help illustrate the difference:

Victoria: … What's intramaxillary and intermaxillary?
Gareth: Uh. Intramaxillary is within the arch, yeah? Inter is between top and bottom. Intra just |means within | =
Wayne: |Intra is within the arch|
Gareth: = the arch …

Victoria: Just within the top arch =
Gareth: Within the top arch …
Victoria: Oh! That's what it means.

Gareth: … Inter, is pretty well international, across continentals, across the ocean.
Xavier: Oh. Yeah.
Gareth: Across the ocean. Intra is within =
Xavier: Yeah, ok.
Gareth: = that is, within the same arch. Alright?
Xavier: There you go.

For the first time since starting the program Victor and Ulysses also turn to look at Gareth, perhaps listening for an explanation:

Victor: You need extraoral and –
Ulysses: Extraoral … – and what?
Victor: And intermaxillary?
Ulysses: Ok. ***[chooses 'Intermaxillary and extraoral']***
Victor: Have I made a mistake? Try intramaxillary and extraoral.
Ulysses: Ok. ***[chooses 'Intramaxillary and extraoral']*** No.
Victor: Oh, I've forgotten the difference between inter and intra.
Ulysses: What? ***[Ulysses' expressive 'what' may indicate either he is surprised that Victor has made a mistake or he is surprised that Victor has admitted to making a mistake]***
Victor: Oh, try extraoral. ***[Ulysses chooses 'Extraoral']*** Oh, try intra and intermaxillary then. ***[chooses 'Intermaxillary', then 'Intramaxillary', both laugh and turn to listen to Gareth, who can be seen talking in the background]***

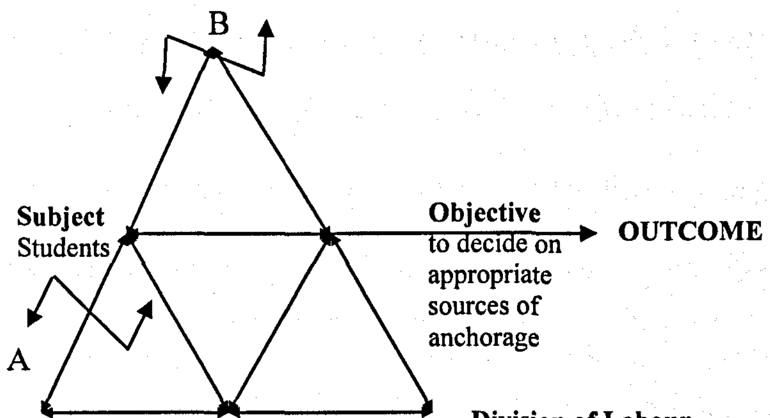
The source of confusion for the students appears to rise from contradictions in trying to remember the difference between intermaxillary and intramaxillary sources of anchorage (Figure 7.4b). This difficulty in deciding on anchorage seems to be due to a secondary (level 2) contradiction (A) in understanding the nature of the procedure required and a primary (level 1) contradiction (B) in forgetting the difference between the different types of mediating tools, possibly because students were associating intermaxillary with internal (Latin *internus*) rather than inter, the Latin for between, as Brian notes:

Brian: See that's where the intra and inter sound quite the same, and they often get confused. It helps if you've done Latin, of course – they don't want inter, they want intra. Perhaps we should have said it's anchorage in the same arch – that's it. It does help to know what the terms mean…

All the students have been offered the opportunity to go and take a coffee break whenever they want. Although most students seem unsettled about being asked to consider extracting the 7s, only Anne, Belinda and Christine left the CAL room for a coffee break, which they do after completing the treatment planning section. They are gone for just over ten minutes. The three students are noticeably more composed on their return, paying more attention to the appliance design sections than to the last part of the treatment planning section, perhaps because the break has given them an opportunity to come to terms with the unexpected choice of 7s for extraction.

Figure 7.4b: Activity system for choosing appropriate anchorage

Mediating tools
- MCQ format options provided by CAL
- orthodontic terminology
- links to digitised image of patient's ('Occl')
- computerised glossary file
- textbooks
- extracted 7s
- difference between inter and intra students may have encountered elsewhere



Rules & Procedures
- confusion over meaning of intermaxillary and intramaxillary – perhaps associating 'inter' with 'internal' rather than the Latin *internus* (between) and *intra* (within)
- recall and application of procedural, factual and conceptual knowledge

Community
- student's partner
- other students
- Gareth
- the Interviewer
- their tutors

Division of Labour
feedback on computer screen
originally provided by orthodontic specialist who developed the questions for the CAL template used as the basis for the program

7.5 Chapter summary

Students' reactions to the CAL questions relating to planning a course of orthodontic treatment facilitated a phenomenological approach to analysing that interactivity. The chapter revealed that the trigger that stimulated the most reflective discursion from students was their encounter with the unexpected which forces them to try and accommodate and assimilate reasons why 7s were chosen for extraction into their understanding of orthodontic procedures.

The sets can be divided into three groups, ranging from students who were unable to draw any conclusions about extraction sites through to those who, on reflection, were able to make a connection between the different degrees of crowding of teeth in the front and back of the mouth to understand why 7s were chosen for extraction. To work their way through the seven treatment planning decisions required students to look beyond the most obvious problem of the partially erupted upper right canine to recognise that the crowding around the posterior teeth, together with the mild degree of crowding of the incisors, indicated 7s rather than the 4s were the teeth for extraction.

This chapter found that the presence of a partner could hinder instead of help a student choose a correct answer – in this case through a partner's focus on the importance of the partially erupted canine. In other questions the pattern of behaviour in which working with a partner helped students to arrive at the correct answer before entering a response or when reflecting on the feedback is repeated, particularly when deciding on extractions and on types of mechanics.

Chapter 8: The Appliance Designs

Chapter 8: The Appliance Designs

8.1 Introduction

This chapter investigates the interactivity that is observed and recorded as students engage in the final activity in the program, where students are asked to reflect on how they might design the orthodontic removable appliances required to treat the case. Reasons are advanced as to why there is a change in the nature of this interactivity at this point in the program. Finally activity theory again provides a heuristic framework to explore the student interactivity that occurs as students work through a series of multiple-choice format questions on designing appliances suitable for achieving the objectives of the case.

8.2 Two different removable appliances

In the version of the program used in this study a template format provides undergraduates at the Dental School with a series of questions through the design stages of the two appliances required to treat the case because, as Brian explains:

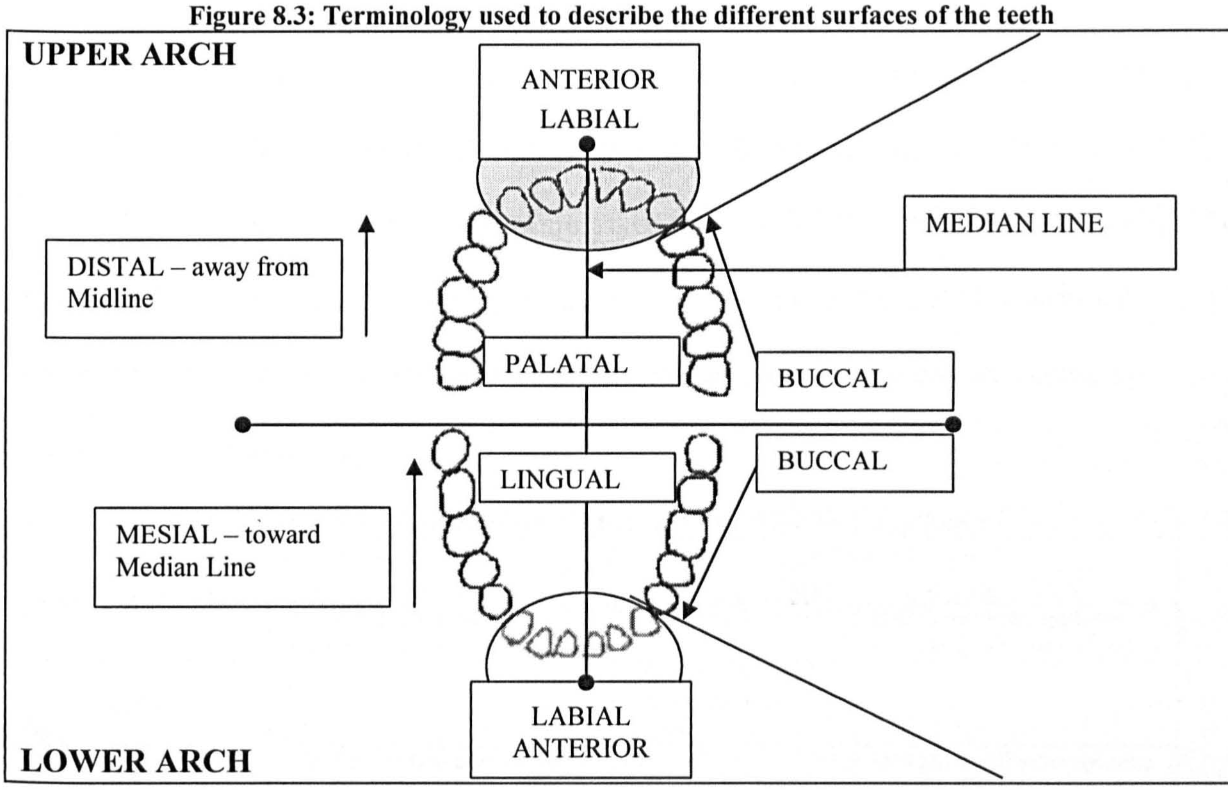
> **Brian:** Eleven years ago we didn't actually give them a template to approach appliance design. We just left them to design appliances, and they made a complete hash of it. And it wasn't until we got these terrible results in their M-year orthodontic exams that we started actually teaching them... And what we learnt is incorporated into the second part of the case assessment...

Accepting that the case is most appropriately treated by the removal of all 4 second molars (7s) the patient in this study can be treated using two different removable appliances. The aim of the first appliance is to make room for the upper right canine and upper right lateral incisor as well as correcting the buccal occlusion on the right (the upper appliance having no effect on the lower arch. It is only the extractions which preserve the lower alignment). Once this has been achieved, the aim of the second appliance is to tip the upper right canine buccally and retrocline the upper right lateral incisor.

8.3 Describing tooth surfaces and movements

To design the appliance students need to refer to the different tooth movements and what they might use to move the teeth into the appropriate position. The terminology to describe these movements is summarised below. Figure 8.3 illustrates some of the relationships between these terms (see Table 5.2 for definitions of each term):

Figure 8.3: Terminology used to describe the different surfaces of the teeth



8.4 Interactivity involving appliance designs

8.4.1 Stages of appliance design

To remind students how they might choose suitable elements for achieving the stated treatment aims, the program takes them through a series of questions for the different stages of design for each appliance. As with the case assessment section where students move from extra-oral via intra-oral to a radiographic examination of the patient and the seven decisions required for treatment planning, these design stages occurred in a specific linear sequence:

1. Active elements – what orthodontic element can be used to achieve the desired tooth movements?

2. Posterior retentive elements – what will hold the appliance in place in the back of the mouth?
3. Anterior retentive elements – what will hold the front of the appliance in place?
4. Baseplate modifications – what, if any, baseplate modifications might be required?
5. Anchorage requirements – where and how the anchorage (to overcome the reaction to the tooth moving forces) will be obtained?

For each appliance the students are asked three questions to help recall the actual sequence (general questions relating to functional requirements) as well as questions relating to each specific appliance (specific questions). These questions are shown for comparison in Table 8.4.1.

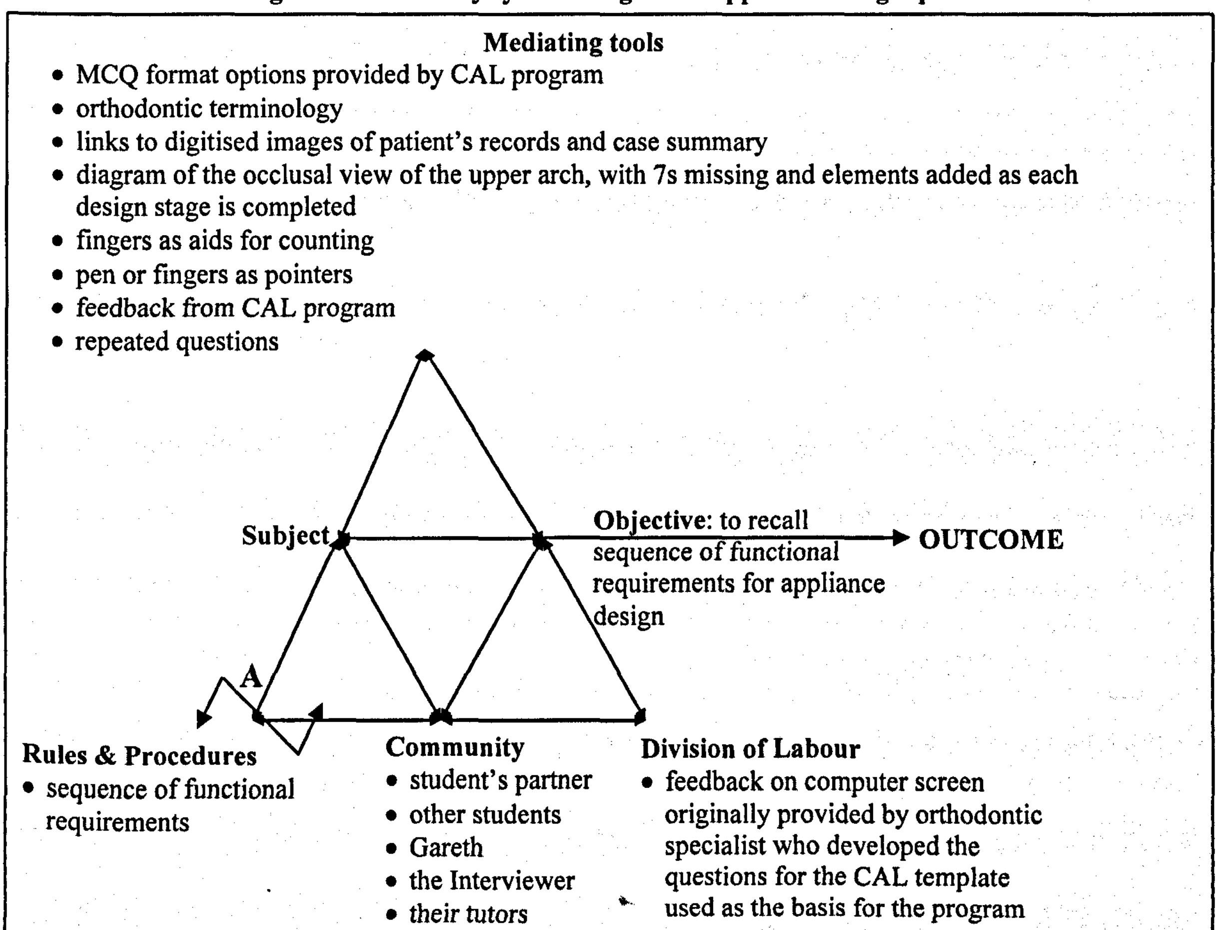
Table 8.4.1: Comparison of questions asked for each appliance

Appliance Design 1		Appliance Design 2	
General questions	**Specific questions**	**General questions**	**Specific questions**
	Q43 What is the 1st tooth movement for this patient?		Q52 What is the 1st tooth movement for this patient?
Q44 What is the 1st stage in appliance design		Q53 What is the 1st stage in appliance design	
	Q45 How will you move the upper right buccal segment distally?		Q54 How will you move the upper right canine buccally?
			Q55 How will you move upper right lateral incisor palatally?
Q46 What is the 2nd stage in appliance design		Q56 What is the 2nd stage in appliance design	
	Q47 Which teeth will you use?		Q57 Which teeth will you use?
Q48 What is the next stage in designing your appliance?		Q58 What is the next stage in designing your appliance?	
	Q49 What type of anterior retention will you use?		Q59 What type of anterior retention will you use?
	Q50 Which teeth will you use in your anterior retention?		Q60 Do you require any modifications to the baseplate?
	Q51 When moving one buccal segment distally, is it necessary to use extra-oral anchorage?		Q61 Do you require any reinforcement to the anchorage?

As students move through the design stages for each appliance they are provided with a diagram of an occlusal view of the upper arch to which functional elements are added when they correctly answer the questions associated with that stage and the program has moved to the next screen. Students can refresh their memory of the case by clicking on buttons at the bottom of the screen to access digitised images of the dental records or the case summary. They can also access "Clinical Hints" specific to this section of the program.

In terms of Anderson's *et. al.* (2001) taxonomy of educational objectives this design activity asked students to use cognitive processes – remembering, understanding, applying and analyzing procedural knowledge as well as remembering factual and conceptual knowledge (Appendix A, Tables A1 and A2) – to design the two appliances. An activity system for the general sequence of design questions is shown in Figure 8.4a.

Figure 8.4a: Activity system for general appliance design questions



The QSR/N6 analysis shows students using their fingers as "counting aids" to recall where they are in the design sequence, for example, Kate uses her fingers to help her and Jennifer answer question 48:

> **Kate:** ... We've done = ***[counts off options using her fingers, pointing to the screen with the first finger, then with the first two fingers]*** = posterior retention. We've done active elements ... we've not done anterior retention, anchorage requirements and baseplate.

Other students seem more interested in considering the implications of what is revealed in the on-screen diagram. For example Ulysses uses a pen to help work out what an expansion screw might achieve in the first appliance before deciding on the second stage:

Victor: What is the next stage in designing your appliance?
Ulysses: ***[points with pen to right buccal segment]*** What, |what's that?|
Victor: |That's really weird.| No wonder we couldn't make head or tail of it!
Ulysses: ***[moves point of pen around posterior retention on right side of appliance]*** What's that? ***[Victor shakes his head]*** And what the hell's that? ***[points pen at expansion screw]*** ... That's not the expansion screw, is it?
Victor: ... I don't see how you can move – Oh! – Are you trying to move the whole lot? ***[realises they were trying to move the whole buccal segment, not just 1 tooth?]***

The difficulties in recalling the general stages of appliance design appear to arise from a primary contradiction (A) in recalling the correct sequence for dealing with the stages of designing the functional requirements for a removable orthodontic appliance, a situation which improved considerably when students are asked the same questions for the second appliance.

8.4.2 Questions on the appliances

Tooth movements

After giving the aims for each appliance, students are asked to translate these aims into specific tooth movements. As the left buccal occlusion is already in a Class I relationship, the aim for the first appliance is to move the upper right buccal segment distally both to make room for the upper right canine and to correct the ½ unit Class II occlusion on the right. Once the first stage is completed, the second appliance will be able to tip the upper right canine buccally and retrocline the upper right lateral incisor.

Just 10/29 sets choose the correct option for the first appliance, for example when Ulysses uses a pen to help him and Victor reflect on the missing 7s to work out the answer:

Ulysses: Move the upper right buccal segment distally? Because it's only this one that wants to go down here, isn't it? ***[points with pen to first molar, then pulls the pen down to point towards the 7]***
Victor: Because if |we remove the 7|
Ulysses: |If we remove the 7|, and we pull the first molars back, then we pull =
Victor: = then the options are to move the upper right buccal segment distally –
Ulysses: Or we could move both buccal segments distally,

Victor: No, it's only this one that we need to move. ***[points to upper right buccal segment]*** We need to move the right. ***[remembers that left side molars are already in Class I relationship?]***
Ulysses: Yeah, if we do the 7s, then we need to move the upper right buccal segment distally.
Victor: Yeah.
Ulysses: Ok. ***[chooses 'Move upper right buccal segment distally']***

Seven sets choose to move both the first molars (6s) only, 7 sets to move both buccal segments distally. Both options suggest that students, having taken notice of the missing 7s, have forgotten the waiting 8s and believe that all these teeth need to move to create sufficient space at the front of the mouth for the canine, for example:

James: So let's move the upper first molars distally |to create =|
Ian: |Yeah|
James: = some space =
Ian: Yep.
James: ***[chooses 'Move the upper first molars distally']*** Buccal segment distally. Move the upper right buccal segment distally. Oh! Just this side. ***[points to right side of arch]*** Ok.

Four sets (David and Edward; Kate and Jennifer; Michael and Natalie; Oscar and Nigel) opt to move the upper left, rather than the upper right, buccal segment distally, perhaps forgetting that the diagram of the upper arch on the screen is not a mirror image, but is displayed to show the teeth as they are seen if students look directly into a patient's mouth or down at a plaster model of it. This misunderstanding is something that students can reasonably be expected to correct themselves as, for example.:

Edward: Move the upper left buccal segment distally.
David: Right. [***chooses 'Move the upper left buccal segment distally'***]
Edward: Oh! That was the left. ***[points to left side of arch]***
David: ***[chooses 'Move the upper right buccal segment distally']*** Oh, sorry.
Edward: Yeah, you've got to move that there. ***[points to upper right buccal segment and pulls hand down screen]***

The interesting point is that it suggests that all 4 sets have failed to recall the decision to move just the upper right molars distally taken at the end of the treatment planning section (Section 7.4). The feedback in the treatment planning section refers to moving the upper right buccal segment distally to make room for the upper right canine. If misinterpreting the diagram is the underlying reason for these sets choosing the left side, then the feedback to the appliance design question seems sufficiently informative for no further evidence for confusion of this nature to be seen throughout the remaining appliance design section.

Just as students have to learn how to interpret the diagram displayed on the screen, the actual wording of the question ("What is the first movement you intend to carry out?") coupled with a focus on the upper right canine may have confused students in the second appliance, where just 9/29 sets correctly chose to move both the canine and lateral incisor simultaneously. The problem of the partially erupted upper right canine certainly seems to be dominating the thoughts of several students, with 17 sets opting to use the second appliance to move just the canine, for example:

James: … So what, he moves this buccally – ***[points to upper right canine]***… You've got your distal movement, you've got your space, surely you've got to move this in, don't you. Move the right canine buccally. ***[pause 2s]*** What do you reckon? ***[Ian nods, James chooses 'Upper right canine buccally']*** …

On reading the feedback, Ian recalled the stated aims for the appliance. He now suggests moving both teeth simultaneously:

Ian: … Move the upper right – canine buccally and the upper right lateral incisor palatally. Should it be that one? **James**: ***[chooses 'Upper right canine buccally & upper right lateral incisor palatally]*** Yeah, they want you to do both.

A similar discussion takes place between Leonard and Mary who opt to move first the canine and then the incisor, before trying to move both together:

Leonard: Move the upper right canine buccally. **Mary**: … Why don't you try it***? [Leonard chooses 'Upper right canine buccally']*** Why don't we try to move the upper right palatally? **Leonard**: Why? ***[chooses 'Upper right lateral incisor palatally']***. No. **Mary**: No, why don't we try moving that = ***[points to upper right canine]*** = and that = ***[points to upper right lateral incisor]*** = palatally… **Leonard**: ***[chooses 'Upper right canine buccally & upper right lateral incisor palatally']*** Ok, so we move them at the same time.

However not all students are misled by the nature of the question. The discourse between David and Edward and between Ulysses and Victor lets both pairs work out that retroclining the incisor will require simultaneous tipping of the canine before they receive feedback feedback:

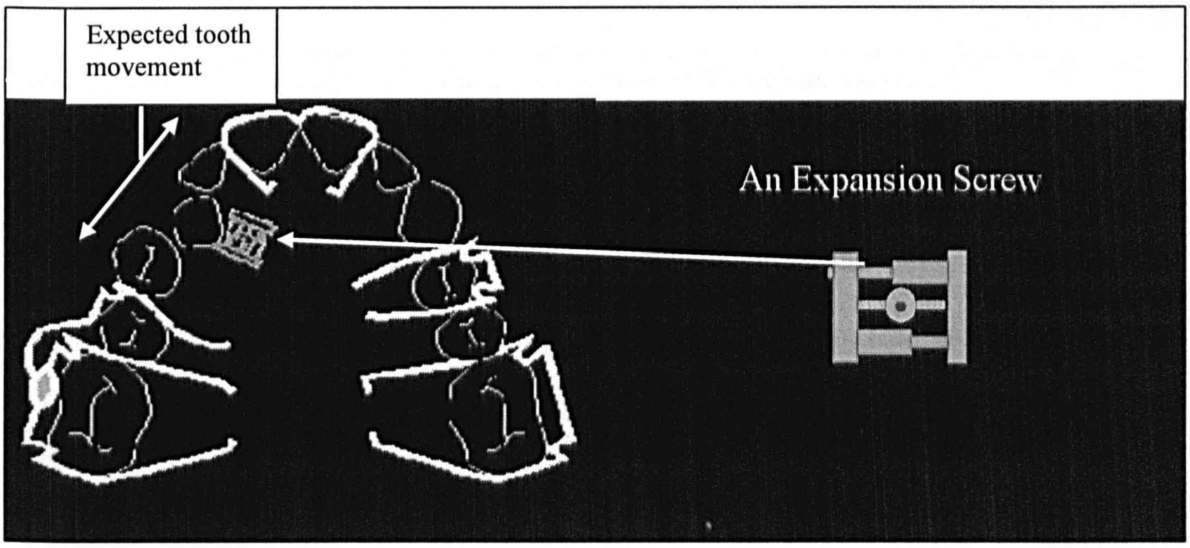
David: Well, if we just move the upper incisor back first, then we want to move the canine. **Edward**: Why don't we just move both? That is, move the upper right canine buccally and the upper right lateral incisor palatally. **David**: Ok, we'll chance it. ***[chooses 'Move the upper right canine buccally and the upper right lateral incisor palatally']*** Ok. YE-ah! …
Ulysses: Well, we can either just move the upper right canine buccally, that's that one = ***[points to 'Move the upper right canine buccally']*** = or we can move the upper right canine buccally and the upper right lateral incisor palatally. ***[points to 'Upper right canine buccally & upper right lateral incisor palatally']*** I reckon it's

that one…
Victor: Yes. ***[Chooses 'Upper right canine buccally & upper right lateral incisor palatally']*** Yes.

Choosing the active elements

Students next have to choose active elements to produce the desired tooth movements for each appliance. In the first appliance distal movement of the right buccal segment can be achieved using an expansion screw, a metal cylindrical object with an internal spiral thread that is turned to "push" teeth in the right direction (Figure 8.4.2a).

Figure 8.4.2a: Diagram of an expansion screw and the expected tooth movement in appliance 1



Just 12/28 sets opt for the expansion screw and nearly as many (9 sets) choose springs. After their choice of springs is rejected by the program, Ian suggests using headgear, believing there is insufficient room for an expansion screw in the back of the mouth:

Ian: That's fine, you're not going to – I don't know. ***[chooses 'Springs']*** It's got to be headgear, you can't have expansion screws on the back –
James: [reading feedback] Apparently that's what we want to do. You see, I thought expansion screws was tucked right up |there|.
Ian: |Yeah|.

When Ulysses suggests using springs, Victor takes charge of the conservation, speaking over Ulysses's words to point out before answering the question that the positioning of the springs means they would not be able to 'tip' the molars back into place:

Ulysses: How are we going to achieve this? With springs?
Victor: You know, remember, when |we use springs,|
Ulysses: |We'd use springs there and there,| ***[picks up pen with left hand and points it at right buccal segment on diagram]***
Victor: They |don't, they don't| =

Ulysses: |Uh, here, with springs| –
Victor:= tip them back. ***[waves left hand towards face to illustrate movement of teeth]***

Having chosen and then ruled out Ulysses' preferred option of springs, Victor gets Ulysses to reflect back on the anchorage question from the treatment planning section to arrive at a conclusion. The interesting point about this exchange, like others involving Ulysses and Victor, is that the correct answer has been provided in the feedback to all three options:

Victor: ... What appliance are we trying to design?
Ulysses: An active removable... I would have thought that they'd use springs ***[points to spring option]***, but ok ... if you can't use springs, then your options are headgear or expansion screw. ***[points at remaining options]***
Victor: Yes, well, it seems that if we're only using intramaxillary, then it would have to be headgear.
Ulysses: ***[chooses 'Headgear']*** No. Expansion screw ***[chooses 'Expansion screw']***
Victor: Yeah.

Leonard, having chosen an expansion screw with comment whilst Mary is distracted writing down an address on a piece of paper for another student, reads and then turns off the feedback before Mary turns back to the screen. Leonard then tries to explain to Mary how an expansion screw can move the buccal segment:

Leonard: Yeah, I think we need an expansion screw to move them back. ***[gestures to diagram, points to upper right buccal segment, Mary looks puzzled, Leonard chooses 'Expansion screw' option]*** Yeah, it's a screw to the baseplate.
Mary: ***[frowns]*** How does that = ***[points to 'Expansion screw' option']*** = move them back ***[points to first molars]*** ...
Leonard: Well because – if you're cutting it this way = ***[brings right hand to screen, little finger drawing a line between the incisors and the buccal segments]*** = and just moving that = ***[moves right hand towards the incisors, points to right molar region with left hand, and drags left hand down screen to illustrate movement of buccal segment]***

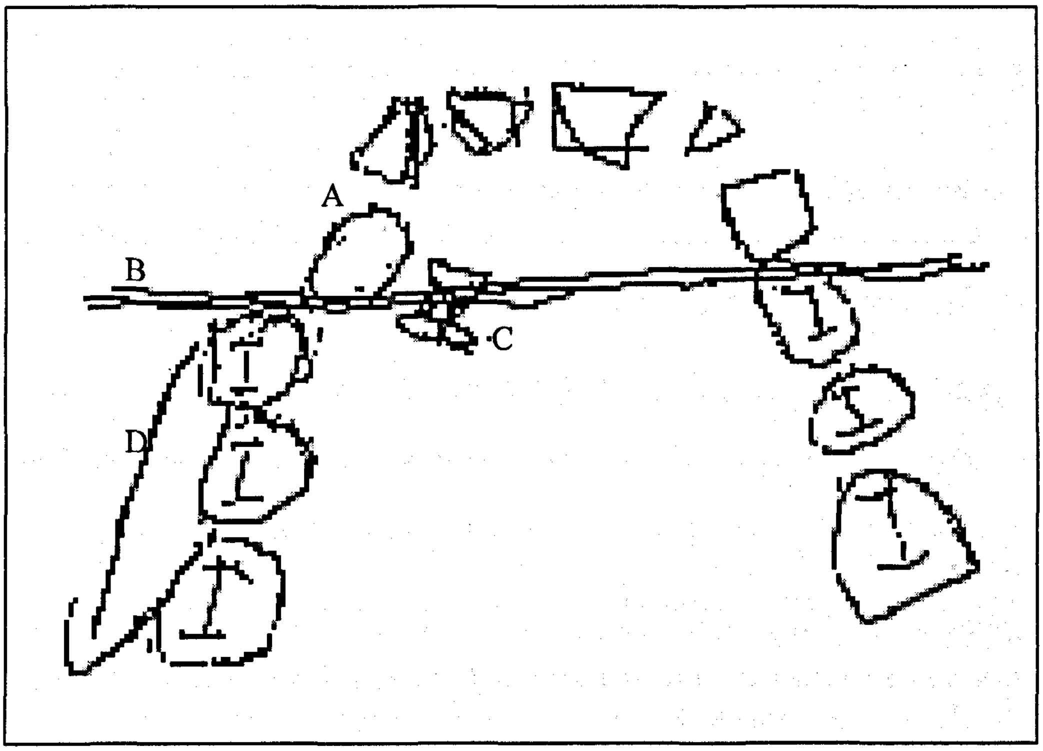
However, as Mary is still unsure how an expansion screw will move the buccal segment Leonard picks up a pen and paper, finding it helpful to use a diagram to illustrate what he means (Figure 8.4.2b):

Leonard: Yeah, you see, here's the arch. ***[draws Figure 8.4.2b]***
Mary: Doesn't the arch just go down?
Leonard: ... It doesn't change.
Mary: Oh?!
Leonard: You see, here's the problem that there was here = ***[points to canine (A)]*** = and the baseplate's there ***[points to centre of arch]***, and you cut it like this = ***[draws line across arch, (B)]*** ... And you put the screw there ***[points to screw (C)]***, and you move it this way = ***[draws arrow (D)]*** = and you move this one sideways = ***[points to canine (A)]*** = |like this|.
Mary: |Oh, right.| Ok.

Brian suggests that Leonard's ability to explain to Mary how the expansion screw might work probably came from his experience of a course on orthodontic techniques:

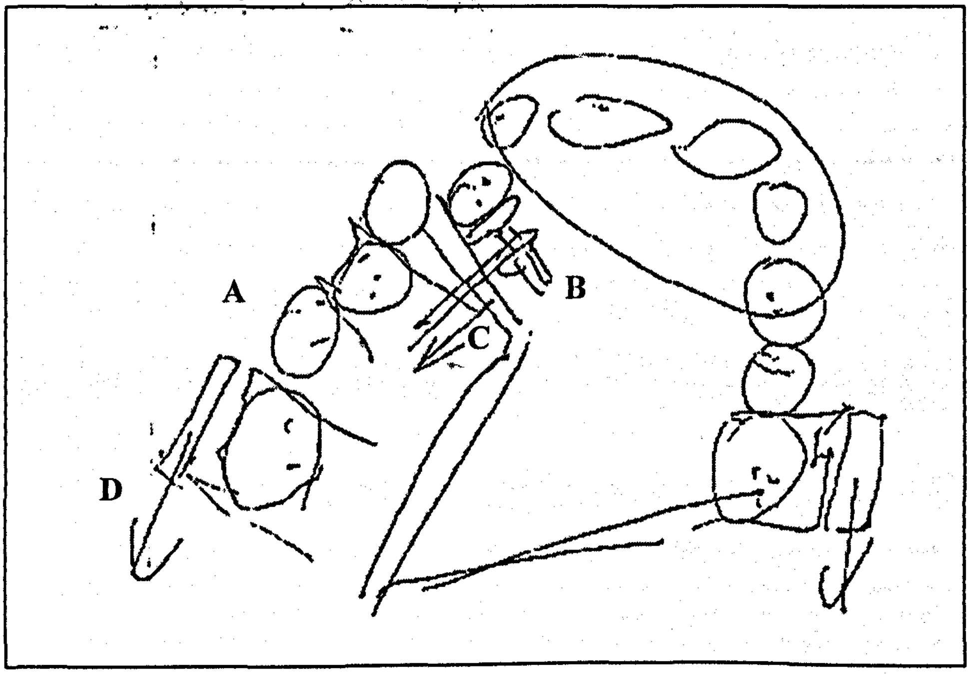
Brian: ... So he's explaining how he would use a screw plate. You wouldn't believe they made one in their ortho technique course, but maybe she didn't complete it?

Figure 8.4.2b: Diagram drawn by Leonard for Mary



Having spent a disproportionate length of time trying to help Winifred on this question compared to the other students in the session – Gareth resorts to a similar diagram to explain what will happen if an expansion screw is used (Figure 8.4.2c):

Figure 8.4.2c: Diagram drawn by Gareth for the first appliance



Gareth: ... So ... bearing in mind the appliance design = ***[starts to drawFigure 8.4.2c]*** = you want these three teeth to go back = ***[draws teeth in right buccal segment, A]*** = you move the whole of this. Right? Now it is possible for this kind of appliance which bolts onto there= ***[draws expansion screw, B]*** = on this side like this, right?... Which I would say is backwards. Put a screw in there. ***[points to B]***
Xavier: Oh, I see. Yeah. |Ohh|.
Winifred: |And then| you just, I see.
Gareth: ... Which is bearing it down backwards ... The anchorage you're getting is you're pitching this = ***[points to expansion screw]*** =against the whole of this = ***[points to buccal segment, draws arrow C]]*** = so it possible to obtain this kind of = ***[draws arrow, D]***
Xavier: = distal movement here
Gareth: = distal movement with this intramaxillary anchorage within the canine. Can you understand?
Xavier: Yeah, I understand that...

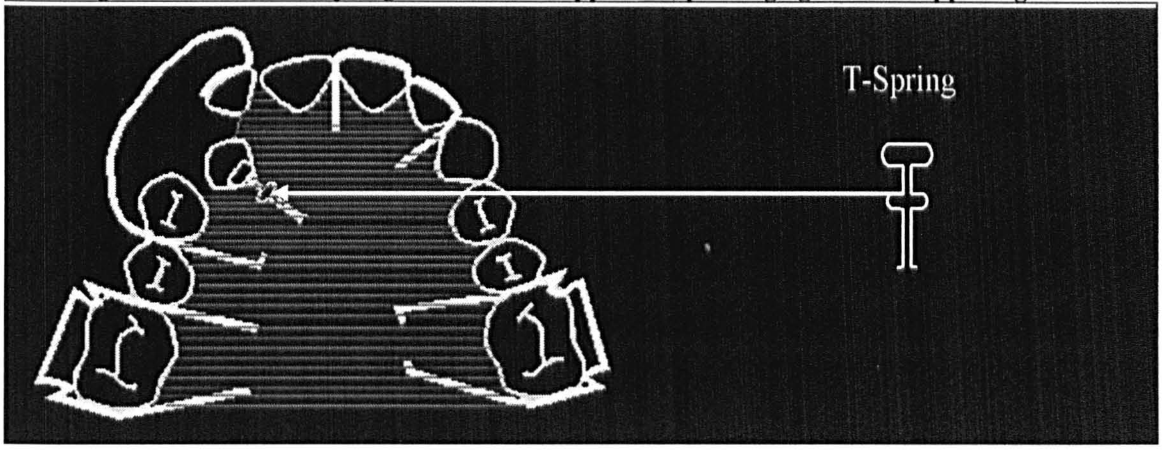
Although Xavier appears satisfied with this explanation, Winifred is very much quieter, and still seems unsure about what is going on – and Gareth goes into a long discussion about this point with her – see resources CD.

In the second appliance the program splits the active elements question into 2 parts. First students are asked to decide what they will use to move the upper right canine, with 21/27 sets opting for either a T-spring (11 sets) or a Z-spring (10 sets). Springs work from the palatal aspect of the mouth to provide buccal movement on the canines (Harty, 1994). A T-spring, involving a double length of wire with a T-shaped tip, is preferred to a Z-spring. T-springs, and is considered more effective because the bulky shape of a Z-spring means it will not fit as well into the appliance and, by cramping the space for the tongue, is less comfortable for the patient to wear (Figure 8.4.2d). Brian does not expect students to have too many problems with this question because the use of T-springs to move the canine into place is:

Brian: ... a very simple, one-dimensional movement... by this time, they ought to have seen they were ... needing trivial amounts of space.

Incidentally the belief that springs can be used to move teeth buccally may be a clue as to why some students opt for springs in the first appliance – it is possible that, due to their lack of experience in designing removable appliances, they may have confuse "buccal movement of the teeth" with "distal movement of the buccal segment".

Figure 8.4.2d: The T-spring in the second appliance, pushing against the upper right canine



Initially Ulysses appears distracted by the option for a buccal canine retractor, however rejecting this movement, Victor suggests a spring, forming a T-shape with his hands to describe the expected movement:

Victor: Presumably you would use a Z-spring or T-spring.
Ulysses: I don't know. Oh, hang on.
Victor: ***[points to upper right canine with second finger of left hand, and illustrates canine moving outwards by pushing fingers of right hand against palm of left hand, moving both hands towards the screen]*** You just move that out.
Ulysses: ... So you just push that up ***[points to upper canine, moves pen in expected direction]*** ...

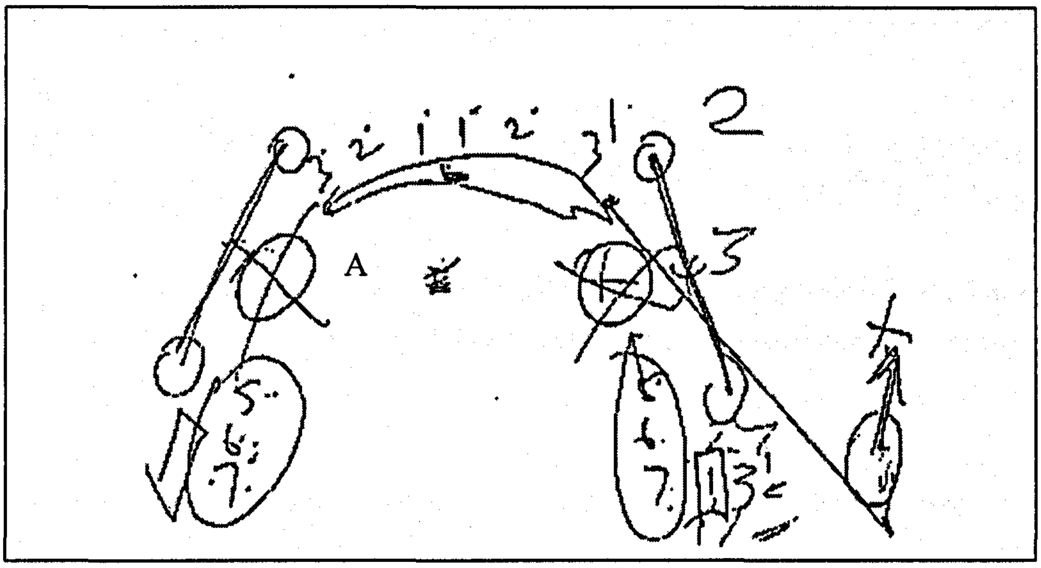
Perhaps influenced by the first appliance, 3 sets opt for an expansion screw, for example having rejected a spring, Leonard goes along with Mary's suggestion of an expansion screw:

Leonard: How are you going to move the upper right canine buccally? A Z-spring?
Mary: How about a palatal canine retractor?
Leonard: |No, a Z-spring|
Mary: |Oh, but you| will need to use the 4s to use it.
Leonard: A Z-spring will fit on a canine... A Z-spring or a T-spring is not going to work. That's not what we want.
Mary: An expansion screw?
Leonard: An expansion screw. ***[chooses 'Expansion screw', then chooses 'Z-spring']***

In session 6 Gareth helps students understand which element to choose by drawing his second diagram (Figure 8.4.2e) to show Xenie why a spring is required:

Gareth: You can't use an expansion screw ... you need a spring here. ***[draws second diagram, Figure 8.4.2e, position of spring indicated by A]***
Xenie: Oh, so you need a spring on that bit.
Gareth: Yeah.
Xenie: So you could, you kind of |...|
Gareth: |... you can|, that's right, you can use that and join it to that point. Yeah...

Figure 8.4.2e: Second figure drawn by Gareth

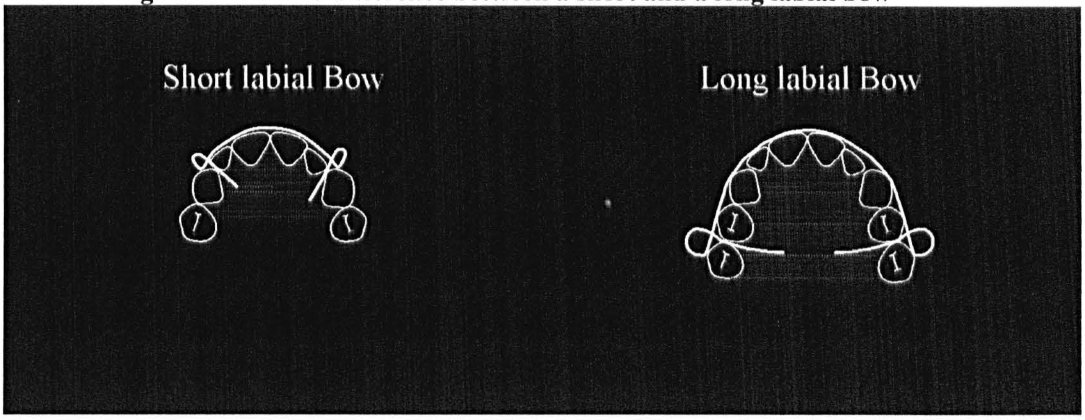


Having identified the T-spring as the active element for the canine the program asks students to decide what to use to move the upper right lateral incisor palatally. The analysis shows there is very little discussion about the possible options displayed on the screen with students apparently making use of the feedback to understand why the buccal approaching spring, rather than, for example, the labial bow, is used to move the upper right lateral incisor palatally. Again the presence of a partner helps, for example when Olga explains to Peter, post-feedback, how a buccal approaching spring can push the incisor into position:

Peter: Maybe with that one.
Olga: Uh-huh. Ok. A buccal approaching spring? ***[Peter chooses 'Buccal approaching spring']*** Right. Ok, then.
Peter: Where does that come from? From there? ***[points to buccal segment]***
Olga: Oh, well, it just clips in and pushes that = ***[points to upper right incisor]*** = from the outside in.
Peter: Ok.

Some students want to use an orthodontic bow rather than a buccal approaching spring. To clarify this point, there are two types of orthodontic bows (Figure 8.4.2f), or pieces of wire bent to the shape of the dental arch in the incisor region which can be placed either labially or lingually in the mouth, depending on the required outcome (Harty, 1994). A labial bow, more usually used as a retentive device, cannot be used for tooth movement because the stiffness of the bow may damage teeth if used for retraction.

Figure 8.4.2f: The difference between a short and a long labial bow



Kevin explains in his talk-back interview that part of the problem is likely to be due to their relative lack of experience with orthodontic removable appliance design rather than any other underlying misconception of the topic:

> **Kevin**: The springs bit here, I thought springs tipped teeth, and I saw that as a bodily movement, but as it turns out the t-spring or the z-spring can move it bodily, whereas if it – I don't know – ask me again in a year's time, when I've moved on.

Choosing the posterior retention

Students now need to decide how the appliance can be retained in the back of the mouth. Most students (21/28 sets) choose both upper first permanent molars. For example, after realising that retention is required to hold the appliance in place, Ian and James opt for both upper 6s:

> **James** : Well, retention's just stopping it falling out, isn't it? So – both upper first permanent molars and both upper first premolars?
> **Ian**: Why not just both upper first permanent molars?
> **James**: Yeah. ***[chooses 'Both upper first permanent molars', reads feedback]*** Do you think any other teeth ought to be clasped? Why not try again?

Ian and James eventually find that they are expected to use both upper first permanent molars, the upper right second premolar and upper left first premolar by choosing each of the remaining options. Anne, Belinda and Christine also use a process of elimination to find the right answer, apparently believing that, because they are trying to move the back teeth, posterior retention should be kept to a minimum so as not to inhibit this movement:

> **Belinda**: … We can't have too many to be retained, because we're trying to move them ***[points to upper right molars]*** …
> **Anne**: Let's eliminate the ones that don't apply, and then just choose one from the ones that are left. … ***[cups right hand towards screen]*** I don't see how you can use both first molars when they're moving …

Belinda: I agree with that. Just the first molars then. ***[chooses 'Both upper first permanent molars']***

Ulysses and Victor also reflect on how the retention might be linked to the movement of the teeth. Despite realising that more teeth may be required for retention they, too, initially opt for just the first molars before going through the remaining options.

Victor: If you've got retention for those teeth = ***[points to upper right molars in his own mouth using the first finger of his right hand]*** = and you're moving them back, how's this all going to work?
Victor: Retention using the first upper permanent molars =
Ulysses: ***[makes a cup shape with right hand]*** = anchoring onto the first upper premolars, = ***[gestures to right buccal segment with right hand, palm facing towards Victor, fingers pointed, pushes hand away from body diagonally towards image on the screen]***= you tend to push the whole of this buccal segment back.
Ulysses: So you need to get more in, you need to have more in your retention…

Feedback from the computer reveals that both the upper right second premolar and upper left first premolar are required to ensure adequate posterior retention to move the buccal segment distally. In the second appliance the majority of students (18/29 sets) choose first molars plus one or two of the premolars, finding out from the feedback that the first molars alone can provide sufficient posterior retention to tip the canine and retrocline the incisor.

Where the second appliance is concerned, the log-files reveal a bug in the program that was not picked up in the pilot study, when both students (possibly because they were more familiar with appliance design by the end of the M-year) correctly chose "both upper first permanent molars". In the main study, perhaps influenced by the feedback from the computer for their earlier choice of posterior retention, nearly half the students (14/29 sets) choose either "both upper first permanent molars and the upper right first premolar" or "both upper first permanent molars and the upper left first premolar", both of which are recorded as identical options by the computer. It proved impossible from the transcripts alone to assign all the sets to the correct options. Having chosen one option, by this stage in the program most students end up working through the remaining options in turn, apparently following the instructions on the screen to "take a look at the other options" rather than spending time reflecting on their choices beforehand.

In this question the computer has been programmed to provide specific feedback for each option, leading both Adam and Bill and Ian and James to wonder why there is a problem with 2 wires passing through the same embrasure when using both the upper first permanent molars and the upper left first premolar. Perhaps concentrating solely on the posterior retention, Ian and James are sufficiently confused about this point to turn to the Interviewer for help. Despite being advised by the Interviewer to go and speak to their tutor waiting in the room next door, neither student feels the need to leave the CAL room. Instead Ian and James opt to continue through to the end of the program, perhaps finding the answer to their query from the diagram on the next screen which showed the error in the program as according to Brian the diagram, which conflicts with the commentary, should have made sense to the students.

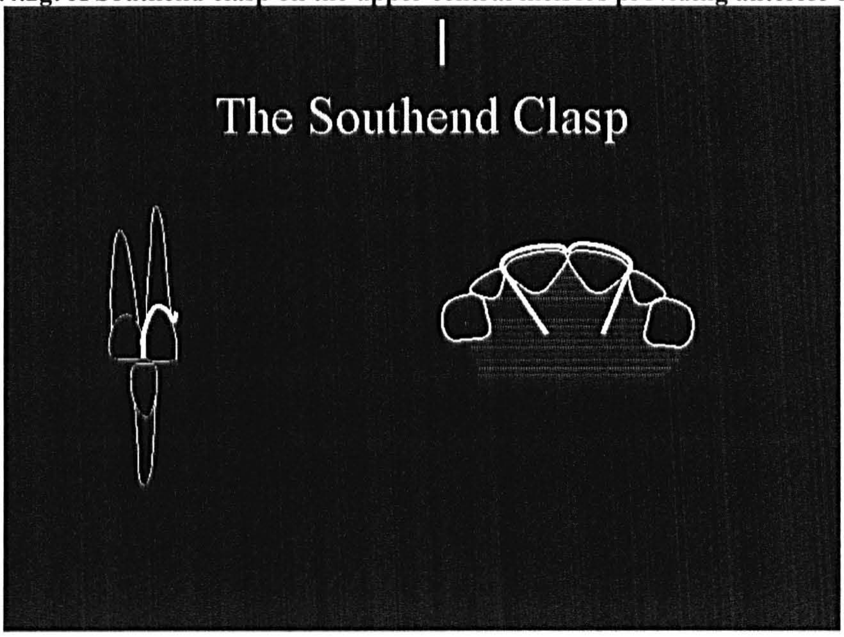
Choosing anterior retention

The program then asks students to consider what type of anterior retention should be provided for each appliance. For the first appliance, students are provided with two separate questions on this topic, the first asking them to choose a retentive element, the second to identify which teeth will be used to hold this element. These questions are combined in the second appliance. For both appliances the element of choice is a Southend Clasp (Figure 8.4.2g), rather than a labial bow. The Southend clasp is preferred because it is usually more effective and less obtrusive than a labial bow (Stephens, 1979). Although labial bows can sometimes help with anterior retention they will normally only be chosen if there is more than one reason for using such a device (e.g. to carry an auxiliary spring), something which is not necessary in this case.

The majority of students correctly identify a Southend Clasp as the element of choice for the anterior retention in both the first appliance (16/28 sets) and the second (26/28 sets). For example, Ian and James eliminate a labial bow in the first appliance because they believe "it would not fit as well", with James using his hands to help Ian remember the shape of the clasp:

James: Southend clasp. ***[chooses 'Southend clasp']*** Oh yeah.
Ian: I've forgotten what they look like now – ***[mumbles]***
James: They look like = ***[draws M-shape with fingers around incisors on diagram]***

Figure 8.4.2g: A Southend clasp on the upper central incisors providing anterior retention



Elizabeth also uses her hands to help illustrate the Southend Clasp's shape to their partners:

Felicity: What's a Southend =
Elizabeth: = a Southend Clasp is the one like that ***[points to screen, draws M- shape with right hand around the incisors, then repeats with left hand]***...

Having chosen a Southend Clasp, Jennifer uses her hand to draw a similar shape around the incisors, representing the clasp, to show Kate which teeth would need to be used in the retention:

Kate: On which teeth do you want to place the Southend clasp? All four incisors? ***[chooses 'All four incisors]***
Jennifer: ***[points to upper central incisors]*** You need it there and there. ***[draws M-shape around incisors]***

Ulysses too, uses his hands to direct attention to relevant part of the appliance as he explains that:

Ulysses: ... ***[points to right buccal segment]*** = a short labial bow goes from behind. ***[declares]*** You can't have a long bow there, there's no space...
Victor: No.
Ulysses: And this can't go there, = ***[points to 'Anterior crib', then to buccal segment]*** = because that's going back, so it's go for a short labial bow or a Southend clasp.

Having discounted a long labial bow, Victor decides that the answer is:

Victor: ... probably a Southend clasp. Check on that one there. ***[directs attention to 'Southend clasp']***
Ulysses: Go for a Southend clasp.
Victor: ... Ok. ... ***[chooses 'Southend clasp option]*** Yeah.

Nine sets opt for a long labial bow, possibly because, like Belinda, they believe it will help with anchorage as well as retention, but more likely because it is an element commonly found on upper removable appliances. Post-feedback from the program Adam realises that a labial bow will not be ideal because there is not enough room for the wires.

For the second appliance the program asks students to decide what anterior retention they will use, with options including both a functional element and the teeth which might retain that element. The majority of students (26/28 sets) choose one of the two Southend clasp options (18 sets choosing both upper central incisors, 8 sets the upper right central and lateral incisors), possibly because, like Kevin, they rely on their memory of feedback from the questions about anterior retention in the first appliance:

Kevin: ... Southend? I don't know. Southend, only 'cos it was used last time.

Rachel focuses on the upper right canine in her answer and her reflections, together with the feedback from the program, seem to help her arrive at the correct answer on their second attempt:

Rachel: ... No, I think it's a Southend clasp on the upper right central and lateral incisors. Because it'll provide more rotation there ***[points to upper right canine]*** **Queenie**: Yeah. **Rachel**: Yeah. **Queenie**: The Southend's going to be here, isn't it? ***[points to labial region, chooses 'Southend clasp on upper right central and lateral incisors']*** OH! Ok. **Rachel**: Or on there. ***[points to Southend clasp on both central incisors']*** On that one. Yeah. I'm sure it goes on there. ***[Queenie chooses 'Southend clasp on both central incisors']***

Adam realises pre-feedback that a Southend clasp can not be used on the lateral incisors, with Bill accepting the two central incisors without further explanation. This pattern of accepting a suggestion from a partner without further comment is seen far more frequently during the appliance design sections than in the earlier sections. Most students are more passive and less discursive whilst working through the answers, often guessing answers or working through each option in turn.

It is possible close to the end of the program (having been working on the case for, on average, nearly forty-five minutes, Appendix D, Table D7) some students are beginning to find it relatively more difficult to concentrate. For example, Isabel, having chosen a

Southend Clasp on the upper right central and lateral incisors "to tip the upper right canine buccally" agrees with Helen to opt out of any further reflection on the options and see what the program reveals:

> **Isabel**: … Always no … Oh, let's just forget it, yeah.
> **Helen**: Yeah.
> **Isabel**: Let's just try them all.
> **Helen**: Yeah. ***[chooses remaining options in turn]***

In the final questions this pattern of behaviour is observed even between students like Ulysses and Victor who have previously taken time to reflect on nearly all of the questions relating to the case assessment, treatment plan and early part of the appliance designs. Another factor that may account for this passivity is that, having only recently encountered appliance design in their lectures and tutor groups, their passivity may be due to a lack of familiarity with appliance design compared to their understanding of classification and treatment planning activities, as Kevin suggests in the post-session interview:

> **Kevin**: … I didn't have a clue about any of this – not because of a problem with the program, but because of my knowledge being deficit – but then the answers were explained.

The passive nature of many of the observed and recorded interactions meant that, unlike in the case assessment or treatment planning activities, there are fewer opportunities to gain additional information from the context in which the study took place. Despite this increased passivity amongst students, however, the QSR/N6 analysis reveals that asking students questions about the appliances can trigger reflective questions in students who have previously been relatively passive about discussing the case. It is possible that being asked by the computer to come up with an appliance, following extraction of the 7s, forces these students into reflecting back on the case, and particularly the extractions, when trying to decide which teeth to move. For example, having made little effort to find out why 7s are chosen for extraction earlier in the session (Section 7.3), Michael and Natalie finally try to make sense of the request to extract 7s when asked to choose tooth movements for the first appliance:

Michael: ... You want to move this forward = ***[points to upper right canine]***
Natalie: Yeah.
Michael: And you do that by extracting that. ***[points to gap where upper right 7 would have been]***
Natalie: ***[chooses 'Move the upper right canine buccally']*** No, the 7s have been extracted. So the upper 6 left, so you need to bring this back to here. ***[points to upper first molar, then to gap]***

Although they, too, have appeared to have forgotten the waiting 8s this reflectivity about possible tooth movements continues a couple of questions later. After Natalie suggests that the second stage for designing an appliance might be posterior retention, Michael retorts:

Michael: ... Anchorage!
Natalie: Really? Why?
Michael: Posterior retention? Come on, it pushes them forwards ***[points to upper molars]***
Natalie Yeah...
Michael: It's this, this, this. Anchorage, anchorage.
Natalie I bet it's not. ***[chooses 'Anchorage']*** Yeah.

On discovering that anchorage is not the answer they are looking for, Michael reverts to Natalie's original suggestion:

Michael: ... I think it's the first thing you did. ***[chooses 'Posterior retention']***
Natalie Yeah. It's because [posterior retention] pushes down that 7. ***[points to upper right molars]***

The questions on tooth movements for each appliance lead to a similar increase in interactivity in their discourse between Queenie and Rachel. This reaction may account for why, despite their apparent passivity over the program as a whole, Queenie and Rachel are able to explain that posterior crowding is a reason why 7s are chosen in the post-session interview:

Queenie: If you move that, then the canine can drop. ***[points to premolars]***
Rachel: I see. But surely they = ***[points to molars]*** = should be moved distally?
Queenie: Well, you could do that.... So what you're doing, when you do this appliance, is that you're not going to do that = ***[points to premolars]*** = you're going to move that. ***[points to upper right molars]***

Rachel: ... We've just got to move that to there and then that to there. ***[points to canine, then to lateral incisor]***
Queenie: Yes, then the two fit.
Rachel: Because if you just move that buccally, rather than reducing that ***[points to canine then to gap on diagram]***
Queenie: So you'd move the upper right canine buccally?
Rachel: Yeah, so that you can maintain the occlusion. Yeah.
Queenie: Ok. ***[chooses 'Upper right canine buccally & upper right lateral incisor palatally']***

Brian suggests these students may have become more discursive during the appliance design section because:

Brian: ... it's an easier problem to deal with because it's all there in front of you, with a plan-view diagram that they've got – and it's very 2-dimensional... So they haven't got to juggle so many things. I think it is simpler... Appliance design is something which they enjoy doing

Brian goes on to note that when graduates:

> **Brian**: ... do their practitioner postgraduate courses for this ... general dental practitioners... love spending time on appliance design. It's almost as good as playing computer games...

Baseplate modifications and anchorage requirements

The final question for the first appliance asks students to consider whether extra-oral anchorage might be required to reinforce the retention. Most students agree to chose one of the options without debate; seemingly happy to let the program supply them with an answer through "Trial and Error", for example:

> **Ulysses**: ... I've no idea which one it is. You might as well try them all.
> **Victor**: Ok.

The QSR/N6 analysis indicates some students reflect back on the extracted 7s when considering the possible answers for this question. For example Leonard and Mary seem to believe the upper right 6 will need to move to fill the space created by removing the 7s and will thus not be available for anchorage:

> **Mary**: ... You also have the second molar to move. Yeah... If you've got rid of these 7s.
> **Leonard**: Yeah, ... if you've got rid of the 7s too... If you're trying to move all these teeth = ***[points to buccal segment]*** = ... you don't want them in your anchorage too?
> **Mary**: No.
> **Leonard**: Yes.
> **Mary**: So you'll be putting it all be on one side.
> **Leonard**: So your anchorage is all on that side...So you'll need anchorage in all cases.
> **Mary**: Yes. ***[Leonard chooses 'In all cases']***

After reading the feedback on the screen, Leonard agrees with Mary when she realises that the level of posterior crowding might mean that:

> **Mary**: ... you're not trying to move the 7 as well.
> **Leonard**: Yes.

Ian and James also reflect back on what the program has already revealed about the case whilst trying to sort out the extra-oral anchorage:

> **James**: ... [The CAL program has] already told us you don't need [extra-oral anchorage]. Because if you've taken out the 7s, surely there is no resistance to that lot moving back ***[referring to the 6s]***.
> **Ian**: No.
> **James**: If you were moving the 6s and the 7s, then there's a massive amount of – unless an upper second [...] ***[chooses 'Unless an upper second molar has been removed']*** – evidence of posterior crowding. Ok.
> **Ian**: ***[reads]*** Although there is evidence of posterior crowding, it is intended to extract upper right 7, extraoral anchorage is not required ...

For the second appliance the final two questions ask students to consider whether any modification is required to the baseplate as well as whether the anchorage elements requires any additional reinforcement. An orthodontic baseplate is the acrylic resin base of a removable appliance that holds any springs, wires or clasps in position (Harty, 1994). As orthodontic specialists can have different opinions about the requirements for both questions students have been provided with a non-committal "not sure" type option to choose. For the baseplate the majority of the students (17/29 sets) choose this "probably not" option. For example, Elizabeth interlocks her hands to demonstrate how the teeth might come together before deciding that they probably will not need any baseplate modifications:

Elizabeth: Oh, you'll need one if, because if we – ***[pause 2s]*** Oh no, ***[pushes left hand towards screen, palm down]*** Ok, so if we haven't got a crossbite, ok, then that can go like this ***[raises right hand and brings the fingers down towards her left hand, interlocks her fingers and moves both hands downwards]*** No. No, I don't think so.
Felicity: No.
Elizabeth: There's been a bit there as it erupted = ***[points to upper right canine]*** = so … you possibly don't need anything.
Felicity: As it erupted, no. ***[shakes head, then nods head]***
Elizabeth: No.

Although Laura feels that the overjet (which is, in fact, average in this case, Table 6.8.3) might need to be reduced, she uses feedback from the program to understand that a biteplane can be used if desired to move the canine across the lower teeth. The other set that discuss biteplanes when thinking about the baseplate are Ian and James, who again reflect on the case before concluding in the following conversation that there is usually more than one way of treating a case:

Ian: Do we need any biteplanes?
James: No, because you haven't got over-erupted or under-erupted teeth, have you?
Ian: Well, 3's not erupted properly yet, has it?
James: No, but would you need a biteplane?
Ian: No.
James: Ok, so we'll put no. ***[chooses 'No']***
Ian: ***[reads feedback]***… That's the thing, for an average situation … there's something you could use and then there's three or four you might use.
James: Yeah.

As with the question on the baseplate the option "Probably not" provided for the final question in the program on anchorage requirements is chosen by the majority of students (18/29 sets). However even now, despite the length of time they have been working, some students still found energy to discuss what is happening, primarily because like Ian and James they are still aware of the problem of the upper right canine.

> **Leonard**: … pushing that canine over the bite?
> **Mary**: Yes, well it's not there, |it's not = |
> **Leonard**: |It's not –|
> **Mary**: = fully erupted.
> **Leonard**: I see. Then no. ***[chooses 'no, both read feedback]*** Ok?

David and Edward also reflect on what might happen to the canine:

> **David**: But if that canine's erupting = ***[points to upper right canine]*** = and … so's that canine, *I think it should be stuck on there or on there.* ***[points to first molars]*** Because you see it has a biteplane sticking there, sticking out. ***[pause 2s]*** What do you think?
> **Edward**: Oh!
> **David**: Probably not?
> **Edward**: Ok.
> **David**: ***[chooses 'Probably not']*** … The forces of tooth movement in this second appliance cancel out – oh, I see. ***[pause 2s]***
> **Edward**: David, what do you think of this canine going here and that going there? ***[gestures towards upper right lateral incisor]***…

This point is picked up pre-feedback by Ian and James when reflecting on the anchorage, probably following on from their conversation about the baseplate:

> **Ian**: … Do you require use of the headgear?
> **James**: I can't see it… because I don't see that as a movement that way = ***[points to upper right canine]*** = and that's a movement that way = ***[gestures towards upper right lateral incisor]*** = and these movements are almost reciprocal to one another, don't they?
> **Ian**: |Probably not|
> **James**: |Probably not| Yeah. Because … they're pretty … reciprocal, aren't they? ***[chooses 'Probably not']***

Ulysses and Victor also go further than the immediate question, reflecting on the tooth movements for both appliances in their discussions about the anchorage for the second appliance:

> **Victor**: … No. What do you reckon?
> **Ulysses**: Yes it will.
> **Victor**: ***[points to upper right canine with first finger of left hand, then gestures towards right buccal segment with second finger of left hand, palm up, pulling buccal segment down the screen]*** Yeah, well, if you're going to be moving the buccal segment, then they're obviously not going to be moving distally, are they? Because there's going to be a gap there ***[points to right canine]***…
> **Ulysses**: Yes … this is the second appliance. The first one moved this back ***[points towards right buccal segment with pen in right hand, pulls pen down twice to show buccal segment moving]***, and this will move this back there and this there ***[uses similar gestures to show canine and incisor moving]***, won't it?
> **Victor**: So which one?
> **Ulysses**: Probably not.
> **Victor**: Ok. ***[chooses 'probably not]***

One student in each of the remaining pairs chooses an option accepted without comment by their partner e.g.:

> **Kate**: Do we need to reinforce the anchorage?
> **Jennifer**: Probably not. That seems about right.
> **Kate**: Ok. *[chooses 'Probably not']*

After finishing the questions for each appliance, students are provided with a diagram of each appliance on the screen plus a series of digitised photographs of the actual appliances and the appliances *in situ* as they are taken through a series of screens which provide a textual summary of the actual treatment carried out on JB, together with a complete set of digital images of her teeth after treatment has been completed.

Not all the students have given up completely; even at this late stage students could be overheard commenting about the case. For example, Olga and Peter appear impressed by the original treatment results:

> **Olga**: Well, if you look at that, that's incredible.
> **Peter**: Hmm. *[pause 22s]* This is just what happened. Yes. Ok. *[pause 8s]* What's? What's that? Let's go back a bit. *[returns to previous screen, pause 9s]* Oh-kay! Cool!!

Similarly Mary, looking at the treatment records displayed on the screen, raises the topic of JB's dental age, possibly because she is finally starting to register the fact that JB is dentally advanced for her age:

> **Mary**: ... It's unusual for molars to be fully formed and erupted at that age.
> **Leonard**: Ok?...

8.5 Student interactivity when reflecting on appliance design

Although the QSR/N6 analysis shows there is generally less interactivity between students whilst they work on the appliance designs it is still possible to draw some conclusions about the nature of this interactivity. The *proviso* is that the findings should be considered more tentative than the case assessment/treatment planning findings as they are reliant more on making inferences about students' understanding of orthodontics by analysing results from the quantitative log-file data than from what students suggest as reasons when negotiating answers with their partners.

QSR/N6 analysis indicated some potential triggers for reflective behaviour from the students. Table 8.5a shows the number of instances of coding of reflective behaviour per question in the appliance designs.

Table 8.5a: Number of Instances of behaviour classified as reflective recorded during appliance design activity

Triggering Questions	No. of Incidents of Reflective Discursions	Trigger
Appliance Design 1		
43-45	12	Which teeth needed moving
46-47	8	Which teeth were available at the back of the mouth for posterior retention if the 7s are extracted
49-50	12	How an expansion screw or springs might work in an appliance
Appliance Design 2		
52-55	17	Deciding what to use to move the canine buccally and the lateral incisor palatally
56-57	6	Which teeth are available at the back of the mouth for posterior retention.
58-61	14	The difference between a labial bow and a Southend Clasp.

Three triggers for reflective behaviour have been identified for each appliance:

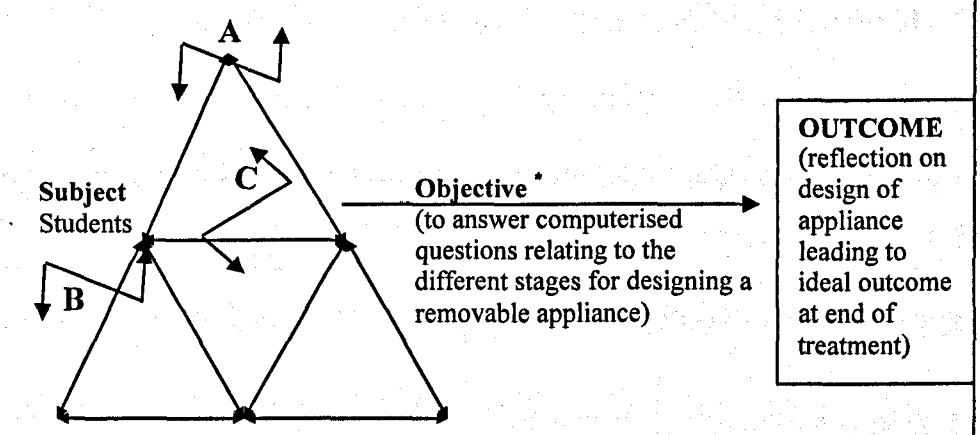
1. Asking students to think about which teeth to move
2. Asking students to think about how the appliance can be retained by teeth at the back of the mouth
3. Asking students to think about how different parts of the appliance could be used to carry out these movements.

The transcripts indicate that discussions within pairs followed a similar pattern. With no significant difference in responses between pairs and individuals, it is probable that individual students are thinking along similar lines as students in pairs. The appliance designs have provided students with an additional opportunity to reflect back on the case, helping them to a better understanding of why they have been asked to do the unexpected. The reality of the case is helping students to a deeper understanding both about why JB needs to have second molars extracted and why premolars are normally chosen for extraction. Any recommendations for future guidelines for the development of CAL can therefore be based on the idea that it is content, rather than programming style, which is most effective in supporting student learning. An activity system that describes what happened in the appliance design sections is shown in Figure 8.5.

Figure 8.5: Activity system for using CAL to learn about designing orthodontic removable appliances

Mediating tools

- MCQ format questions provided by CAL program
- orthodontic terminology and memories of case summary and treatment plan
- links to digitised images of patient's records
- diagram of occlusal view of upper arch and appliances
- pen and/or fingers as pointers
- pen and paper
- recall of relevant features of the case:
- mental model of direction of required tooth movements
- memory of movements or action of different types of functional
- (for the 2nd appliance) recall of outcome and feedback in response to questions for first appliance



Rules & Procedures
- understanding of rules and procedures for designing an orthodontic appliance
- recall of correct sequence of events for designing a removable appliance

Community
- student's partner
- other students
- Gareth
- Interviewer

Division of Labour
- when students used their fingers or a pen to help their explanation
- when one student drew a diagram to help his partner understand how an expansion screw would work
- when the tutor draws diagrams

From the QSR/N6 analysis it is possible to identify some reasons why students may be struggling with answering the questions about the appliance designs. One reason seems to be a lack of familiarity with designing appliances and remembering what different appliance elements can do. The activity system suggests there is a primary contradiction (A) in choosing the right mediating tool to achieve the desired objective and a secondary level contradiction in understanding the correct procedural sequence (B).

By the second appliance the analysis of the transcripts suggests some students seem to gain enough confidence in their memory of how the different elements might work to help their partners identify a spring rather than the expansion screw as the active element.

The transcripts suggest that another difficulty for the students lay in their inability to pull into focus the relevant features of the case (the posterior crowding and the waiting 8s, the mildly crowded incisors, the extracted 7s and the proposed plan of treatment) and link these features to understand and choose which element will be best suited to meeting the desired outcome for each appliance. There is a further secondary level contradiction in understanding the desired outcome (C) (e.g. switching focus away from making space for the partially erupted upper right canine to taking into account the waiting third molars).

In particular some of the students still seemed to have a problem switching their focus away from the partially erupted upper right canine to understand that they needed to make room for the crowded third molars. Similarly when deciding on posterior retention for the first appliance, several students opted for retention on as few teeth as possible – apparently wanting to minimise any interference with the movement of the buccal segment into the gap created by the 7s. Similarly although the stated aim for the second appliance is to tip the upper right canine buccally and retrocline the upper right lateral incisor rather than movement of a whole buccal segment, some students opted for the same elements in the second appliance as the first.

8.6 Chapter summary

Following the extraction site questions there was a change in the type of interactions between the students, which became more noticeable when students entered the appliance design section. Student interactivity seemed to be more passive during the appliance design sections either because of 'fatigue' and/or because they were less familiar with orthodontic design procedures. Despite this reduced interactivity, using QSR/N6 to code for reflectivity showed that the appliance design sections, a later addition to the program, could be effective in getting some students who had previously been very passive to do more thinking about why they were being asked to extract the second molars rather than the premolars.

Although designing an appliance to carry out a course of orthodontic treatment was considered to be less complicated than making diagnosis decisions or planning how the case might be treated, students still found it difficult to come up with the right answer, frequently guessing or working through all the options in turn until they found what is needed.

Chapter 9: Discussion

Chapter 9: Discussion

9.1 Introduction

The purpose of this chapter is to discuss the analysis of the results presented in the previous 3 chapters. This chapter starts by drawing together the main findings of the results chapters before examining possible differences in the interrelationships between the students based on these findings. The chapter concludes by proposing a series of guidelines for the future development of CAL in dentistry.

9.2 Students' conceptions and reflections on orthodontics

The purpose of this section is to provide an overview of what happens when students interact with a CAL program, each other and their tutor to learn about orthodontics, and to explore in more depth what can be inferred about why this interactivity occurs.

9.2.1 Putting theory into practice

Students are observed and recorded as they work through an orthodontic case presented via dental records and questions displayed on a computer screen. Taking place at the start of the M-year, this study provides an opportunity to observe students when they first put theory into practice.

One source of difficulty that influences student interactivity identified in this study arises from their lack of experience in using orthodontic terminology. Activity theory suggests that the main difficulties facing students in understanding how to use the correct symbology to answer questions about an orthodontic case are due to both primary and secondary contradictions in the system. If the cause of these difficulties is a lack of practice at using the terminology, increasing familiarity will be expected to naturally lead to an improved confidence in approaching the task. Even before the end of the first section students who experience difficulties when they first have to use FDI notation to identify teeth are able to switch between both forms of tooth identification before they move into the treatment planning section of the study. Similarly students in the pilot have no difficulty identifying absent teeth, suggesting they are able to draw on a deeper understanding gained from a combination of their experiences during the M-year.

Some students have problems because they ignore or fail to choose appropriate records to examine when answering a question. For example students do need to check other features of the program to assess the upper right canine. Most students fail to do either, consequently guessing the answers. Other instances where the program's presentation of the case questions may have restricted students' choice of dental records are seen in both the extra-oral and the radiographic sections of the case assessment. It is impossible to separate out the degree to which it is student understanding about which tool (e.g. dental record) to choose rather than their understanding of the rules governing orthodontic procedures that is the underlying source of the contradiction.

Students' inability to draw on marginal aspects of the case is highlighted by other studies, where one difference between novices and experts has been identified as the expert's ability to move confidently between theme, thematic background and margin at will, in a dynamic process. Conversely novices appear to be stuck with just the theme, unable to bring background and margin into focus without further help (Marton and Booth, 1997). It is expected that increasing experience of assessing different orthodontic cases will improve students' performance, as is seen in the pilot study where students work through the program at the end, rather than the beginning, of the M-year.

Assessing whether teeth are absent from the mouth reveals a quaternary contradiction between orthodontics and restorative dentistry (Section 6.4.1). Several students include the upper right second molar (and occasionally even the upper right canine) as absent teeth, relying on a definition from restorative dentistry that a tooth needs to be functional to be counted as present in the mouth. Most students realize from the feedback that orthodontists will judge a tooth to be present as long as any part of it can be seen.

Once they have settled down to using the computer and familiarise themselves with how to answer the questions several students are observed talking about the case as if the computer does not exist. From the intra-oral section onwards students rarely mention the computer until they are specifically asked about their reactions to using a computerised case in the post-session interviews. For example, when Ian and James are discussing what tooth movements are required for the second appliance design they used the words "he moves" and "they want" as if they have become accustomed to "seeing through" the computer to try and make sense of what might be required to design the appliance by the orthodontic specialists who developed the material for the case study.

9.2.2 Dealing with reality

The other source of difficulty that influences students' interactivity identified in this study arises because students are confronted with the complexities of dealing with reality, particularly when reflecting on the treatment plan. The QSR/N6 analysis of the transcripts show many students seem over-focused on the problem of the partially erupted upper right canine, ignoring or forgetting other important features arising from the reality of the case. Most students, even in the pilot study, want to delay treatment to let this canine erupt, forgetting that the other 3 canines are fully erupted which indicates this canine is stuck.

The complexity of having to deal with the reality of the case first becomes apparent in the pilot study when students are asked to chose teeth for extraction. Activity theory suggests a primary/secondary contradiction in the rules constituency of the system, with some students choosing premolars because they are automatically following the rule "premolars are chosen for extraction". Conversely other students choose premolars because they seem to believe that premolar extraction is justified by the extra degree of crowding in the labial segment. In both cases students seem to forget or ignore both the mildness of the labial crowding and the problems of posterior crowding arising from the "hidden" third molars.

Forgetting/ignoring the waiting 8s lead several students to believe the 6s need to be moved back using fixed appliance treatment in both lower and upper arch, and also triggers plenty of reflection between students when thinking about what they can use to treat the case once 7s have been removed. In the Appliance Design section students' focus on the presence of the upper right canine seems to interfere with their ability to draw on other relevant aspects of the case to answer the questions on the screen.

Activity theory suggests there is a possible quaternary contradiction, with restorative dentistry, when some students mention their unease at extracting healthy, rather than diseased, molars. As with other learning situations (Piaget, 1954; Papert 1980), to understand what is happening students needed to assimilate and accommodate two competing agents. The emphasis on premolar extractions is so firmly embedded into students' belief systems that it can even blocked the concept of undertaking compensating extractions in the opposing arch. Following feedback in the lower arch several students prefer to stick with premolar extractions rather than switch to extractions of second molars in the upper arch. To accommodate the unexpected, students have to return to their original understanding of the procedures and find out how to incorporate the complexity introduced by the unexpected into their underlying model of what they should be doing.

Like medical students (Feltovich, Spiro and Coulson, 1989), dental undergraduates are taught a simple introductory overview when first encountering a complex situation. Although it has been found that these introductory procedures can be useful in helping students establish a mental model of procedural knowledge (Jonassen and Henning, 1999), this oversimplification can prevent students adjusting to the complexity of reality (Spiro *et. al.* 1992). Other studies have found that students all too often resist dealing with more difficult situations by falling back on earlier, simple models that 'provide 'lenses' for filtering out ill-fitting aspects of the new material' (Feltovich, Spiro and Coulson, 1989, p.118). In this study it has been suggested that the difficulty the students had in working out why the 7s should be extracted relates directly to an oversimplification due to their prior experience of orthodontic teaching. Hence students' focus on the question at hand, especially when coupled with the partially erupted upper right canine, seems to render the rest of the case, and particularly the crowded second/third molar region, 'invisible' – even after the tutor in session 6 drops very large hints about the 8s!

In other studies oversimplification leading to a reductive bias has been associated with one of 3 models of learning: addivity, discreteness and compartmentalization (Spiro *et al.*, 1992). It has been suggested that a cause of this oversimplification is due to using just one perspective to look at a phenomenon, thereby missing other important concepts that could lead to a deeper understanding of the topic (Spiro *et al.*, 1992). This study supports this view with most students, even if they choose the correct teeth, expressing surprise at being asked to extract second molars. Hence the primary instructional material can be described as directly influencing students' errors and underlying misconceptions (Feltovich, Spiro and Coulson, 1989). Therefore compartmentalization appears to be at the source of students' problems when dealing with reality. As novices, students are so focused on the individual questions that they are unable to bring other relevant aspects of the case to the foreground to understand the relationship between the case as a whole and the teeth that need to be extracted. They seem to find it difficult to move between theme (question in focus), thematic background (rules about compensating extractions, *etc*) and margin (crowding in back of mouth), in the dynamic process labelled elsewhere as appresentation (Marton and Booth, 1997).

9.2.3 Differences between students

A phenomenological analysis of students' reactions to the unexpected enables students to be grouped according to whether they adopt a surface approach to learning, moving on without really reflecting about the feedback, or a deeper approach to learning. Even before they answer the questions relating to upper arch extractions most students working in pairs in the latter group have put forward at least one reason relating to crowding for why 7s are chosen. Working across all the data, and taking as a baseline the overview of treatment planning responses in Table 7.4c, it becomes possible to sub-divide the sets according to whether they display an active or a passive approach to working through the program (Table 9.2.3). Just one student (Frank) has been moved from a deep to surface approach in the exercise, primarily because he is frequently recorded adopting a "Trial & Error" approach, much to the annoyance of his partner, Gita, who usually wants to take more time to reflect on the question.

Table 9.2.3: Classification of students as adopting a Deep/Surface and/or Active/Passive approach

Deep, Active Elizabeth & Felicity, Kevin, Leonard & Mary, Ian & James, Ulysses & Victor, Una & Wayne, Henry & Laura, Olga & Peter
Deep, Passive Nigel & Oscar, Queenie & Rachel, Gita
Surface, Active Adam & Bill, Anne, Belinda & Christine, David & Edward, Jennifer & Kate, Sophie & Tina, Charles, Debbie
Surface, Passive Michael & Natalie, Frank, Helen & Isabel

Students in pairs have been assigned to Active or Passive groups depending both on their degree of discursivity about the questions and whether or not this reflectivity enables them to come to any conclusions about the case. Although they pre-review the case, David and Edward, Jennifer and Kate have all been assigned to the Surface, Active category because both sets, despite their discursions, frequently fail to look beyond the focus of the question (for example in the appliance design section (Section 8.4.2) when they fail to recall that in the treatment planning section they discovered that only the upper right molars would need to be moved distally). In the study, students working as individuals were recorded turning to other students for advice at the same key points in the study where students working as partners also raised queries about what was happening. There was nothing to suggest that students working as individuals were following different lines of thought to those working in pairs.

The QSR/N6 analysis reveals that students in pairs adopt a range of roles from "expert/teacher – novice/student" through to a more equal partnership in which students divide the task of explaining between themselves. For example Elizabeth and Leonard frequently adopt the role of "teacher" when talking about the case, whereas Olga and Peter, Ulysses and Victor adopt a more equal division of roles in their discussions. Both partnerships seem equally likely to succeed – or fail. For example, in group 1, Belinda's adoption of the role of "expert" is much less successful than Elizabeth's, whereas the more equal partnership between Michael and Natalie seems to lead to a passive relationship that is as unsuccessful as that in Belinda's set. For most questions the presence of a partner seems to help students by enabling a process of reflective discursion where one student is observed adapting his/her response according to the words of the other student. This type of "adaptive discursivity" is frequently observed after feedback from the program, particularly when talking to a partner seemed to help students adjust their explanations in a way that can help them assimilate the new information into their previous understanding of orthodontics.

Although there is a significant difference between students working in mixed gender pairs who get more of questions 15 to 20 wrong than students in same sex pairs ($p<0.05$, Appendix D, Table D3), care needs to be taken interpreting this result because of the small numbers of students involved in the study. As a heuristic device this finding suggests there could be gender differences in interactivity in the pairs. As gender is not the main focus of this study, the result has been noted and could form a future research project.

The difference in the number of correct responses between same and mixed sex pairs may have risen because there are several points in the case when tension can be observed between these students due to disagreement about how to answer the questions. This tension is frequently observed when one student (usually Gita, but sometimes Laura) wants to work out what was happening whilst their partner preferred guessing and moving straight to the next question. Frank and Gita appear unable to arrive at any consensus about how to answer the questions and thus find it very difficult to come to any sort of agreement about a negotiated response to questions on the screen. As the sample size is too small to draw any conclusions the point has been highlighted for future study on gender issues, because it is impossible to tell, from the data collected for this study, whether the source of these tensions is due to the different gender of the students in each pair or to a personality clash between the two students.

9.2.4 Motivation

Some of the most influential factors behind the approach that students adopt towards learning has been found to be the degree of motivation they feel towards the subject (Fransson, 1977) and how it is assessed (Marton and Ramsden, 1988). One student's previous experience of orthodontics seems to have acted as a demotivating factor in his approach to the subject. It is interesting to speculate the extent to which James' dissatisfaction influenced his partner's impression that orthodontics is not as highly rated by undergraduates as other dental specialties:

> **Ian**: … I get the impression … that people … don't place quite as much emphasis on their orthodontics as they do on other things, do you agree with that James?
> **James**: … If I was thinking I need to know something, I wouldn't be too concerned if I thought "Oh, I'm not really too sure about that in ortho, I'd be more concerned about something I didn't know about … a Cons problem or something.

A major motivating factor is seen as the need to revise for end-of-year examinations which have to be passed to qualify as a dentist (Fairclough and Carrotte, 1995). Kevin candidly raises this point during his post-session, talk-back interview:

> **Kevin**: … We've got a big orthodontic exam at the end of this year… and that's … really when you'd bring all ortho knowledge back together and you have to swot for it… Students don't usually do things unless there's exams…
> I'm not putting in my full effort to tell you the truth. But if you had an exam in this, or if the answers were being put into an assessment, then I'd be really … sweating over these questions…

Kevin adds that he plans to

> **Kevin**: … go through all the other cases, especially after doing this, 'cos I've learnt so much this morning ... And it's pictures and interaction as well, which sticks, as opposed to your hard text and late nights the night before.

Kevin observes that it will probably take the pressure of these exams to "drive" students into finding the tutor:

> **Kevin**: If there was an exam the following – I would put money on the fact that they would go and ask him! It's just a standard student thing – "Oh … I'll put it off until … the exam shows up."

A similar point is made by Kate in her post-session interview:

> **Kate:** ... I doubt that I'd have spoken to my tutor. I'd have probably kept it in mind when I was revising or something... I maybe have asked then, if I hadn't found out before, but I wouldn't have gone and spoken to anyone now, no... [But] exams really do focus our minds.

In session 6 students are happy to work with substitute tutor present in CAL room – suggesting that students' reluctance to contact a tutor may be due partly to disinclination to do anything more than the minimum to track down information.

A lack of motivation could be why so few students look at the glossary file (Section 6.2.4) – when provided with a hard copy of the glossary file students are observed using that copy to help them track down relevant orthodontic information. Students may not have opened the electronic form of the file either because they are unfamiliar with using this type of technology – or possibly because they are all too familiar with the problems of trying to track down information using a computer!

Another reason why students may be reluctant to try and find out more about the case could be an unwillingness to risk approaching the tutor with a question due to their tutor's role in assessing their ability. This reluctance is apparent even when students have obtained consensus with other students over the unexpectedness of the response and after being reminded by the Interviewer that the tutor is waiting next door. Although this point has been left for future study, it implies that using computers to assess students may be counterproductive, weakening students' perceptions of computers as tools for supporting learning.

Paradoxically some students seem to be driven by the need to get a high score displayed on the screen. The evidence for this activity can be seen in those groups that frequently continue to look for the correct answer, even if the feedback provides this information, for example Adam and Bill, Ian and James and Ulysses and Victor usually re-enter the correct answer every time they give an incorrect answer whether or not the correct answer is given in the feedback. One explanation is that they are searching for more information about an incorrect answer.

Another explanation for this interactivity with the computer is that these students are likely to be familiar with other software developed using the CALScribe template that they have used in the J-year and elsewhere. One of the features of the CALScribe template is that it provides the opportunity to give students a chance to improve their score by getting the correct response on a second attempt. These students may have been trying to improve their score by having a second attempt at an incorrectly answered question. If so, this finding seems to agree with the kind of automatic response that Leontiev (1972, 1975, 1978) suggests arose from increasing familiarity with an activity, and indicates some students may operate the software in an almost automatic, sub-conscious manner because of their familiarity with these programs.

The success of the program is mainly due to the content of material and how it is presented rather than technological complexity – with students observed learning as they work through the case due to the reality of problem they are being asked to solve. Students are not put off using the program because of the MCQ 'drill & practice' style of questioning, particularly in the case assessment section where it is possible to provide students with options that cover the complete range of possible answers. One change to the program might be to provide students with a scenario in which they have to request additional information from the computer, e.g. additional radiographs to check for the presence of teeth that could not be seen in the intra-oral examination.

Finally, despite the confusion expressed by some students over the presence of some general questions that are not relevant to diagnosing and treating case JB, these questions should continue to be included to encourage students to build a mental image of the whole case and to help students remember and recall everything they need to take into account when assessing a patient for orthodontic treatment. In future as GDPs they will need to ask all these questions to ensure they have carried out a full and complete orthodontic assessment of their patients.

The actual content of the program is accurate, having been used by students to learn about orthodontics for well over a decade, as well as (in a previous incarnation) having been tested by GDPs nationwide. The main difficulty with the program is its lack of adaptivity – particularly at "flash points" where the reality of case conflicts with the simplistic procedures taught to students. Microworlds will be unlikely to be able to solve this problem – their reliance on simplification can make it difficult for a microworld to replicate the messy complexity of reality (Edwards, 1997). However there are several points in the case where transcripts indicate students are encountering a conflict between their underlying understanding of orthodontics and the reality of the case. These "flash points" provide an opportunity to introduce a series of intermediate cases to help students resolve conflict in their underlying theory, similar to the "transitional" cases proposed elsewhere by Papert (1980).

The advantage of this study is to highlight the importance of these "flash points" for stimulating student reflectivity on learning about orthodontics. The difficulty is that observing and analyzing the depth of interactivity recorded for this study takes considerable time, which will not normally be available to subject specialists trying to develop future case studies in dentistry.

9.3 Guidelines for the future development of CAL in dentistry

Having discussed students' interactivity when using the orthodontic CAL case study, and investigated students' underlying conceptions of orthodontics that lie underneath this interactivity, this section explores the implication of the findings of this study for the future design and development of CAL in dentistry. The purpose of this section is to use the findings of this study to suggest guidelines for the future development of CAL in dentistry. The recommendations that follow are based on providing CAL material for students who, like the M-year students in the main study, are at an advanced post-introductory stage in their training.

While students are learning to master a procedure they are involved in actions which are basic operations that should eventually be performed unconsciously. Part of the difficulty for students is that they have to focus deliberate attention on what they're doing whilst simultaneously 'working with fewer cognitive resources than they will have available later as they gain expertise and experience in their tasks.' (Nardi, 1996a, p.12).

Subjects dependent on procedural knowledge provide specialists with a strong structure for developing a narrative approach for the delivery of case study material (Anderson *et al.*, 2001). The procedural nature of dental techniques offers a vast array of linear or sequential algorithms that can be used to produce computerised case studies in specialities other than orthodontics:

> **Brian**: Dentists are fortunate; they can get by with a lot of binary decisions, if this, then that. And they don't even say – if not this, then something else.

One priority for these guidelines is to supply a toolbox of skills and heuristic strategies that can be used to support the act of learning about dentistry. The increasing recognition of the need for CPD for GDPs means that these recommendations may also apply to the provision of material to qualified dentists seeking to improve their understanding of a particular aspect of their domain. In this study students can be seen reflecting back on the extraction site issue as future questions, without mentioning the extractions themselves, force students to consider the impact that second molar extractions will have on how the case is treated and the appliances that could be used for that purpose.

The advantage of a linear, procedural approach is that narrative cases can be put together much more quickly than trying to produce a simulation or modelling program. This narrative form is said elsewhere to provide 'a means of "constructing" a world, of characterizing its flow, of segmenting events within that world' (Bruner, 1990, p.56). The possibility of a narrative approach does not suggest that complex software will be ineffective. For example there may a role for developing more complex software to help students improve their pattern recognition skills, helping them to put together a 3-dimensional model of the case because, as Brian observed:

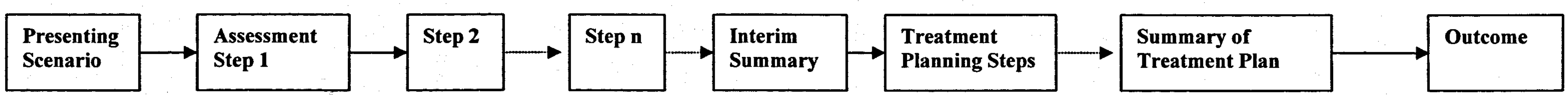
> **Brian**: I think there is a certain amount of pattern recognition in the orthodontic treatment plan because once you have a reasonable amount of clinical experience you are able to say: "This case is like that one I had three years ago. … And that that one's like that one, and that one's like one"…

The trigger that leads to greater understanding on the part of students seems to lie primarily in the reality of the case (i.e. the ill-structuredness of the knowledge domain). The idea of conceptual oversimplification can explain why students struggle to come to terms with extracting second molars. It has been suggested that one way to help students attain advanced learning skills in a subject is to provide them with stories about real cases 'in new situations that differ from the conditions of initial instruction' (Spiro *et al.*, 1992). A strong sequential function helps with learning both by providing a structure for retelling that story to help others discover something new about the world (Brown and Duguid, 2000) as well as providing students with a means to mitigate or make 'comprehensible a deviation from a canonical cultural pattern' (Bruner, 1990, pp.49-50).

Sub-dividing the case into sections, as suggested by Papert (1980), provides students with a simpler set of problems to solve; case assessment, treatment planning and appliance design. Each section concentrates on helping students to think about a different set of skills. A different activity for each section implies there will be a different activity system underpinning each section. Therefore within the narrative sequence proposed for developing CAL case studies there is the potential for adopting different narrative styles depending on the outcome that students are expected to achieve. A model for this narrative approach is shown in Figure 9.3.

Currently there are two different approaches that teachers can use to produce CAL material. The first is to use generic software that is easy to master but has little or not functionality for developing any degree of complexity in the program; the second is to use complex programming tools that provide much greater functionality but require specialist IT skills to master.

Figure 9.3: Linear nature of narrative sequence for procedural case study in dentistry



Constraints on resources for the development of CAL in dentistry have led to the current situation where facilities are concentrated on the provision of information as Word, PowerPoint and simple .html documents via Learning Management Systems such as Blackboard. The problem is the demand for interoperability has led to developing a 'lowest common denominator, one-size-fits-all' system better suited to the bureaucratic demands of data management than to developing innovative programs that make use of the potential for learning models possible through advances in hardware and software technology.

A new approach would be to develop a tool that would provide specialists with the means to:

1. Import narrative material from a file format such as Word or PowerPoint with which specialists are already familiar
2. Provide specialists with the means to develop their own narrative material

The potential for this type of tool is to use the power of a story as a resource for designing useful tools (Brown and Duguid, 2000). Although there is already plenty of available software that provides specialists with a way to deliver case studies in this fashion the starting point for the specialist is to choose cases involving real patients that students are likely to encounter as GDPs, preferably with one or more key points in which students have to confront the unexpected. It has been suggested elsewhere that presenting students with the unexpected alongside subversive arguments in the form of Socratic dialogues can help to erode the original theory so that it can evolve into a deeper understanding of the topic (Papert, 1980).

Each unexpected point could be identified as a situation where an expert might revert to a conscious action rather than carry out an unconscious operation. With Case JB, this point occurs when students are asked to decide which teeth should be extracted. Confronted with extracting the second molars the transcripts show that students keep returning to reflect more deeply about why the 7s are chosen and, in the process, hopefully learning more about why first premolars are usually chosen for extraction:

Brian: … If we'd used a case where they could go straight to 4 first premolars … They'd all have been happy, in every detail – even though they wouldn't actually have known any more why they took out first premolars in that case – and why they should not take the first premolars in a case like JB.

The scenario provides core information about the case, as a single-perspective commentary, removing some of the complexity to show the way through the procedural maze. But having removed some of the complexity, activity theory suggests that students are finding it difficult to modify the simple schema they are using to map out a treatment plan that can accommodate the complexity in the case arising from the combination of crowded posterior teeth and the mildness of the labial crowding around the partially erupted canine.

9.3.1 Alternative perspectives on the unexpected

The next part of the programming template would be provide an opportunity to deliver alternative perspectives on unexpected material of the type mentioned above by providing links between the unexpected and the ordinary (Bruner, 1990), thus helping to restore some of the complexity to the case.

The teacher's aim should be to identify those points where the reality of the case leads to complexity and an unexpected response. Another way to identify these points is ask specialists to 'step-back' and try to recall any tacit knowledge that they may be using sub-consciously when making judgements about how to treat the case. In the hierarchical structure of activity identified by Leont'ev (Figure 2.4c), it is argued that someone can become consciously aware of the upper activity level if driven to do so by the action level – i.e. by the required outcome of the Activity (Andreassen, 2000; Zinchenko, 1995). Specialists should be able to identify suitable scenarios where the reality of the case provides students with opportunities to engage with, assimilate and accommodate a deeper understanding of orthodontics.

To find out what is happening students nearly always asked questions. In session 6 Gareth acts as someone who, having been asked a question, tells a "story" that covers the reasons why 7s are chosen for extraction. The story is thus able to act, in the words of

Bruner, as 'an account of a possible world in which the encountered exception is somehow made to make sense or have "meaning"' (Bruner, 1990, p.49). Gareth brings together the constituents of the story – the crowded 8s, the mild labial crowding and the need to balance (compensate) extractions – as part of a plot that provides meaning by putting each constituent into its proper place within the sequence (Bruner, 1990).

To help students focus on the scenario itself it is important they should not be too distracted from the strong linear sequence running through the program as this sequence provides the storyline that offers a framework for students to reconstruct their own understanding of the concept. So any diversion offered to students for providing an alternative perspective should be kept short and to the point. As well as avoiding distracting students from the baseline scenario itself, brief diversions would meet the expectations of users of the Internet that links to media would be limited to short soundbites lasting between 30 and 60 seconds.

With 61 questions to case JB, developing alternative perspectives for every question would be extremely time-consuming and almost impossible to achieve. However student responses to each question are not completely random, but follow a distinct pattern even when encountering the unexpected. The development of an alternative perspective can thus be focused on those few points in a case where the proposed procedure needs to depart radically from the simplistic one taught to students. Elsewhere it has been suggested that this approach is likely to work because 'what students know can be described in a relatively concise way, as long as you penetrate to the level of what the concept means to the student' (Laurillard, 2002, p.30).

There are different ways in which an alternative perspective can be offered to students. Perhaps the simplest option will be for the specialist to record a short soundbite explaining why the case has departed from expected procedures, emphasing differences between the complexity of the case and the simplistic schema resulting in this departure.

This "soundbite" may offer a solution to the problem where students' underlying simplified assumptions have had a major impact on learning outcomes.

Another approach would be to provide students with the opportunity to "listen-in" on previously asked questions about this aspect of the case. This opportunity would involve gathering students' questions during the testing phase e.g. via an email link at a suitable point, or node, which lets students send their questions about the unexpected to a specialist tutor. If an underlying question is revealed – e.g. "But why are 7s chosen for extraction?" – specialists could text back a response or even record a simulated conversation with a tutor group. In this simulation, students would ask their question and use their tutor's response to reflect further on, and probe more deeply, the unexpected. By listening in on this "virtual dialogue" between students and tutor, future students would have access to evidence that their confusion was not unexpected. The additional perspectives provided by this "virtual dialogue" may also help future students accommodate this unexpected material into their understanding of the subject.

A further development for either option would be to present students with an alternative scenario which shows them what would happen (and why) if they continue with the simplistic procedure rather than dealing with the complexity of the case. Limiting the use of these alternative paths to points in the case where students encounter the unexpected, and sticking to a scenario rather than a modelling approach, alleviates the problem of finding the time and resources to develop a full simulation of the case.

In an ever-more crowded curriculum, where there is a possibility that orthodontics is perceived as being of less importance to a GDP than other specialties, students may have neither the inclination nor the luxury of sufficient time to work through a full discovery-learning module attached to a case. However they may be prepared to spend time reflecting on a shortened summary or alternative scenario loop related to an unexpected finding.

The timing of when to introduce this node is important. One of the findings of this study is that students frequently reflect back on the extractions as they try to answer later questions in both the treatment planning and appliance design sections. If the node is introduced too early, students may not be as active in their reflections. The suggestion for JB is to include the node just before the end of the treatment planning section, after students have reflected on the extractions whilst trying to decide what mechanics might be used in each arch. This timing would provide students with additional information about the extractions before they started to design the appliances, which they can use to help support their understanding of how the appliances would be expected to move teeth into their final positions. It is important to note that the point when this node is introduced, however, is likely to be different depending on the reality of the case in question. One focus of future research in this area will be to try and find the optimum time for introducing such nodes. Modifying Figure 9.3 to include this type of node would give Figure 9.3.1a.

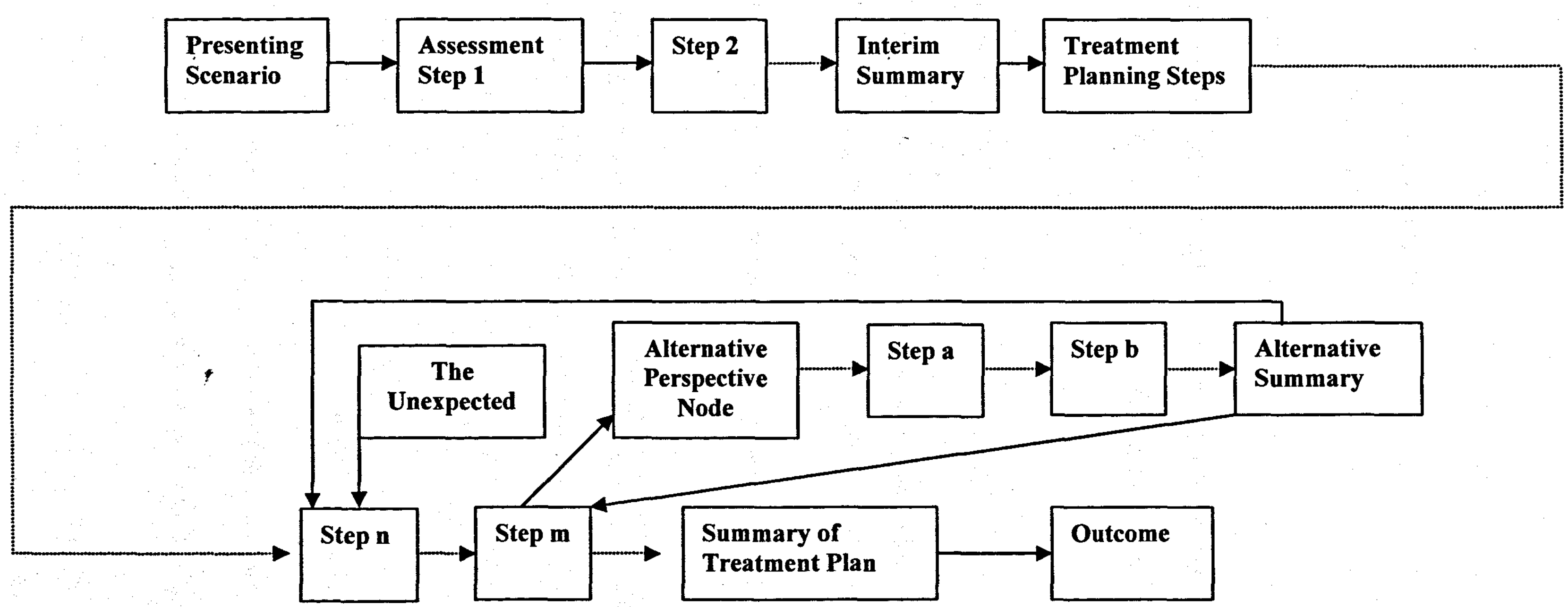
Brian explained that he had always wanted to expand the program to provide an opportunity to let students "learn from their mistakes":

> **Brian:** ... I'd always wanted to ... take these [questions] into a computer modelling [which would] ... take [students] through the case with all their mistakes, and let them see what a horrendous mess they could end up with... Yeah, so we do something ... which includes growth and tooth eruption and mesial migration and the effect of extracting only one tooth ...

However the computer resources and time required for developing this type of program would currently be prohibitive. The findings of this study suggested that, as an interim measure, two alternative scenarios could be added to the case:

1. What might happen if the case was left untreated (i.e. "looping" where students wanted to wait for the upper right canine to erupt)
2. What would be the impact on the case and how it would have had to be treated if premolars rather than second molars had been extracted.

Figure 9.3.1a: Narrative sequence with nodes alternative perspectives



The most time-demanding activity in this study is that required to transcribe the audio and video recordings. The usefulness of this activity is that with recordings of conversations for all except 6 students (42/48 students), it is possible to be reasonably confident that the description of students' conceptions about this case in relation to orthodontics is fairly comprehensive.

For the future development of CAL, a logging system similar to the one used in this study would provide a much quicker means of identifying points in a linear sequence where students consistently chose an incorrect option. An analysis of the log-files collected in the main study identifies these points as questions relating to:

- Upper/lower face height
- Absent teeth
- Angulation of the partially erupted upper right canine and its canine relationship
- The overbite
- The molar occlusion on the left
- Timing of treatment
- Choosing teeth for extraction
- Lower arch mechanics
- Source of anchorage
- Tooth movements for both appliances

The transcripts indicate that some of the problems facing students in these questions are related to their lack of familiarity with the terminology. Testing students at different stages in their training (e.g. at the start of both the M- and S-years) would "weed out" those responses where a lack of familiarity was the underlying problem.

Having to deal with fewer than 10 sets of queries from students about the case would also significantly speed up the development time of future computerised case studies. After identifying these potential nodes an email facility can be added to the question to provide students with a link to the specialist developing the program. To find out more about what students are thinking, it has been suggested elsewhere that they should be asked to explain (briefly) why they have provided a particular answer, what criteria they considered relevant in their answer and why they thought answering the question in this way was important to the case (Anderson *et al.*, 2001). As some of the students seem to change their minds after receiving feedback, a similar link can be provided that asks students to send an email to say whether the further information provided in the feedback has changed their understanding of this case in any way, and if so how their understanding has changed.

Although the data provided by this means will not be as descriptively rich as that obtained from recording and transcribing, it will be considerably quicker to capture electronically, important in a domain where time available for CAL development is limited.

9.3.2 Links to underlying theory

The other type of misconception observed occurs because students are unfamiliar with using theory to deal with a real orthodontic case. Students are expected to become increasingly familiar with using orthodontic terminology and procedures over time. However it is possible to add a layer to the proposed tool that, rather than providing students with anecdotal stories, provides access to the underlying theory. The means of delivering this theory should be adaptable – for JB this underlying theory could be via a link as simple as access to a database containing a library of orthodontic definitions, or hints on what mediating tools (e.g. which records) or procedures students should use to answer a question. It can also include animations, graphical depictions or other visual simulations of what to expect if a particular course of treatment is adopted.

The difficulty is that although access to the full database might provide students with the opportunity to explore all the theory, their reluctance to access the glossary file in this study suggests that a link to an entry-level node to a database would need to be specific for each question. The alternative, going to a home page or a search facility page for the database, may not be used any more than the glossary file in this study. Combining the idea of anecdotal nodes for the unexpected "above" the scenario with links to specific theory "under" the scenario suggests a representational model of the type in Figure 9.3.2.

9.3.3 Application of findings to case JB

As Papert (1980) says about students in general, it is suggested that gaining a deeper understanding required students to see the whole as well as the parts:

> **Brian:** I would have said it was being able to visualize the future effects of what you are doing. Because you can't visualize three things at once so we divide it into sections: Examination image, appliance design image, treatment plan image...

Breaking down the case means tutors can:

> **Brian:** ... say to a student "Look at those models take as long as you like to study them" and when they have finished say "Right now turn away and describe what you have just seen" – they can do it!

As long as they are given an opportunity and sufficient time to do a structured clinical examination then students can be asked:

> **Brian:** ... to throw away the paper and not refer to the models they can describe the case exactly – they now hold a picture of it in their minds...

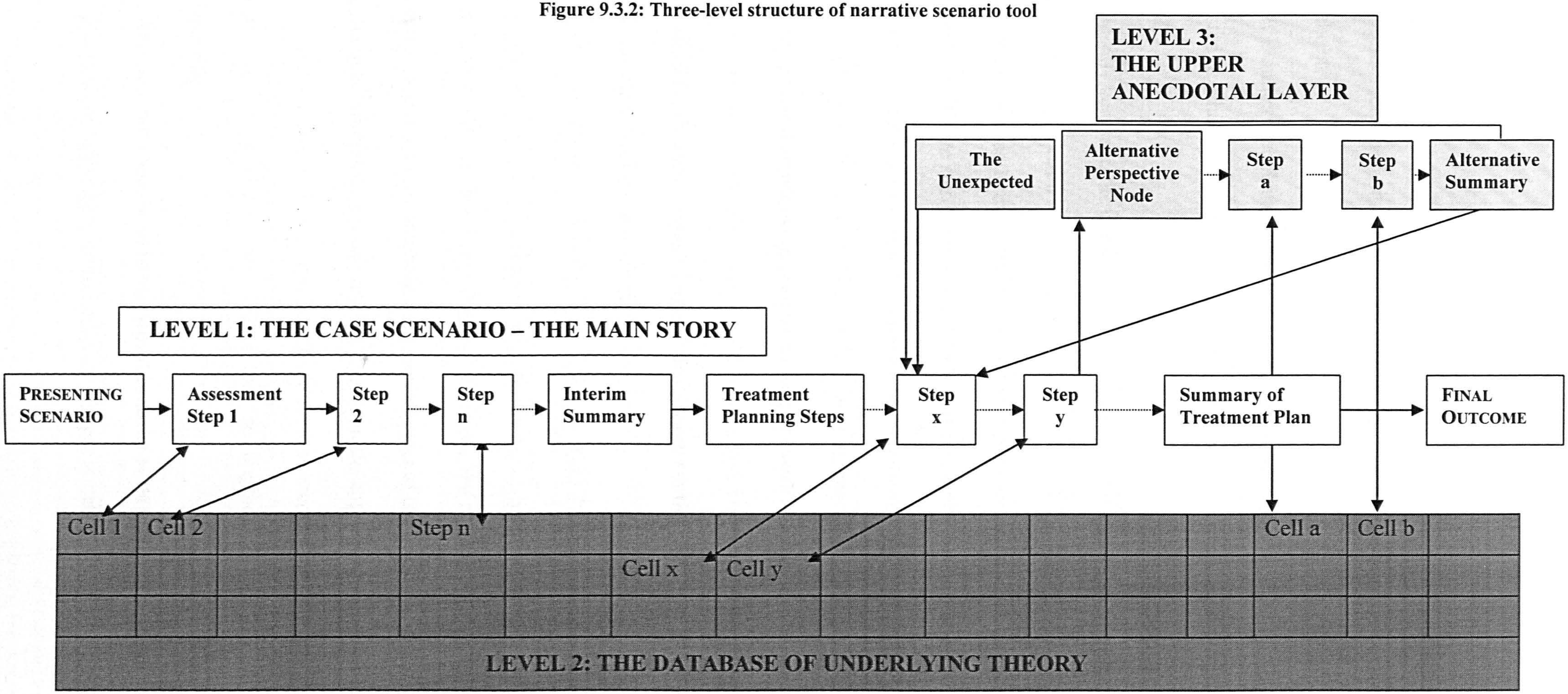
For this case, having split the program into case assessment, treatment planning and appliance design, one solution is to develop the separate sections as follows:

Case Assessment

- Split into 3 screens, extra-oral, intra-oral and radiographic examination
- Provide all questions for each sub-section either via drop-down MCQ boxes or free response questions – keeping the question types as in the original template.

With all questions relating to one sub-section on the same screen, students can be provided with a way to overview the whole sub-section at the same time as answering each separate question. This approach provides students with the means to see the whole sequence as all aspects of each examination will be covered on the one screen.

Figure 9.3.2: Three-level structure of narrative scenario tool



Treatment Planning

- Keep the questions relating to each decision on the same screen, as this is the section requiring students to take more time reflecting on the unexpected reality of the case.

It is anticipated that this section will be where students would encounter the unexpected in other cases, due to the conceptual nature of the problem-solving activity involved.

Ideally access to the decisions that are currently provided as an introduction to the treatment planning section would be moved into the underlying theory. Here they can be accessed as an entry node from the case summary screen for any student wishing to refresh his/her memory before starting the case. Other students, more familiar, confident or impatient about making the decisions could move straight into the treatment planning activity. The latter path would provide students with an unbroken route from case assessment to treatment planning, perhaps making it easier to remember the interim assessment summary. Naturally a link would be provided from each decision screen to its related cell in the database, again giving students more control over how they use the program and when (and if) they access the theory.

Unlike the treatment planning section, the appliance designs are a relatively straight forward application of procedural knowledge following a sequence through the general stages of design. Like the treatment planning decisions, the latter stages can be delivered via an entry node link to the database from the last page of the treatment planning section, letting students familiar with those stages focus in on the appliances.

Finally an anecdotal node can be offered on the outcome screen to provide students with a summary about why this case differs from the simplistic theoretical outline they were expecting.

Although not considered in this study, because of its focus on students' interactivity as they use CAL to learn about orthodontics, the linear scenario outlined as lying at the centre of a triardic structure of theory, scenario and anecdote suggested for developing future case studies may be worthwhile exploring in future research. For instance, rather than a linear structure, a mixed hierarchical scenario can be used to provide alternative routes through a case to students in disciplines with a non-binary (multiple choice) decision process (i.e. where they are faced with decisions with more than one possible correct option).

The key for success for both a linear and a mixed-hierarchical scenario structure will be to return students to the underlying scenario relatively quickly after a visit to either anecdote or theory, to maintain the framework and flow of the scenario so that the computer can act 'as a transitional object to mediate relationships that are ultimately between person and person' (Papert, 1980, p.183).

9.4 Chapter summary

This chapter started with an overview of the key findings, looking at the impact this research had on understanding students' misconceptions about orthodontics in the context of case JB. Two different sources of difficulties for students were outlined: one arising from students' lack of familiarity with using specialist terminology, which could be expected to improve as students gain more experience of putting theory into practice. The other source arose from students' encounter with the unexpected, requiring students to assimilate and accommodate increasing complexity into their underlying conceptions of orthodontics. After exploring students' reflections and conceptions of orthodontics and the impact of having to deal with the complexity of a real case, the chapter ended by suggesting guidelines for future CAL development based on using a narrative paradigm to provide students with a framework that could help them reconstruct their underlying conceptions of orthodontics when faced with the unexpected reality of a case.

Chapter 10: Conclusions

Chapter 10: Conclusions

10.1 Introduction

This chapter summarizes the main findings of the research carried out for this thesis and the implications this study has for future research into computer-assisted learning in orthodontics. This chapter provides a critical reflection on the study and its contribution to knowledge. It then reviews the guidelines and recommendations for how CAL design in dentistry might be improved. This chapter ends by making suggestions for future research in this area.

10.2 Outcomes

The outcome of this research was to provide a new and deeper insight into how dental students interact with a CAL program, each other and their tutor to learn about orthodontics. Adopting a mixed methods approach to the study has provided an opportunity to use research techniques drawn from a range of disciplines to investigate students' underlying conceptions of orthodontics. The findings of this analysis have provided a deeper insight into the underlying conceptions that can influence students' interactivity in a way not possible with the previous, mainly quantitative studies into the use of CAL in dentistry. These insights into students' interactivity will prove very useful for future CAL development in dentistry, if only to give their designers areas on which they can focus in a discipline with limited resources for the production of this material.

10.2.1 The research questions

The research questions chosen for this phenomenological study were:

1. How do students interact with a computer program, each other and their tutor when they use CAL?
2. Using activity theory as a framework, what can be inferred about the conceptions of orthodontics held by students that might have influenced the observed interactivity?

3. What are the implications of the answers to 1 and 2 for the future design and development of orthodontic CAL?

A primarily qualitative methodological approach was adopted to facilitate this investigation into how students learn, with the collection of relevant quantitative data used to provide a contextual background to the study.

The importance of this research arose from the need to understand how students learn from CAL programs in orthodontics. The use of computers for learning offers several potential educational and economic advantages in orthodontics including the opportunity to follow a case from diagnosis through to completion that would, in real life, take longer than the time most students have to spend on orthodontic training.

10.2.2 The programs

Two orthodontic CAL programs were developed for this study. The first took students through a series of questions relating a linear narrative or story of the procedures needed to diagnose and treat a 'simple' orthodontic case. The second was an introductory hypermedia package added to a series of MCQ type questions designed to test students' factual knowledge on orthodontics.

10.2.3 The methodology

Activity theory was used as a framework to draw together and combine the qualitative and quantitative data collected during the study. This data was used to analyze students' interactivity with the CAL, each other and their tutor as they worked through a series of questions related to an orthodontic case. This approach made it possible to explore students' interactivity at various different levels and to examine what can be inferred about students' underlying conceptions of orthodontics that might influence the observed interactivity. This research used activity theory to provide a structure for building a series of activity systems associated with student interactivity. Activity systems highlighted key features of student interactivity, focusing on different levels, for example how students interact with:

1. The computerised orthodontic questions about the case
2. The main activity of each sub-section of the case (case assessment, treatment planning, appliance design)
3. Other students and/or their tutor
4. Orthodontics as a specialty
5. Orthodontics compared to other dental specialties

A phenomenological approach was also used to investigate student interactivity. This approach allowed students' interactions to be grouped according to whether they took a deep or surface approach to learning about the unexpected. A wider analysis across the program facilitated a further division according to whether students' interactions could be described as active or passive.

The analysis was deepened by using discourse analysis research techniques with further clarity provided by cross-referencing transcripts of students' conversations with the computer generated log-files of student actions taken in response to the questions asked by the program. These discourse analysis techniques provided another way of making inferences about students' internal understandings of the case that had not previously been used to study student interactivity when using CAL to learn about orthodontics. The software qualitative analysis program QSR/N6 was used to provide a means of tracking and recording the findings of this analysis.

For the pilot study clinical students volunteered to be observed and recorded whilst using one of two programs towards the end of the academic year. Although the hypermedia program offered an opportunity to follow different ways students make use of the package, the narrative structure of the case study made it possible to compare interactivity on a "like-for-like" basis. The main study thus concentrated on the computerised case study CAL package and students in their second year of clinical training.

The other action resulting from the pilot was to let students choose to work either on their own or with a partner. Thus it became possible to analyze student discourse as they negotiated over answers *in situ*, rather than having to rely on talk-back interviews or talk-aloud protocols to investigate the way students made decisions about the case.

Taking place at the start of the academic year following the pilot, the main study occurred when most students first had an opportunity to work through a complete case study. The timing of the study provided an opportunity to observe students as they familiarised themselves with putting theory into practice.

10.3 Key findings from the main study

The research in this study using activity theory identified two very different types of misconceptions that impacted on students' abilities to learn; one caused by students lack of experience in putting theory into practice, the other arising when the complex reality of the case came into conflict with students' understanding, and reliance on, simple taught procedures to plan a course of treatment.

The first misconception resulted in primary/secondary level contradictions within the "mediating tools" and "rules and procedures" constituencies of the activity systems. Occasionally this misconception may have resulted from the way the questions were presented, which obscured "peripheral" details needed by students to use to answer the question.

Activity theory highlighted other potential sources of conflict in the students' interactivity. At a quaternary level contradictions arose where students' understanding of what they were trying to achieve came into conflict with another rule-producing activity in dentistry, particularly that of restorative dentistry. At a tertiary level contradictions were identified between students and the objective of the activity system where some students seemed to expect all the questions in the template to be relevant for the case. By the end of the session most students realised they should be using the questions as a checklist to ensure they have covered all points of an orthodontic examination.

Given enough time and practice the incidence of this type of misconception can be expected to decrease. Usually where students made a mistake (and sometimes even when they entered the correct response in error) the QSR/N6 analysis showed they were able to correct these misconceptions using feedback from the computer – even when the feedback was not explicit about the underlying theory.

With regards to CAL design, it can be anticipated that "retrieval" errors of this type would decrease as students gain more experience in orthodontics. Therefore CAL developers do not necessarily have to design programs to take these errors into account. It seems reasonable to assume that background information could be provided by some alternative means, e.g. on computer from a hyptertext glossary file or a link to an accompanying database or via more traditional methods such as books or lectures.

The second type of misconception observed in the study is more interesting. Activity theory showed that the main primary/secondary contradiction in this situation arose between the students and the "rules and procedures" constituency. The cause of this contradiction can be traced back to the complexity of using a real orthodontic case. This complexity created a situation which conflicted with students' understanding of the procedures they had been taught. The discovery that second molars rather than the expected premolars were chosen for extraction caused consternation. About half the sets were able to recognise the degree of crowding as the reason why second molars were chosen after receiving feedback on the lower arch extractions. The remaining sets continued to rely on their understanding of simple taught procedures that were not applicable in this case due to its complexity. The presence of a partially erupted canine acted as a focal point, diverting students' attention away from other important features of the orthodontic case used in this study.

Phenomenology enabled students' interactions with the unexpected to be classified as deep or surface, according to their responses to the feedback provided by the program. This grouping of the students showed that the expectation that they have to answer questions meant that most students could be described as adopting an active approach to learning. Most students talked about features of the case whilst trying to answer the questions, even when they were unable to come to any deeper conclusions about the case. The analysis revealed that the sequence of questions in the program could eventually stimulate reflective discourse about the case even amongst students judged to have adopted a passive, surface approach to the case.

One other tertiary contradiction was identified from James's description of the tension in his relationship with his dentist whilst undergoing orthodontic treatment. As a reluctant patient, James' previous experience was seen to have a negative impact on his attitude towards learning about orthodontics in this study. However in general previous experience of orthodontics as patients was used more positively by students in the study to help them understand what was happening in the case.

10.4 Lessons learned and critical reflection on the study

In this study the dynamic nature of activity theory, by enabling inferences about students' underlying conceptions of orthodontics, made it possible to go beyond prescription in the research. Thus, rather than being a difficult research tool to use, as has been argued elsewhere, this flexibility provided sufficiently adaptable to meet a wide variety of contexts. For example the combination of activity theory with the concept of appresentation provided a way to explore why students over-focused on one feature of the case, the partially erupted upper right canine, at the expense of other relevant features of the case.

The findings of the main study enabled the construction of a phenomenological profile of the students' approaches to learning about orthodontics through their interactions with a CAL program, each other and their tutor. This approach was facilitated by the reality of the case. This reality confronted students with the unexpected, providing an opportunity to group students according to the type of interactivity observed. It would have been difficult to group the students by classifying differences in their interactivity if the case had required more conventional treatment procedures and students had not had to deal with the unexpected.

All the students in the main study came from the same year group and were observed for just one session on the computers. Despite this limitation, studying the whole year group provided an opportunity to collect a considerable amount of qualitative data. These data were sufficiently comprehensive to draw guidelines for the development of future CAL programs based on carefully chosen orthodontic case studies.

Some longitudinal data on students' attitudes to IT was available from a questionnaire survey completed by final year students each year for the four years preceding this study. A shortened version of the questionnaire was used in the main study. Analysis of the survey data indicated that there were no substantial differences between the cohort in the study and those in the previous year.

The results of this research can be considered to be valid to the extent that repeating this phenomenological research with future cohorts of M-year students should produce a similar pattern of student interactivity. Future students will be comparable because they are expected to have a comparable educational background to the students in this study. This expectation also assumes that future students will have received a similar pattern of orthodontic training prior to going through the case. By repeatedly returning to recordings when transcribing the tapes the potential for observer bias was minimised.

Taking into account the reaction of students in the pilot study to the extractions suggests that the findings relating to student interactivity recorded when they encounter the unexpected are likely to be reliable across a wider range of students than just those at the start of their M-year in orthodontics.

The other source of supportive quantitative data came from final year results from orthodontic exams taken in the M- and S-years by the cohort of students involved in the study. A statistical analysis comparing these results with the survey data suggested that gender differences in students' self-assessed confidence in using IT did not impact on their eventual examination results. It was noticeable that only one student who chose to work as an individual in the study ended up in the top half of a ranking of the S-year orthodontic examination results. This result should be treated with caution, but it does tie in with the concept of learning as a social activity and would be worth exploring in more depth in future research.

Although the study could have covered other aspects of learning about orthodontics, the availability of resources and logistical needs of co-ordinating students, tutors, CAL room, and recording facilities limited the main study to data that could be collected in one week via a combination of observations, video, audio recordings and computer-recorded log-files of students using one orthodontic case study together with the questionnaire survey.

There were reasons for considering the results of this study to be applicable to other dental specialties. All specialties expect students to learn how to use the terminology specific to each specialty. Students also need to learn the differences in the way in which one specialty might use the terminology compared to another. Researchers in the medical field have also found that students' actions and (mis)conceptions about a topic tend to be based upon, and grounded within, simplistic procedures. In both dentistry and medicine this simple taught procedures are expected to provide a framework and structure for developing a deeper understanding of the subject. Thus in a domain equally dependent on procedural and conceptual knowledge to carry out case diagnosis and treatment planning activities, medical specialties may also benefit from both the findings of this study and the resulting guidelines for the future development of CAL material.

The ability to be able to deliver a computerised case study over the Internet offers an opportunity to concentrate resources on a series of "flash points" identified by specialists where a real case would require an unexpected (from the students' view) response. The findings of this study suggest that developers can maximise the learning potential of future CAL programs by producing templates of questions linked to the narrative storyline underlying these simple taught procedures. Subject specialists can modify these templates to produce case studies based on records from real patients. Extra resources can be concentrated on identifying "flash points" where students would encounter the unexpected and specialists have an opportunity to provide alternative perspectives that can maximise the learning potential of these "flash points".

Developers can take advantage of recent advances in computer-mediated communication to provide students with a facility to contact the specialist with questions about these points. During the testing phase of a CAL case program students should be encouraged to make use of computer technology such as email or video-conferencing. Students' conceptions of the situation, hopefully articulated in this communication, can be used by developers to build a "dialogue" between students and specialist as they adapt their responses to each others observations. This "dialogue" can then be used to provide future students with access to a "*pseudo* conversation" or alternative perspective on an encounter with the unexpected arising from a complex situation in an ill-structured domain.

It is important that these "*pseudo* conversations" are used sparingly. For example they should not be used for "retrieval-type" errors where the overuse of such a facility may lead to students ignoring the extra information when needed, as they did with the glossary help file in this study. The effectiveness of this approach is one that can be investigated in future research.

The study showed that the power to stimulate reflective discussion mainly lay in the reality of the case and how it was presented on the screen. By asking questions rather than just presenting a narrative case presentation, the CAL program encourages students to talk about what was happening both before and after answering each question. Where reflection occurred, the trigger appeared to be the realization that the case conflicted with simple taught procedures. This encounter with the unexpected forced students to try and assimilate and then accommodate the new information into their existing model of orthodontic treatment.

The computerized case study was not a complex simulation or micro world package but a simple ‘drill & practice’ session based on a template that lets dental specialists input details and questions about a case study into a computerized format with the minimum amount of effort and resources. However the transcripts and observations show that, because the program was grounded in a real-life situation, students could interact and reflect on what they encounter despite this “drill and practice” format.

Although using simulations and microworlds can be extremely effective in encouraging a deeper level of understanding, pragmatically in a domain with an increasingly crowded curriculum most students do not have the luxury of sufficient “spare” time for such discovery learning. Furthermore the results of this study suggest that in dentistry, the requirement to reach a minimum standard of competency means that most students would prefer a greater degree of guidance in their learning than is inherent in discovery learning.

One of the limitations of the research was that institutional effects such as the way in which orthodontic training was organized in the UK have only been only examined from a socio-cultural perspective in the literature review to show why orthodontic training was needed to provide an introductory level of competency for GDPs. As this study was concerned with student interactivity when using a computerized case study to provide an introductory level of training, a full examination of all aspects of institutional effects fell outside the focus of the study and has been raised to highlight an area for future research.

Although one case study alone cannot be considered sufficient to give students a comprehensive insight into practical orthodontics, the guidelines suggested in this study for the future development of CAL do offer dental specialists a way to turn material chosen from carefully selected orthodontic cases into a series of CAL case studies that can provide students with alternative perspectives needed to develop sufficient insight into orthodontics to carry out their future roles as qualified GDPs. The results of the research, not done before in dentistry, highlighted the importance of interactivity when students use CAL to learn about orthodontics.

A strength of this study lies in the depth and richness of data collected through transcriptions of dialogue between students as they negotiate over questions. What was 'new' about this study was that it brings together paradigms and techniques developed from a range of diverse disciplines to investigate how students interact with a CAL program, each other and their tutor to learn about orthodontics, something that has not been done in this way before.

10.5 Recommendations for further research

One interesting finding in this research was that two students (Michael and Natalie) who seemed to prefer a surface, passive style of learning throughout most of the case study did start to ask questions about the extractions as they worked through the final, appliance design section of the program. One area for future research should be to explore this finding in more detail, looking at the relationship between the interactivity of the CAL program and how this might influence the learning approach adopted by students.

This study showed that one of the students' "mediating tools" came from their previous experiences as dental patients. The study leaves further investigation into students' previous experiences and leading on from this, their attitudes towards orthodontics, for future research. Similarly training for other dental specialties was examined only as and when it influenced students' understanding of orthodontics. So one area for future research would be to find out whether similar results can be obtained in other dental specialties.

Students' increasing confidence in using the terminology in the research study suggested that providing specific feedback on all aspects of a case study is not essential. Indeed although they could access background information via the glossary file very few students opened this file, even after prompting from the Interviewer. It was possible that the provision of a link to the hypertext file on every screen meant students ignored it as a possible source of data when encountering the unexpected later in the program. Therefore a question for future research would be to look at whether non-use of the glossary file was due to a problem with tracking down information on a computer in general or whether it was specific to this particular program. It is possible that future students will be more willing to access information over a computer as they gain experience with using computer search engines to track down information.

Another area for future research would be to investigate at what point students should be provided with information about a topic. For example, is it better to include information about dealing with a partially erupted tooth as part of an underlying database glossary file (i.e. it is something that would be covered in general background theory when orthodontics is taught), or should it be included as an anecdotal type response. Another question is: what are the cut-off points for identifying when it would be appropriate to use an "anecdotal-type" response rather than a link to an underlying theoretical database.

Other potential research topics arise from the quantitative data analysis, carried out to check the cohort of students in the main study were comparable to students in previous years, and include looking at whether confidence levels in using IT have an impact on how students use orthodontic CAL, and whether gender differences impact on their interactivity with CAL.

10.6 Chapter summary

This chapter outlined the main conclusions of this phenomenological study into how dental students use CAL to interact with a computer, each other and their tutor to learn about orthodontics. Using mixed-methodology research techniques allowed an in-depth examination of the qualitative data to be conceptualised against a background obtained from an analysis of relevant quantitative data.

The findings of the study included the identification and documentation of two different underlying sources of students' misconceptions about orthodontics and the impact of having to deal with records and questions about a real patient. These findings were used to suggest new guidelines to help future CAL development in dentistry.

This research has indicated that a phenomenological approach can be used in dentistry to find out more about how students learn and in educational technology to see how students interact with a CAL program. This approach was facilitated by the students' encounter with the unexpected. To further support the phenomenological approach, research techniques were drawn from a range of disciplines and combined using activity theory to provide further clarity to the analysis of student interactivity as they worked through the program.

Activity theory, as the underlying framework for this study, was used for the first time in dentistry to act both as a paradigm for modelling ways in which students use the computerized case study and as a heuristic device to identify ways in which future dental CAL case studies could be developed. Another advantage of using activity theory was that it facilitated the combination of qualitative and quantitative data collected under the mixed-methodology approach adopted for this study, again something that had not been done before in dentistry. It was suggested that CAL could be used both to support students as they familiarise themselves with a topic and to provide access to "dialogue" on the unexpected collected whilst developing the program. Providing this "dialogue" as a series of "*pseudo* conversations" at relevant points in the program would go some way to giving students access to alternative perspectives on the unexpected.

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Dundee Dental School (http://www.dundee.ac.uk/dentalschool/);
The Eastman Institute (postgraduates only) (http://www.eastman.ucl.ac.uk/);
Glasgow Dental School (http://www.gla.ac.uk/Acad/Dental/);
Leeds Dental Institute (http://www.leeds.ac.uk/dental/dental.html);
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Appendices

Appendix A

Appendix A

Table A1: The Knowledge Dimension (taken from Anderson et al., 2001)

Major Types and Subtypes
A. Factual Knowledge – the basic elements students must know to be acquainted with a discipline or solve problems in it
Aa. Knowledge of terminology Ab. Knowledge of specific details and elements
B. Conceptual Knowledge – The interrelationships among the basic elements within a larger structure that enable them to function together
Ba. Knowledge of classifications and categories Bb. Knowledge of principles and generalizations Bc. Knowledge of theories, models, and structures
C. Procedural Knowledge – How to do something, methods of inquiry, and criteria for using skills, algorithms, techniques, and methods
Ca. Knowledge of subject-specific skills and algorithms Cb. Knowledge of subject-specific techniques and methods Cc. Knowledge of criteria for determining when to use appropriate procedures
D. Metacognitive Knowledge – Knowledge of cognition in general as well as awareness of knowledge of on'es own cognition
Da. Strategic knowledge Db. Knowledge about cognitive tasks, including appropriate contextual and conditional knowledge Dc. Self-knowledge

Table A2: The Cognitive Process Dimension (taken from Anderson et al., 2001)

Categories and Cognitive Processes
1. Remember – Retrieve relevant knowledge from long-term MEMORY
1.1 Recognizing (Identifying) 1.2 Recalling (Retrieving)
2. Understand – Construct meaning from instructional messages, including oral, written and graphic communication
2.1 Interpreting (Clarifying, paraphrasing, representing, translating) 2.2 Exemplifying (Illustrating, instantiating) 2.3 Classifying (Categorizing, subsuming) 2.4 Summarizing (Abstracting, generalizing) 2.5 Inferring (Concluding, extrapolating, interpolating, predicting) 2.6 Comparing (Contrasting, mapping, matching) 2.7 Explaining (Constructing models)
3. Apply – Carry out or use a procedure in a given situation
3.1 Executing (carrying out) 3.2 Implementing (Using)
4. Analyze – Break material into its constituent parts and determine how the parts relate to one another and to an overall structure or purpose
4.1 Differentiating (Discriminating, distinguishing, focusing, selecting) 4.2 Organizing (Finding coherence, integrating, outlining, parsing, structuring) 4.3 Attributing (Deconstructing)
5. Evaluate – Make judgments based on criteria and standards
5.1 Checking (Coordinating, detecting, monitoring, testing) 5.2 Critiquing (Judging)
6. Create – Put elements together to form a coherent or functional whole; reorganize elements into a new patter or structure
6.1 Generating (Hypothesizing) 6.2 Planning (Designing) 6.3 Producing (Constructing)

Table A3: Transcription conventions

(adapted from Couper-Kuhlen, 2001; Cruse, 2004; Schiffrin, 1994; Titscher *et al.*, 2004)

Symbol	**Convention**
Utterance	What is produced in an act of linguistic communication, together with its intended meaning.
{Carriage Return}	End of utterance unit
First word capitalized	Start of sentence
|Line| |Line|	Overlapped speech utterances. Where these overlapping utterances were no start simultaneously, the left-hand line marks the point where the overlap begins, the right-hand line where it ends.
Line= =Line	Latched utterances (one participant continues sentence started earlier by self or by another speaker)
[Action]	Description of action/activities taken by the speaker, from either video or the log files, tied into the appropriate point in the transcript or further comments drawing on log files, video and observations used to enable a discussion of latent meaning-structures not apparent from transcriptions
Line.	Final. End of sentence/utterance. Falling intonation followed by noticeable pause (e.g., as at the end of a declarative sentence)
Line!	Emphasised point of view. Final intonation falling to low from high starting point. Animated tone.
Line;	Final pitch falling slightly
Line -	Speaker pauses during utterance. Final level pitch
Line,	Continuing intonation. Final pitch may rise or fall slightly (less than "." or "?") and may be followed by a slight pause.
Line?	Appeal/question. Rising intonation followed by noticeable pause (e.g., as at the end of an interrogative sentence)
CAPS	Loud volume
[PAUSE *s]	Extended silence – length of time (in seconds). A short, untimed pause within an utterance is marked by a dash (-).
...	Additional words left out of transcript, although spoken and recorded, to aid focus on key point of transcript
[...]	Words undecipherable, either because speakers were too quiet to be picked up on tape, two or more speakers spoke simultaneously or because the noise level in the CAL room interfered with what was being said
Italics	Words/utterances in italics are an approximation of what was recorded, but, even when taken in context, do not make sense from the point of view of the transcriptionist

Appendix B

Appendix B: Relevant Information in the Glossary File

Skeletal pattern (horizontal)

Skeletal Class 1 : The lower dental base is normally related to the upper. Point B lies a few millimetres behind point A.
Skeletal Class 2 : The lower dental base is retruded relative to the upper.
Skeletal Class 3 : The lower dental base is protruded relative to the upper.
The Skeletal Class is clinically assessed by observing the soft tissue profile, and by palpating points A and B with the patient in an upright position with the Frankfort plane horizontal.
Cephalometric assessment: A cephalometric radiograph is an x-ray of the skull taken using standardised conditions so that measurements can be made of the same patient on different occasions, and so that measurements can be compared between patients. Landmarks on the skull can be identified. Although most measurements taken from these landmarks will vary depending on the age, sex or race of the patient some measurements are available that do not vary significantly, and can be used to produce a series of norms for each racial group of patients. These measurements can be used as a tool to help dentists decide whether or not orthodontic treatment is appropriate. A cephalometric assessment is thus made on a cephalometric radiograph by measuring the angle ANB, the angle subtended at the Nasion by the A and B points. (ANB 2-4 degrees = Skeletal 1 ; Less than 2 = Skeletal 3 ; greater than 4 = Skeletal 2)

Skeletal pattern (vertical)

Mandibular plane angle : Two common assessments depending on whether a clinical or 'Ceph' assessment is being carried out:

Frankfort-mandibular plane angle (FMPA)
and Maxillary-mandibular plane angle (MMA)

Both angles give an indication of lower face height and a suggestion of direction of growth. Although there are now better ways of measuring the angles a 'Ceph' would still be required.
Facial proportions : The lower face height taken as a proportion of the total. It is clinically assessed by comparing the lower third of the face (below the naso-labial angle) with the middle third (from the eyebrow line to the naso-labial angle). The two should be approximately equal. The equivalent 'Ceph' measurement is LAFH/TAFH%
Increased lower face heights in absolute terms and increase in LAFH/TAFH% tend to be associated with an increased value of Frankfort/Mandibular or Maxillary planes angle, but the relationship is not very close.

Soft tissue (lips)

Competent lips : A lip posture such that an anterior oral seal can be maintained by lip contact with the facial musculature in a relaxed posture and the mandible in the rest position. May be used where lips would be competent but for the interposition of the upper incisors ("potentially competent").
Incompetent lips : A lip posture such that, with the facial musculature in a relaxed posture and the mandible in the rest position, lip seal does not occur.

Description of tooth positions

Crowding : The inadequacy of space in either arch to permit the correct alignment of all the teeth (including those yet to erupt).
Spacing : An excess of space for the teeth in either arch. May be localised or generalised.
Inclination : The mesio-distal angulation of the long axis of a tooth. Although it has never been defined most of such judgements are made with respect to the occlusal plane.
Rotations : Rotations should only be noted if they are thought to require treatment. These are described in a special way. Decide which surface of the tooth is most displaced from the arch and then give the direction. For example "mesio labial rotation" means that the mesial surface is most out of line lying labial to the arch.
Angulation : The labio-lingual angulation of anterior teeth. Judgments are made with respect to the mean values for the racial group concerned and are measured to the Maxillary plane (or the Frankfort plane) for upper teeth and the Mandibular plane for lower teeth. Hence Proclined, Retroclined, Average inclination. The term "normal angulation" should not be used because of confusion with the statistical and geometric use of the term.

Timing of treatment

Principles of Treatment : The age of 10-14 years is usually regarded as the optimum time for most orthodontic treatment. By this time the greater part of facial growth has taken place, the relationship of the arches is established and will be unlikely to change significantly. Increasing social awareness in children of this age leads to good motivation, although by 14 years cooperation may become less certain.
Early treatment : There is no evidence that orthodontic treatment in the deciduous dentition is any more long lasting than the deciduous teeth themselves. With the eruption of the permanent incisors limited treatment can be an advantage in the correction of crossbites (particularly anterior crossbites where there is any evidence of gingival damage). Other treatment which may be indicated in the period 6-10 years includes the management of unerupted or grossly ectopic teeth and immediate measures which may be required in the event of traumatic loss of maxillary incisors or enforced extraction of deciduous molars (Houston, Stephens and Tulley, 1992).
Late treatment : After 14 years treatment becomes progressively more difficult. Growth is limited and hence spontaneous changes are less likely to occur. In addition cooperation may well leave a great deal to be desired. The range of cases which can be successfully treated with removable appliances in this age range is therefore reduced.
Spontaneous changes : This information explains how the canine can move into the correct orientation as it erupts, if sufficient space is made for it to do so.

Canines

Mesially inclined canines will usually drop distally spontaneously to some extent once space is available, provided:

- They are still erupting
- There is no occlusal interference

This tendency is especially marked in the lower arch but declines rapidly in the first few months after extraction. Certainly it is unusual to see any significant change beyond 6 months post-extraction.

Choosing Teeth for Extraction in Orthodontic Cases

This information is a fuller explanation for non-dental readers of an abbreviated version found in the glossary help file (Houston, Stephens and Tulley, 1992).

Choice of extraction of teeth in the lower arch

It is possible to make some general statements about how to go about choosing teeth for extraction in the lower arch. The first point to note is that some teeth are more suitable than others. For example, it is not usually a good idea to remove upper anterior teeth (i.e. incisors) because of its effect on appearance. In many cases, orthodontic consultants will opt for premolars as their choice for extraction, for two reasons. Firstly, their location in the middle of the arch (which makes them suitable for relieving anterior and posterior crowding). Secondly, because there are two premolars in each quadrant having very similar shapes, then there are fewer problems getting the remaining tooth to form a good contact with adjacent teeth.

It should be noted, though, that there are certain types of cases which will warrant the extraction of almost any other tooth.

Extraction of incisors or canines

The temptation to relieve crowding in the lower teeth in the front of the mouth by extraction of an incisor or canine needs to be resisted except for a few well-defined circumstances, for example if the prognosis for that particular lower incisor is poor due to trauma, caries or gingival recession. Canines, too, should be avoided, as the contact relationship between the lateral incisor and the first premolar is rarely satisfactory after removal of the canine loss due to the shape of the crowns. Any case in which an incisor or canine appears to require extraction needs to be referred, whenever possible, to an orthodontic specialist.

Choosing premolars

As mentioned above, in cases where the lower labial segment crowding is **moderate to severe**, the consensus of opinion is to extract the first premolars. Second premolars are only extracted if they are completely excluded from the arch, perhaps due to early loss of the second deciduous molars, or if a fixed appliance is going to be used in a case where lower labial segment crowding is mild.

Choosing molars

First permanent molars are rarely extracted for orthodontic purposes, because of the likelihood that the contact relationship between the second premolar and the second permanent molar will be less than ideal, or even very poor.

Lower second permanent molars can be chosen for extraction purposes for a number of reasons, including:-

1. *To relieve impaction of the second premolar.*
2. *To relieve impaction of lower third molars*
3. *To relieve minimal lower incisor crowding*
4. *To prevent lower incisor crowding*

Choice of extraction of teeth in the upper arch

It is normal practice to make decisions about the upper arch in relation to what has been decided in the lower arch. In most cases, the aim will be to align the teeth with a normal overbite and overjet for the incisors. The key point is that extraction sites in the lower arch should be matched, wherever possible, by similar extractions in the upper arch (e.g., if the first premolars are chosen for extraction in the lower arch, then the choice in the upper arch should be first premolars, similarly if the second molars are chosen in the lower arch (as in case JB), then the second molars should be extracted from the upper arch, if possible). Again one of the reasons for choosing second permanent molars in the upper arch is to relieve mild crowding in the labial segment, where less than 3 – 4 mm of space is required for the incisors and canines. This, in turn, will allow the third molars, provided they are of good size and favourably positioned, to erupt into a satisfactory position (as in case JB).

Appendix C

Appendix C

Case JB: The examination

Students need to assess the following when carrying out an orthodontic examination (taken from Table 5.1, Houston, Stephens and Tulley, 1992, p.55):-

A. *History*

- Reason for attendance
- Medical history
- Dental history
- Social history

B. *Examination*

1. Extraoral

Skeletal pattern

a. anterior/posterior (skeletal class)
b. vertical (face height/FMPA)
c. lateral (? Facial asymmetry)

Soft tissue

a. lip competence
b. habitually apart/together?
c. Resting (lower) lip line

2. Intraoral

General condition of the mouth

a. oral hygiene/caries rate
b. teeth present

Lower arch

a. labial segment (angulation, rotation, crowding/spacing)
b. canines (angulation, rotation, crowding/spacing)
c. buccal segments (crowding, local tooth displacement)

In occlusion

Incisors:

class
overbite
overjet
center lines
crossbite (? + displacement)

Canines:

relationship

Buccal segments:

molar occlusion
crossbites (? + displacements)

3. Radiographic

Teeth present

Condition of:

crowns
roots and surrounding bone

Medical, social and dental history provided for case JB

Case JB is a female patient aged 10 years and 3 months at the time of assessment. The patient was referred by her father, a university lecturer who was dentally qualified. Both parents were concerned about the late appearance and palatal displacement of the upper right canine.

There is no relevant medical or social history for this patient. The dental history is as follows:-

JB has taken fluoride regularly since birth. She received no dental treatment until aged 7 years when a mucous retaining cyst was removed under local anaesthesia.

Additional information (on screen after extra-oral examination)
The caries experience for this patient was low, and her oral hygiene was good. The patient was described as being advanced dentally for her age.

Images of Case Records

Buttons labeled 'face', 'ceph', 'LS', 'RS', 'LAB', 'Occl' or OPT provided links to digitized images of dental records of case JB taken when she was 10 years 3 months (relating to information held on orthodontic cases in dental practice).

Figure C1: 'Face' – Photograph of JB

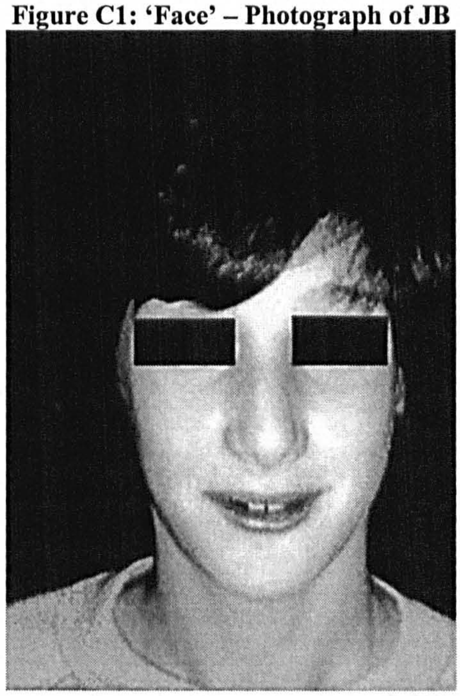


Figure C2: 'LS' – View of left hand side of case models

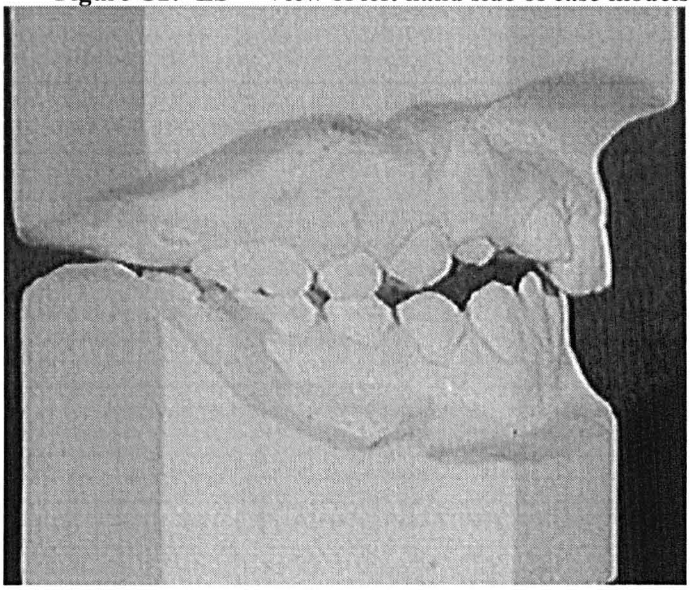


Figure C3: 'RS' – View of right hand side of case models

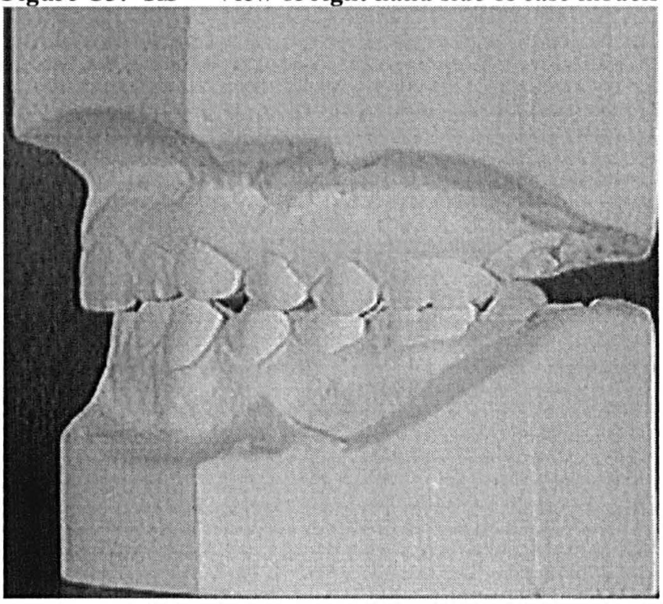


Figure C4: 'LAB' – Labial (front) view of case models

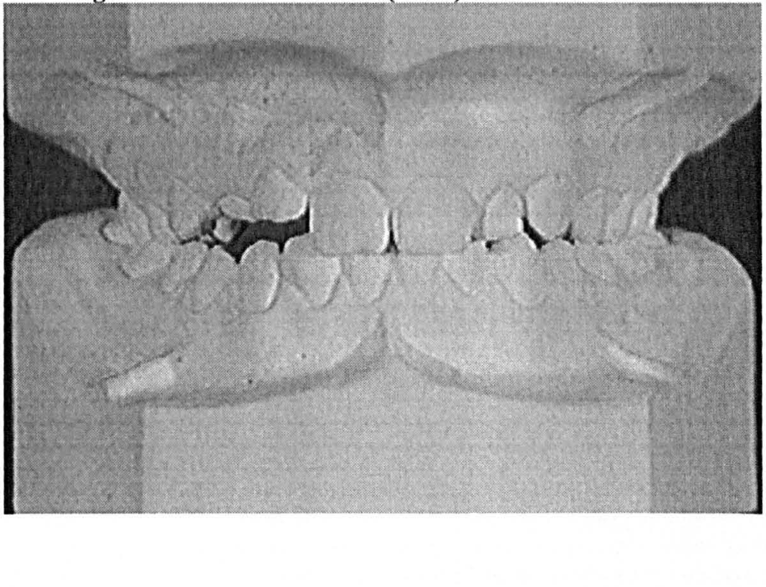


Figure C5: 'Occl' – View of models of upper and lower arch, seen from above (occlusal view)

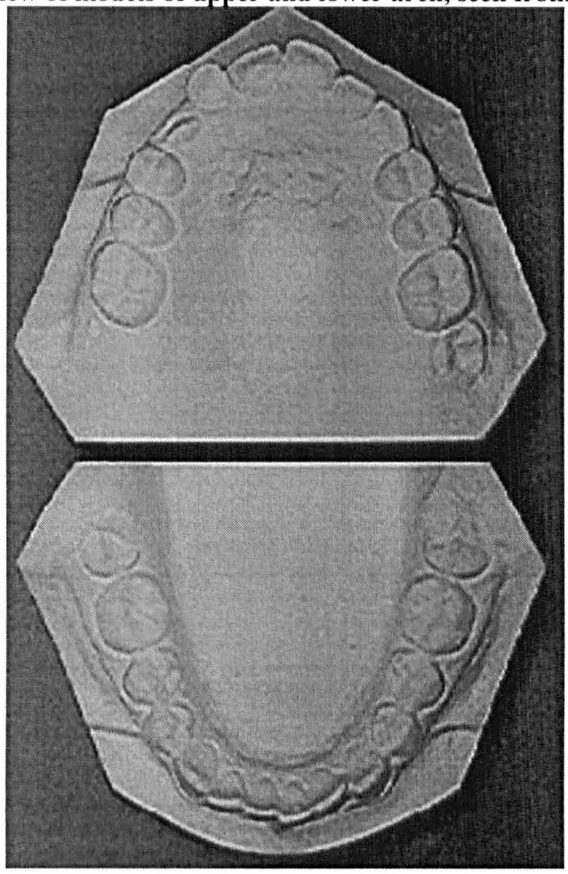
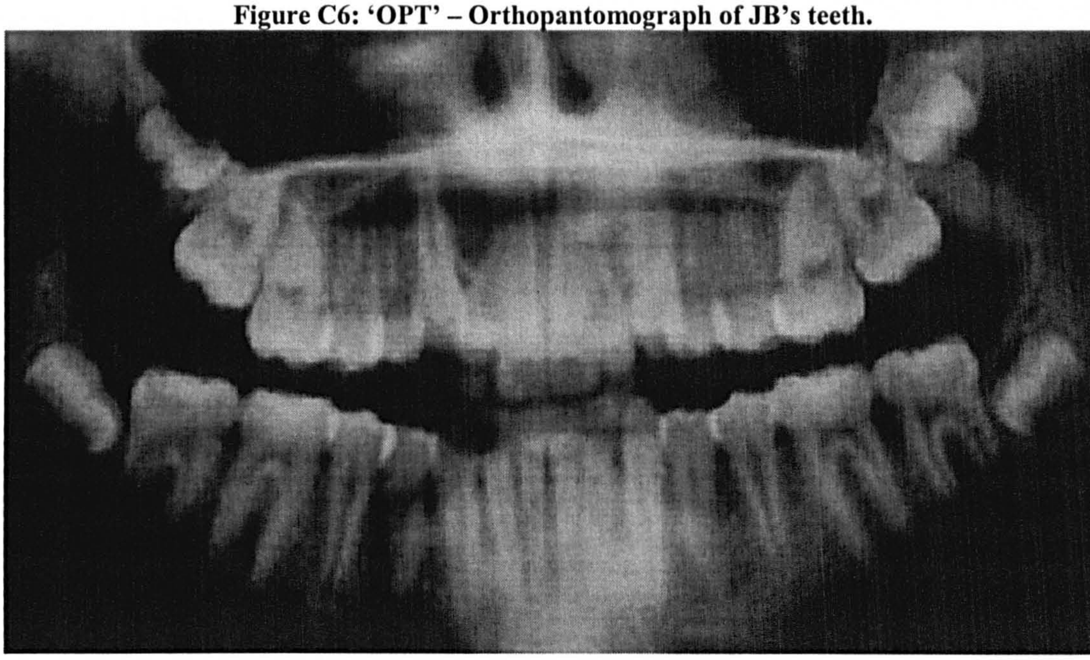
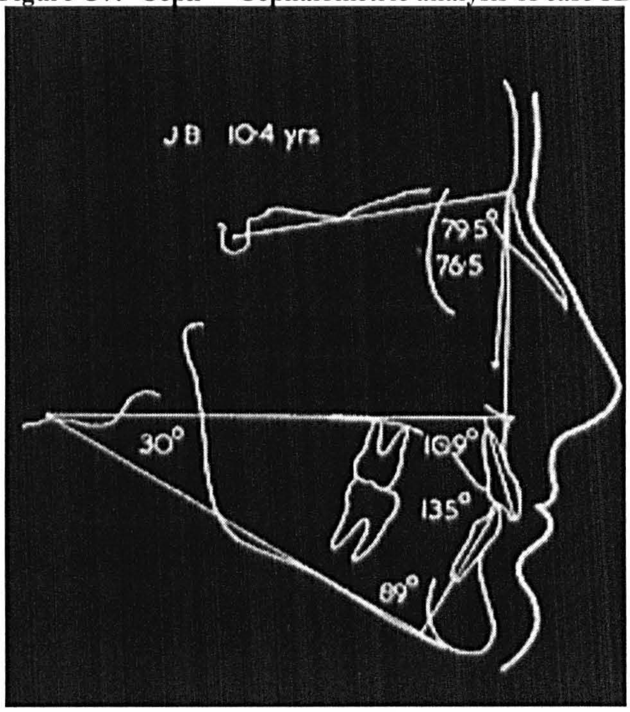


Figure C6: 'OPT' – Orthopantomograph of JB's teeth.



(An OPT is a panoramic x-ray showing a complete view of all dental structures. This type of x-ray is called an OPT because of the trade name of the machine (OptoPanTonogram) used to obtain the radiograph).

Figure C7: 'Ceph' – Cephalometric analysis of case JB



Case Assessment Summary

In general a case assessment summary should include the following (taken from Houston, Stephens and Tulley, 1992, p.79):

1. Details about the patient:
   name, sex, age;
   attitude to the malocclusion and to treatment
   relevant medical history
2. Classification (incisor class)
3. Skeletal base relationships
4. Soft tissue environment
5. Features of the malocclusion:
   - teeth present
   - overjet and overbite where appropriate
   - degree of crowding or spacing (in terms of premolar units per arch)
   - positions of individual teeth;
   - molar occlusion.

Case summary provided for JB:-

JB was 10 years 3 months old, and was concerned about the late appearance and palatal displacement of the upper right canine. As the daughter of a dentally qualified university lecturer, there were no problems with medical or social history.

On examination JB has a Class I malocclusion on a skeletal 1 dental base. There is an average face height. The lower incisors are very mildly crowded but otherwise the lower arch is well aligned. The upper incisors are of average inclination with the upper right lateral crowded labially. The upper left canine is mesially inclined and the upper right is slightly palatally misplaced and short of space.

In occlusion there is a normal overbite and overjet. The molars are near Class I on the left and half a unit II on the right. Third molars are present on the radiograph and there is evidence of upper molar stacking.

Treatment Planning Decisions

1. **To treat or not to treat?** Decide whether treatment is indicated on dental health or aesthetic grounds.
2. **Ideal or compromise?** It is better to achieve a compromise result rather than fail to achieve an ideal result. Compromise treatment must confer benefit and not leave the patient worse off in the long term.
3. **Space requirements:**

LOWER ARCH: Look at the lower arch. Decide whether extractions are indicated and whether the alignment is acceptable. Remember that crowding in the lower incisor region worsens during growth, particularly in boys.

UPPER ARCH: In order to have enough space to reduce any overjet and relieve crowding, the easiest guide to ensure that there is enough room (with or without extraction) is to confirm that there is sufficient room to retract the upper canines into their correct class I articulation with their opponents.

4. **Match of extraction sites:** It is usually desirable to keep extractions in the upper arch opposed to those envisaged in the lower.
5. **Tooth movements required:** List the precise movements required, decide whether the case requires appliances and whether these should be of the fixed or removable type.

Spontaneous changes seldom produce complete alignment except in the very young. A maximum of 5 months should be allowed for these to occur.

Removable appliances are suitable for limited tipping movements.

Myofunctional appliances are suitable for certain severe class II malocclusions in young patients.

Fixed appliances are suitable for the remainder.

6. **Plan the buccal occlusion:**

Is this to be class I or a full unit class II? Does the buccal occlusion need to be preserved or changed?

7. **Plan the anchorage:**

Will headgear be required to reinforce the anchorage or change the buccal occlusion?

Comments on treatment planning decisions

Decisions One and Two: To treat or not? If treated, should you aim for an ideal or a compromise outcome of treatment

It may appear that, in the context of a CAL package based around an orthodontic case study, these questions are irrelevant – almost by definition any case chosen as a basis for students at the stage of advanced (post-introductory) learning will not only require orthodontic treatment, but will also aim for an ideal outcome as a result of that treatment. However these questions are included, as they are ones that students will encounter and need to answer in the 'real' life situation that they will face in General Dental Practice.

Decision Three: Regarding space requirements

Feedback to incorrect answer suggesting a delay in extracting teeth in the lower arch

In fact extractions are required in the lower arch. In this sort of case there is always some room for argument. The lower arch is acceptable at present but will almost certainly get more crowded. However, one can be certain that there is going to be inadequate room for the lower third molars. Although it would be possible to adopt a wait and see policy with regard to further the anterior crowding this would run the risk of the lower arch becoming crowded during upper arch treatment.

Feedback to incorrect answer suggesting a delay in extracting teeth in the upper arch

Your answer is incorrect. There is little canine/incisor crowding but evidence of some upper molar stacking so extraction will be required. However, there is some argument about which teeth should be removed and when.

Decision Four: Choice of extraction sites

(NB: note that in the introductory information decision four makes a point of emphasizing the importance of trying to ensure that extraction sites are balanced (matched))

Feedback to responses to choice of extractions in the lower arch.

In the lower arch the best choice is to extract 3747 (the lower second molars), for the following reasons: It is true that there are a number of possibilities here. The first premolars are obviously inappropriate, as the degree of crowding is too mild and would leave too much space. The second premolars might be acceptable if fixed appliances are going to be used but again the degree of crowding doesn't justify it. That leaves doing nothing, which runs the risk of significant deterioration in a patient of this age or the extraction of either the lower second or third molars. The former has the advantage that it will reduce the degree of later crowding.

Feedback to responses to choice of extractions in the lower arch.

In the upper arch, the correct teeth to extract for this patient are 1727 (the upper second molars). This is because as so little space is required there is not really a case for the removal of premolars. Also remember that, as a general rule, you should try to keep extraction sites in the upper arch opposite those in the lower. The choice here rests between the extraction of either upper second molars or upper third molars. As it is easier to remove erupted teeth the second molars are preferable.

<u>Decision Five</u>: Tooth movements required.

Excluding any retaining appliance, what type of mechanics do you intend to use in the lower and then upper arch?

No appliance is the appropriate treatment for the lower arch, whilst an active removable appliance would be appropriate in the upper arch. This would be used to provide space for the upper right canine and lateral incisor and to align these teeth.

<u>Decision Six</u>: Plan the buccal occlusion (the way the back teeth will fit together at the end of treatment)

You should be aiming for a Class I buccal segment occlusion on both the left and right side.

A Class I buccal occlusion can be obtained on the left with only very slight distal movement of this segment. In a case such as this amounts to holding the upper molar whilst mandibular growth provides the necessary forward movement of the lower molar. On the right a Class I buccal occlusion should be maintained by active distal movement of the upper right buccal segment.

Interim summary offered at this point:

Left side:

You have chosen to maintain or effect a slight distal movement of the upper left buccal segment to achieve a fully intercuspated Class I occlusion.

Right side:

You have chosen to achieve a Class I buccal segment occlusion on the right, and decided to attain it by active distal movement of the upper right molar.

<u>Decision Seven</u>: Plan the anchorage

Bearing in mind the space requirement of this case, the tooth movements you are intending to carry out, and the appliances you have chosen, what will be your source(s) of anchorage?

Choices offered:-

1. Intramaxillary
2. Intermaxillary
3. Extraoral
4. Intermaxillary and Extraoral
5. Intramaxillary and Extraoral

Explanation of terms used:

Intermaxillary – within the same arch (Latin: *internus* – within)

Intramaxillary – between arches (Latin: *intra* – between)

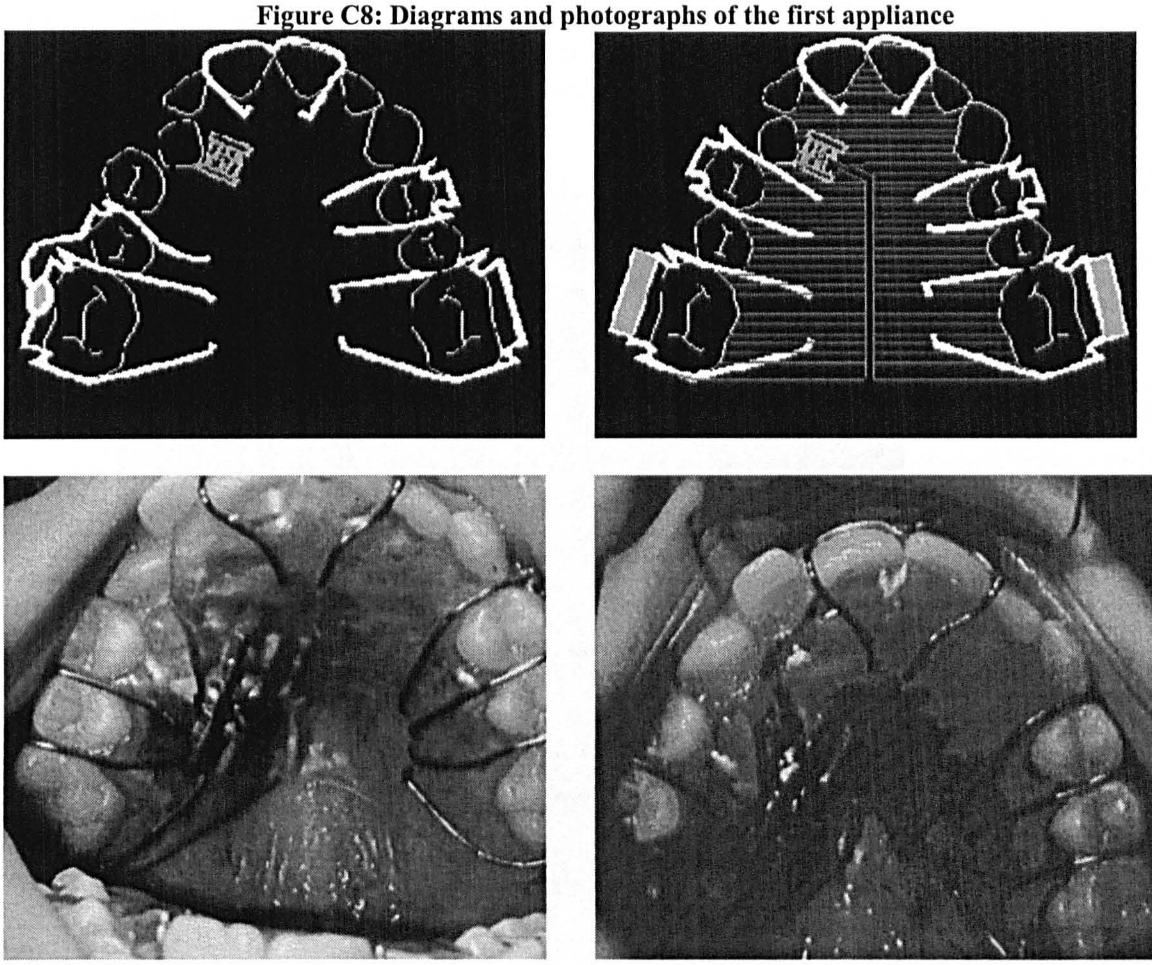
Extraoral – anchorage provided from outside the mouth, using headgear.

Feedback offered to students

It is generally possible to achieve distal movement of one buccal segment without the use of extraoral anchorage. However it is wise to include the provision for adding extraoral traction should this prove necessary.

Appliance Designs

Figure C8: Diagrams and photographs of the first appliance

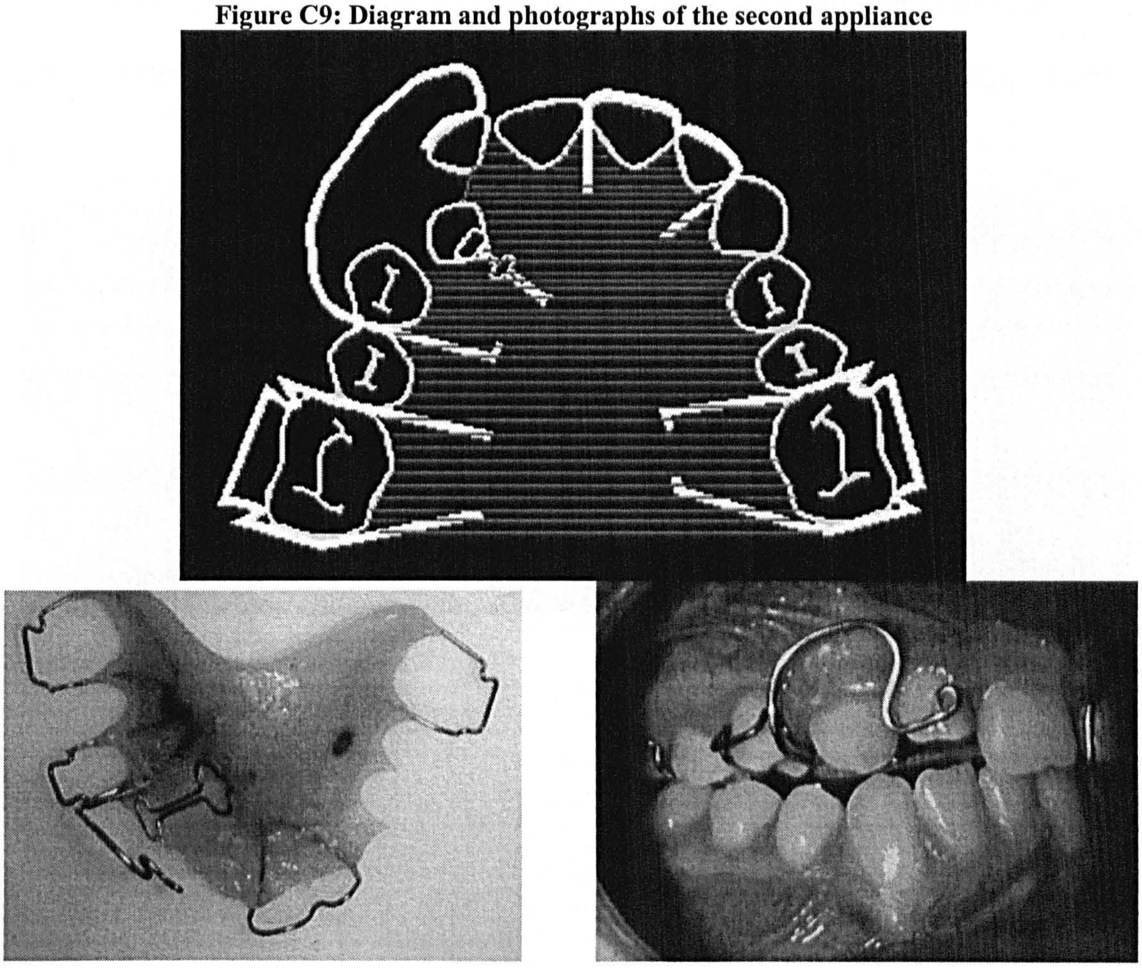


Treatment Aims of First Appliance

1. Relief of posterior crowding and preservation of the lower arch alignment by extraction of all four second molars.
2. Accommodation of the upper right canine and lateral incisor.
3. Correction of the buccal occlusion on the right.

Although there is evidence of posterior crowding, it is intended to extract upper right 7, and so extraoral anchorage is not required. Were this not the case, it would be necessary to modify the appliance shown in Figure A8 and add molar tubes for extraoral anchorage as shown in the second diagram and photograph. Note this only applies to unilateral movement, where both buccal segments are being moved distally, extraoral anchorage is always required.

Figure C9: Diagram and photographs of the second appliance



Treatment Aims of Appliance used in Second Stage of Treatment

1. To tip the upper right canine buccally.
2. To retrocline the upper right lateral incisor.

Here is the design which was actually used (Figure 9). As has already been mentioned, the crib on the upper right first premolar proved rather inconvenient and was eventually cut off, which demonstrated that adequate retention was available elsewhere. It can also be seen that the boxing out for the t-spring had the effect of propping the bite open which facilitated correcting the crossbite affecting the upper right canine.

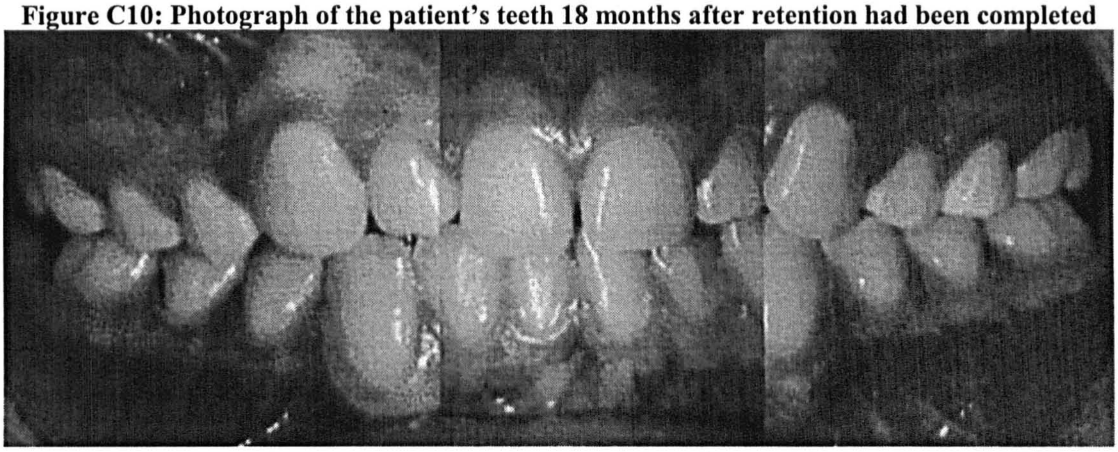
Summary of Treatment Outcomes

This Class I case was treated with a maxillary removable appliance, the aim of which was to accommodate the upper right canine and lateral incisor. Two appliances were used: the first (figure A8) was an upper screw plate without headgear support to move the upper right buccal segment distally.

The second (figure A9) carried a t-spring to move the upper canine buccally, and a labially approaching spring to align the lateral incisor. Relief of crowding was obtained by extraction of all four second molars. Treatment took 12 months, and was followed by a 6 month period of retention, of which 3 months was full-time wear and the remainder night-only wear.

Records shown here (figure A10) are of the occlusion 18 months out of retention. Despite the fact that lower third molars are generally much less predictable in their behaviour following the loss of second molars than those in the upper arch, all four third molars had erupted into excellent occlusion by the age of 16 years.

Figure C10: Photograph of the patient's teeth 18 months after retention had been completed



Appendix D

Appendix D

D1: The M-year questionnaire

Name ______________________________ **Date** __________________

Computer No: ________________________

	Section A - General							
1	Age (please put 99 if you prefer not to respond)					O O years		
2	Gender					Male	O	
						Female	O	
3	Are you from overseas?					Yes	O	
						No	O	
4	Is English your first (native) language?					Yes	O	
						No	O	
	Section B - Your IT Skills							
5	How would you grade your general IT skills? (Tick one only)					beginner	O	
						competent in some basic skills	O	
						competent in most basic skills	O	
						expert	O	
6	How would you rate your ability to use a word-processor to produce a page of text?							
		O	O	O	O	O		
		1	2	3	4	5		
		Unable <--->Expert						
7	How would you rate your ability to carry out file management (e.g. save, delete, copy, merge and find files)?							
		O	O	O	O	O		
		1	2	3	4	5		
		Unable <--->Expert						
8	How would you rate your ability to send and receive email?							
		O	O	O	O	O		
		1	2	3	4	5		
		Unable <--->Expert						
9	How would you rate your ability to use the Internet and the World Wide Web?							
		O	O	O	O	O		
		1	2	3	4	5		
		Unable <--->Expert						
10	How would you rate your ability to use a database to track down information or a spreadsheet for statistical analysis?							
		O	O	O	O	O		
		1	2	3	4	5		
		Unable <--->Expert						
11	How would you rate your ability to design and set up a database?							
		O	O	O	O	O		
		1	2	3	4	5		

12	How would you rate your ability to use a computer to design graphics images?							
		O	O	O	O	O		
		1	2	3	4	5		
		Unable <-->Expert						
13	How would you rate your ability to set up and program a computer?							
		O	O	O	O	O		
		1	2	3	4	5		
		Unable <-->Expert						
14	How would you rate your interest in developments in information technology generally?							
		O	O	O	O	O		
		1	2	3	4	5		
	Not Interested <-->Very Interested							

Section C - Additional Comments

Please complete the following :-

15 The use of IT has <u>benefited</u> my learning process because :-

____

____

____

16 The use of IT has <u>obstructed</u> my learning process because :-

____

____

____

Would you be willing to be interviewed or contacted following the completion of this questionnaire?	Yes No	O O

If 'Yes' please provide the following

Your name : ____________________________

Your E-mail address : ____________________________

OR

Your preferred contact information : ____________________________

____

All information provided will remain confidential

Thank you for completing this questionnaire

D2: Analysis of Self-Assessed Confidence Levels in Using Computers

Table D2: Confidence levels in using computers

	IT Skills	WP	Fl Mgt	Email	WWW	Use db	Setup db	Graphics	Program	Interest	Over all activities
Males (Obs)	68	98	93	103	102	74	55	57	46	72	768
Females (Obs)	55	93	75	93	76	50	32	38	31	56	599
Totals	123.00	191.00	168.00	196.00	178.00	124.00	87.00	95.00	77.00	128.00	1367.00
Expected (E)	61.50	95.50	84.00	98.00	89.00	62.00	43.50	47.50	38.50	64.00	683.50
O-E (m)	6.50	2.50	9.00	5.00	13.00	12.00	11.50	9.50	7.50	8.00	84.50
{O-E (m)}2	42.25	6.25	81.00	25.00	169.00	144.00	132.25	90.25	56.25	64.00	7140.25
O-E (f)	-6.50	-2.50	-9.00	-5.00	-13.00	-12.00	-11.50	-9.50	-7.50	-8.00	-84.50
{O-E (f)}2	42.25	6.25	81.00	25.00	169.00	144.00	132.25	90.25	56.25	64.00	7140.25
{(O-E)2}/E (m)	0.687	0.065	0.96	0.25	1.90	2.32	3.04	1.9	1.46	1	10.45
{(O-E)2}/E (f)	0.687	0.065	0.96	0.25	1.90	2.32	3.04	1.9	1.46	1	10.45
Chi squared =	1.37	0.13	1.93	0.51	3.80	4.64	6.08	3.8	2.92	2	20.89
prob less than	0.3	0.8	0.2	0.5	0.1	0.05	0.02	0.1	0.1	0.2	0.001
	ns	ns	ns	ns	ns		just ns	ns	ns	ns	

Chi sqr = sum[{(O-E)2}/E]	
critical values	
5% level = 3.84	0.05
1% level = 6.64	0.01
0.1% level = 10.83	0.001

This data was obtained from a questionnaire survey administered to all students asking them to assessed how confident they felt about using different types of computer software. Other data collected included gender, age and whether or not they came from overseas and, if so, whether English was their native language. Apart from gender, the numbers of students from overseas or for whom English was not their first language was too small to use in a statistical analysis.

Results indicate female students significantly more likely ($p<0.001$) than male students to express lower confidence levels over all computerized activities, due to accumulative effects of lower self-assessed confidence scores across these activities. On individual activities (e.g., word processing, *etc*), sample size is too small to reveal any significant differences, except when using databases ($p<0.05$).

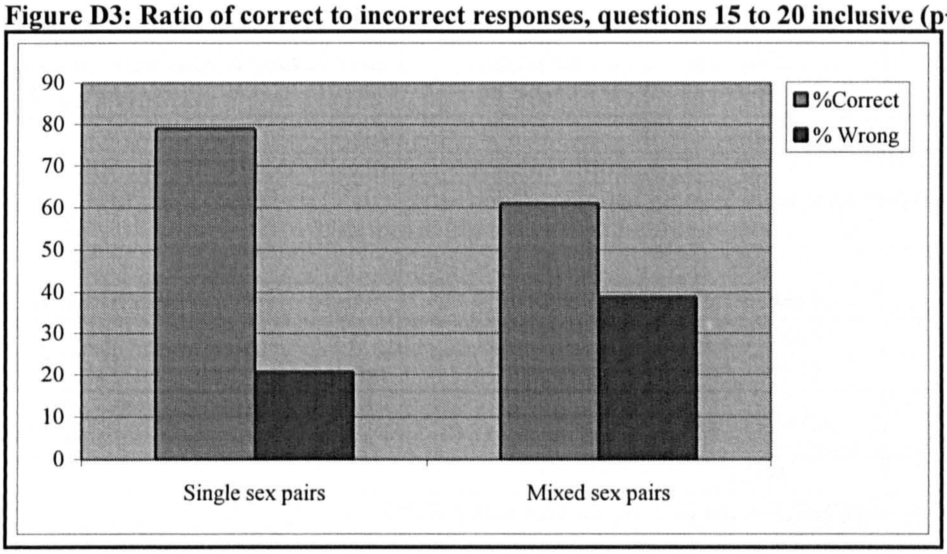
D3: Analysis of Raw Data from Computer Log Files

For most of the case study, the differences between single and mixed sex pairs were insignificant, probably due to the impact of other factors influencing students (e.g., the nature of the actions they were being asked to carry out had more effect than differences between the pairs). However in the classification section, computer calculated chi tests carried out on questions 15 to 20 (chosen because at this point in the program students had become both more familiar with using orthodontic terminology through answering similar questions earlier in the case, and avoiding the different issues surrounding the problem of dealing with the partially erupted upper right canine) revealed that mixed pairs were significantly more likely to get these questions wrong than students working in same sex pairs ($p<0.05$, Table D2 and Figure D2).

Table D3: Collated data taken from log files comparing gender of single and mixed sex pairs

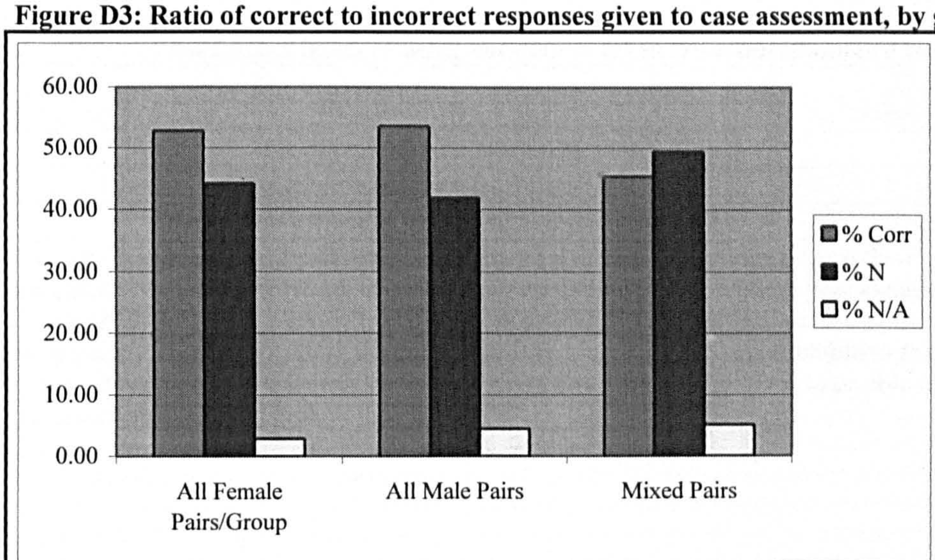
Gender mix of pair	Number of correct responses	Number of incorrect responses	Total number of responses
Single	57	15	72
Mixed	22	14	36
	79	29	108
Chitest	0.0459	df = 1	Significant at $p < 0.05$

Figure D3: Ratio of correct to incorrect responses, questions 15 to 20 inclusive ($p<0.05$)



The difference between single and mixed sex pairs can also be seen in Figure D3, where pattern in the ratio of correct to incorrect responses between single and mixed sex pairs was compared. The small size of the sample meant that any differences were not significant statistically. As an analysis of gender differences was not the focus of this study, this result was not followed up and has been left for future research.

Figure D3: Ratio of correct to incorrect responses given to case assessment, by gender of pairs/groups



Key
Corr : Correct response given
N : iNcorrect response
N/A : Question not Answered

D4: Statistical Tests carried out on End of M- and S-year Orthodontic Exam Results

Table D4a: Computer calculated chi test results on actual versus expected end of M- and S-year orthodontic exam results for male versus female students

Actual total marks	M Year	S Year	Totals
Females	1885	3962	5847
Males	1764	3582	5346
.	3649	7544	11193
Expected total marks	**M Year**	**S Year**	**Totals**
Females	1906.165	3940.835165	5847
Males	1742.835	3603.164835	5346
	3649	7544	11193
Where expected total marks = (column total * row total)/grand total			
Computer calculated Chi test = 0.393 (ns)			
	(O-E)	**(O-E)2**	**(O-E)2/E**
Male students M year results	21.16484	447.9502476	0.257024
Male students S year results	-21.1648	447.9502476	0.124321
Female students M year results	-21.1648	447.9502476	0.235001
Female students S year results	21.16484	447.9502476	0.113669
		Total =	**0.730015**
df = (nr-1)(nc-1), df = 1 where nr = number of rows and nc = number of columns. Therefore a continuity correction (Yates correction) is required because there is one degree of freedom. This means that the chi test becomes: $\{(O-E)-1/2\}^2$			
	(O-E)	**{(O-E)-1/2}2**	**(O-E)2/E**
Male students M year results	21.16484	427.0354124	0.245023
Male students S year results	-21.1648	469.3650827	0.130265
Female students M year results	-21.1648	469.3650827	0.269311
Female students S year results	21.16484	427.0354124	0.118517
		Total =	**0.763116**
With Yates correction, Chi sqr = 0.763 (ns)			
H_o: there is no significant difference between male and female students in end of year results. If $\chi^2 < 3.81$ do not reject H_o, if $\chi^2 > 3.81$ reject H_o. $\chi^2 < 3.81$, therefore H_o is accepted – i.e. there is no significant differences between male and female students in end of year examination results.			

Table D4b: Computer calculated correlation values between end of M- and S-year orthodontic exam results in M year, S year and across both years compared with combined results of self-assessed confidence levels in using computers taken from questionnaire survey data.

	Correlation value (r)
Correlation with results from M year	-0.016
Correlation with results from S year	0.0080
Correlation with combined results from both years	-0.00065

The very low values for the correlation constant (r) (Table D4a) indicates that there appears to be no correlation between confidence in using computers and outcome of final year examinations. Hence students are either finding other ways of learning about orthodontics if they are unsure of using computers, their computer skills are sufficiently advanced that lack of confidence is not inhibiting their use as a learning tool, or they are able to improve their computing skills to a high enough level to be able to cope with using computers as a learning tool.

D5: End of S-year Orthodontic Section of Child Dental Health Exam

Table D5: Mann-Whitney U test on top half of year, ranked by results of the final year orthodontic sections of the Child Dental Health exams comparing students in pairs with individuals

Pseudonym	Set	Groups Rank	Individuals Rank	Final mark – S year
Queenie	S5-g1	1		179
Mary	S4-g1	2		175
Una	S6-g2	3		173
Rachel	S5-g1	4		172
George	S3-i1		5.5	171
Olga	S4-g4	5.5		171
David	S2-g2	7		168
Peter	S4-g4	8		167
Victor	S6-g1	9		166
Frank	S2-g3	10.5		164
Steve	S5-g3	10.5		164
Adam	S1-g2	12		163
Tina	S5-g2	14		162
Victoria	S6-i1		14	162
Xavier	S6-i2		14	162
Xenie	S6-i4		16	160
Christine	S1-g1	17		157
Oscar	S4-g3	18		156
Jennifer	S3-g1	19		155
Charles	S1-i2		21.5	154
Debbie	S1-i1		21.5	154
Leonard	S4-g1	21.5		154
Quentin	S5-i2		21.5	154
Helen	S2-g4	24.5		153
Laura	S3-g2	24.5		153
Anne	S1-g1	27.5		152
Henry	S3-g2	27.5		152
Michael	S4-g2	27.5		152
Ulysses	S6-g1	27.5		152
Ian	S3-g3	30		151
Natalie	S4-g2	31		150
Wayne	S6-g2	32		146
Elizabeth	S2-g1	33.5		145
Nigel	S4-g3	33.5		145
Sophie	S5-g2	35		142
Kevin	S3-i2		36	139
Belinda	S1-g1	37.5		138
Winifred	S6-i3		37.5	138
Gita	S2-g3	39.5		137
Ralph	S5-i3		39.5	137
Edward	S2-g2	41		136
Isabel	S2-g4	42		132
Terry	S5-g3	43		131
Felicity	S2-g1	44		128
Bill	S1-g2	45		126
James	S3-g3	46		124
Pamela	S5-i1		47	123
Kate	S3-g1	48		112

Analysis of S year rankings comparing students who chose to work in pairs with those who chose to work as individuals during the main study. The final mark in the last column is a combination of the mark from 2 written orthodontic questions in the Child Dental Health paper, together with the case presentation mark and the diagnosis mark. These marks were available as they were used to calculate the best student in the subject for the purposes of awarding the John Wilkie prize in orthodontics at Bristol Dental School.

Taking the top 23 results (cut-off point chosen so that ranking of students was for those in top half of year (i.e. with rank <= 24))

n1	16	162	114
n2	7	R1	R2
n1n2 =	112		

H_0: Whether or not students worked individually or in pairs made no difference to final year rankings

H_1: Students choosing to work in pairs were more likely to get into the top half of the final S year (median result for top 16 pairs (165.4) > median result for top 7 individuals (159.6)
In other words, do the two populations have distributions with different medians?

U1 = n1n2 + (1/2)n1(n1+1)-R1 =		86
U2 = n1n2 + (1/2)n2(n2+1)-R2 =		26
	Check U1+U2	112
	So Calc U = 26 (smaller of U1 and U2)	

Tab U = 26 from tables for 5% significance level, two-sided H_1, n1=16, n2=7

Using the Mann-Whitney U test, looking at the rankings of individuals and pairs in the top 23 students at the end of the S year (23 students chosen as the closest cutoff point to half the students in the year)

As Cal U = Tab U, then despite the small size of the sample, there is a possibility (significant on the 5% level) that students who chose to work in pairs were more likely to end up in the top half of end of S year exams than students who chose to work as individuals.

There is no way of knowing whether students did better because they worked in pairs, or whether they chose to work in pairs because they were stronger students
However research on social nature of learning suggests that the former may be applicable in this case

x_1 (mean for highest 16 ranking pairs) = 165.37
x_2 (mean for highest 7 ranking individuals) = 159.57

48 students ranked (cutoff point chosen as rank of 24 or less (48/2), therefore 24th and 25th ranked students ignored as their ranks were 24.5 each, i.e. >24).

2 students did not take part in the main study, so were not used here
student 1 - final year score 128 - not included in calculation
student 2 - final year score 159 (ranked 17th), but ignored as unable to classify as group or individual.

D6: Using the glossary help file

Table D6 Opening the glossary help file

Set type	Open glossary file	Do not open glossary file
Pairs	4	14
Individuals	7	4

χ^2 test = 0.0123 (df = 1)
Significant at p <0.02 level

Results of computer-generated χ^2 test
H_0 – there is no significant difference between individuals and pairs in their decision as to whether or not to open the glossary help file

A, a χ^2 test on the extraction choices in the upper arch revealed that there was a significant difference between individuals and pairs at the <2% level (p=0.0123, df=1).

D7: Time Spent on Different Sections of the Program

Table D7: Time taken by students to reach the Appliance Design section and then to complete the case

Set	End (time)/ hrs:min	Q43 reached (time)/ hrs:min	Start (time)/ hrs:min	Time taken to Q43 hrs:min	Time taken to complete hrs:min
Pairs					
Michael & Natalie	14:42	14:35	14:02	00:33	00:40
Nigel & Oscar	14:42	14:34	14:02	00:32	00:40
Ulysses & Victor	14:51	14:40	14:09	00:31	00:42
Una & Wayne	14:48	14:38	14:02	00:36	00:46
Jennifer & Kate	10:59	10:50	10:11	00:39	00:48
Anne, Belinda & Christine*	11:08	10:45	10:06	00:39	00:49
Elizabeth & Felicity	14:53	14:41	14:03	00:38	00:50
David & Edward	14:50	14:37	13:58	00:39	00:52
Henry & Laura	10:51	10:42	09:58	00:44	00:53
Ian & James	11:01	10:50	10:07	00:43	00:54
Olga & Peter	14:57	14:45	14:01	00:44	00:56
Queenie & Rachel	11:08	10:52	10:12	00:40	00:56
Steve & Terry	11:09	10:53	10:13	00:40	00:56
Helen & Isabel	15:10	14:49	14:09	00:40	01:01
Adam & Bill	11:07	10:53	10:06	00:47	01:01
Leonard & Mary	15:03	14:48	13:59	00:49	01:04
Frank & Gita	15:17	14:59	14:10	00:49	01:07
Sophie & Tina	11:28	11:09	10:11	00:58	01:17
*Anne, Belinda & Christine's coffee break lasted from 10:45 to 10:58, so 13 mins has been taken off their total time to complete. Although it was likely that they would have continued to discuss the case over coffee, the computer was not being used during this time.			**Average**	**00:41:10**	**00:54:00**
Individuals					
George	10:39	10:30	10:07	00:23	00:32
Quentin	11:02	10:48	10:11	00:37	00:51
Kevin	12:18	12:03	11:26	00:37	00:52
Pamela	11:04	10:53	10:11	00:42	00:53
Debbie	11:04	10:49	10:06	00:43	00:58
Charles	11:06	10:49	10:05	00:44	01:01
Ralph	11:19	10:49	10:11	00:38	01:08
Xenie	15:14	14:59	14:05	00:54	01:09
Winifred	15:25	15:09	14:03	01:06	01:22
Xavier	15:13	14:59	14:02	57:00	01:11
Victoria	15:37	*15:18	14:05	01:13	01:32
			Average	**00:46:44**	**01:02:38**
Averages for individuals and pairs			**Average**	**00:43:17**	**00:57:43**

D8: Percentage of Sets Getting Each Answer Correct

Table D8 Percentage* of sets finding the correct answer first time round, in the case assessment, treatment planning and appliance design sub-sections

CA Questions	% correct	TP Questions	% correct	AD Questions	% correct
1	52	30	**24**	**Appliance 1**	
2	**17**	31	100	43	**34**
3	62	32	**34**	44	42
4	79	33	71	45	43
5	79	34	**10**	46	**28**
6	**7**	35	41	47	N/A
7	52	36	**36**	48	64
8	65	37	42	49	57
9	69	38	96	50	79
10	72	39	88	51	48
11	54	40	50	**Appliance 2**	
12	69	41	81	52	**31**
13	**38**	42	**21**	53	80
14	65			54	41
15	86			55	52
16	97			56	77
17	72			57	41
18	**7**			58	82
19	83			59	64
20	93			60	N/A
21	82			61	N/A
22	48				
23	78				
24	79				
25	4				
26	79				
27	93				
28	67				
29	93				

* The results have been converted to percentages for comparison purposes, because some sets did not enter an answer for every question onto the computer. Some students arrived at the correct answer and moved on without entering it into the computer (particularly when asked to answer the general appliance design questions for a second time). Others skipped a question for no apparent reason, or because they 'gave up' and decided to move onto the next question without bothering to record an answer.

An analysis of the pattern of student responses to the questions revealed no overall significant difference between individuals and pairs across all questions. However there were some occasions where working in a pair seemed to help students, and others where the presence of a partner acted in the other direction. These instances, and the impact they had on student responses, are discussed at appropriate places within the thesis itself.

D9: Choices of Extraction Sites in Upper Arch (question 34)

Table D9a Chosen responses for timing of treatment

Set type	Treat now	Delay treatment
Pairs	3	15
Individuals	6	5

χ^2 test = 0.0059 (df = 1)
Significant at p <0.01 level

Table D9b Comparison of numbers of sets per extraction sites for groups 1 & 2 against groups 3 and 4

Groups	Choice in Lower Arch			Choice in Upper Arch		
	First premolars (4s)	Second premolars (5s)	Second molars (7s)	First premolars (4s)	Second molars (7s)	Others (5s or 6s)
1 and 2i	10	1	1	9	3	-
2ii and 3	9	2	-	1	6	4

The total number of sets included in this table was 23. 6 sets were excluded from these calculations for the following reasons: In session 6, the analysis of the transcripts revealed that only Victor and Ulysses worked on the extraction choices on their own, the remaining students (Victoria, Xavier, Winifred, Xenie, Una and Wayne) were all helped by Gareth before entering extraction choices in the upper arch. George was also excluded as he admitted having previously worked on the case as a "board study" beforehand.

Criteria for classification

Groups 1 & 2i
Group 1 – students who were unable to draw any conclusions about why 7s were chosen for extraction
Group 2i – students who identified the need for extractions in the upper arch to "balance" (compensate for) those in the lower arch, but did not identify any other reasons for extracting 7s

Groups 2ii & 3
Group 2ii – students who recognized that the degree of crowding around the posterior teeth (and one group who recognized the mild degree of crowding in the incisor region, but not the posterior crowding) as reasons for extracting the 7s
Group 3 – students who recognized both that the degree of crowding around the posterior teeth and the mild degree of crowding in the incisor region as reasons for extracting the 7s.

Results of computer-generated χ^2 test
H_o – there is no significant difference between Groups 1/2i and Groups 2ii/3 in their extraction choices

A χ^2 test on the extraction choices in the lower arch, comparing groups 1 and 2 with groups 3 and 4 revealed no significant difference between groups 1 and 2 and groups 3 and 4 (p= 0.65, df=2).

In contrast, a χ^2 test on the extraction choices in the upper arch revealed that there was a significant difference between the combined groups 1&2 and the combined groups 3&4 at the <1% level (p=0.0096, df=2).