Chapter 1

The theory and practice behind studio teaching

"*Tell me and I'll listen. Show me and I'll understand. Involve me and I'll learn"*
Teton Lakota Native American saying

1.1 Introduction

Cognitive researchers, from Piaget onwards, have shown that real learning and understanding are better accomplished through cooperative and interactive techniques. Recent developments in these theories of learning emphasise the importance of communications and collaboration, both between teacher and students and students themselves. Coincident with some of the latest developments in the theory and practice of cooperative and interactive learning has been the development of computer technology, especially the rapid acceptance and use of the World Wide Web/Internet, coupled with the widespread adoption of computers in education at all levels.

The synthesis of these two developments has given rise over the past decade or so to completely new paradigms of teaching, usually starting with science and technology, and then gradually migrating into other academic disciplines. This introductory section seeks to consider some of the more significant of these efforts, and then show how it has been applied to engineering and applied science courses at university level. As this is an attempt to put the development of the studio teaching paradigm into the historical context of educational developments up to the mid 1990s, a discussion of more recent developments is left until a later chapter. The chapter is then concluded with a series of questions raised by these developments, and also an outline of the research methodology used to try and answer them.

As is inevitable in such cases, there will be many interesting ideas discussed at a very superficial level. This is just to try and set the background of the work being reported; it is just not possible in the space allowed to explore all the fascinating byways of educational theory and practice!

1.2 Historical background

The development of small group interactive learning pedagogies over the past 30 to 40 years differs on each side of the Atlantic. Around 100 years ago, John Dewey in the USA, began arguing for the kind of change that would move schools away from authoritarian classrooms with abstract notions to environments in which learning is achieved through experimentation, practice and exposure to the real world. In the 1920s he was promoting cooperative learning as part of his project method of instruction (Dewey, 1924). Also, at this time, Piaget started producing his seminal works on how knowledge develops in children. Although "Dewey in the USA, Montessori in Italy and Freire in Brazil fought harder for immediate change in schools, Piaget's influence on modern education is deeper and more persuasive" (Papert, 1999). The work of Piaget is central to understanding how small group interactive learning takes place, and will be considered in detail below.

The ideas put forward by Jane Abercrombie (1960) in the 1960s in the UK had an almost immediate impact on the primary and tertiary education sectors there. However, in the US it was the rapid changes and expansion of tertiary education that caused a rethinking of traditional methods of teaching.

The term collaborative learning was coined, and the basic idea first developed, in the 1950's and 1960's by a group of British secondary school teachers and by a biologist studying British postgraduate education-specifically, medical education. Two of the early researchers were Mason (1970), and James (1968). Mason and James were colleagues at Goldsmith's College, University of London, and were committed during the Vietnam era to democratising education and to eliminating from education what were perceived by them as socially destructive authoritarian social forms. Collaborative learning, as they thought of it emerged, from this largely political, topical effort.

Many of these themes had already been explored and their educational value affirmed by the earlier findings of Abercrombie. Her *Anatomy of Judgement: an investigation into the process of perception and reasoning* (1960) culminated ten years of research on the selection and training of medical students at University College, University of London. This research suggested that the art of medical judgement, diagnosis and other key elements of medical practice, were better learned in small groups of students arriving at a diagnosis collaboratively than by students working individually.

She began her study by observing groups of medical students with a teaching doctor gathered round a ward bed to diagnose a patient. She then made some small, but significant changes, by asking the students to make a group diagnosis instead of each one making an individual diagnosis in turn. She asked the students to discuss the case as a group and them come to a consensus, a single diagnosis they could all agree on. What she found was that students learning this way acquired good medical judgement faster than individuals working alone. (ibid., p19)

In 1964 the Hale Committee on University Teaching Methods (University Grants Committee (UGC), 1964) reported that discussion in small groups was to be preferred to large, impersonal lectures. They advocated a more student-centred approach to teaching, and this stimulated much discussion about university teaching. A few years later, The National Union of Students, *Report of the Commission on Teaching in Higher Education* (1969) indicated a distinct preference for small-group teaching.[1] The report showed that, at the top of a list of functions, over 50% of student respondents agreed that the function of group teaching was "to encourage learning and to facilitate the exchange of ideas', as compared to the (lowest placed) 17% who agreed that it was "to train students to work independently" (ibid., Table XV). Abercrombie delves deeper into the

[1] I was involved with this commission, as both an undergraduate and postgraduate student at the University of Surrey. The Students' Union set up an Education Committee, of which I was a member, to provide feedback on discussion papers sent by the NUS to each university. This resulted in a comprehensive report which was presented both to the NUS and the University Senate. This resulted in the establishment of a University Education Committee, with me as a student member. Some innovative ideas were implemented by many departments as a result of this committee, and one outcome was the foundation of the Institute for Educational Technology headed by Prof. Lewis Elton. This pioneered many applications of technology in aiding learning (and provided the initial stimulus for the work I have done in this area over the past 30 years) and has since evolved into the Department of Educational Studies.

implications of these, and other, reports in *Aims and Techniques of Group Teaching,* (SRHE, 1970).

On the other hand, in the United States, a different motivation for investigating new pedagogies arose. According to Brufee (1992, p24):

> "For American college teachers, the roots of collaborative learning lie neither in radical politics nor in research. They lie in the nearly desperate response of harried colleges during the early 1970's to a pressing educational need. A decade ago, faculty and administrators in institutions throughout the country became aware that, increasingly, students entering college had difficulty doing as well in academic studies as their native ability suggested they should be able to do. Of course, some of these students were poorly prepared academically. Many more of them, however, had on paper excellent secondary preparation. The common denominator among both the poorly prepared and the seemingly well prepared was that, for cultural reasons we may not yet fully understand, all these students seemed to have difficulty adapting to the traditional or "normal" conventions of the college classroom."

Symptomatic of the difficulties these students had adapting to college life and work was that many refused help when it was offered. The help offered was mostly tutoring and counselling programmes staffed by graduate students and other professionals. These failed because undergraduates refused to use them. Solutions to this problem included mandated programmes that forced students to accept help they evidently did not want through to sink-or-swim programmes that assumed that students who needed help didn't belong in college if they didn't seek it.

Some college faculty members argued that students were refusing help because the kind of help provided seemed merely an extension of the work, the expectations, and above all the social structure of traditional classroom learning. The social organisation of learning was fashionable in the late 1960s, and the writing at that time, about changes in primary and secondary education, seemed to suggest that it was traditional classroom learning that possibly left these students unprepared in the first place (See Brufee, ibid., p24). They needed help that was not an extension of but an alternative to traditional classroom teaching. Some colleges tried peer tutoring, where teachers could reach students by organising them to teach each other.

Peer tutoring was just one way of doing that. Collectively, peer tutoring and similar modes such as peer criticism and classroom group work were classified as collaborative learning, as defined by the British researchers led by Abercrombie. In practice, the term meant a form of indirect teaching in which the teacher sets the problem and organises students to work it out collaboratively. The term encompassed a range of methodologies, for example, students learn to describe the organisational structure of a peer's paper, paraphrase it, and comment both on what seems well done and what the author might do to improve the work. The teacher then evaluates both the essay and the critical response. In another type of collaborative learning students in small groups work toward a consensus in response to a task set by the teacher.

Whereas as the work of Brufee, and even Abercrombie, uses small group methods, it does not usually involve a teacher being present. The students work everything out themselves with little guidance as they go along. Cooperative learning, on the other hand, involves not only interaction within the group, but also within a more formal learning environment, usually with the teacher being present. This has led to something of a split in the ranks of the small group interactive learning proponents.

According to Mills and Cottell (1998, 6)

> "Bruffee (1995), sees cooperative learning, because it was developed at the pre-collegiate level, as a more "repressive" form of pedagogy with teacher-developed goals and assessments, constant supervision, and the discouragement of dissent. Collaborative learning, he feels, is more adult-centred because it assumes student responsibility for governance and evaluation and encourages disagreement. Bruffee's position fails to recognise the major concerns of virtually all faculty committed to group work: time and content coverage. In an ideal learning environment, students would be free to explore topics as a "shared conversation," reach their own conclusions, and clarify, and sometimes resolve, any academic or interpersonal disagreements".

Unfortunately, the typical classroom is still bounded by the traditional constraints of the timetable and the pressure of working within disciplines especially at the tertiary level. The curriculum also has to introduce students to important concepts and core knowledge. Furthermore, "in classrooms filled with diverse learners at all levels of academic preparation and social enculturation, there are compelling reasons why faculty and students should deliberately create an environment where learning can be both efficient and effective" (ibid., p6). Advocates of pure collaborative learning also neglect to consider that in practice other aspects must be taken into account. These include instructional activity; the instructor's role; the students' roles; the introduction of group dynamics and group formation; rules for instruction; and assessment/evaluation. Faculty may also vary their approaches within an activity.

In practice, most teachers using small group interactive teaching use a mixture of both approaches. For example "during a peer-editing session, the students' roles within deliberately teacher-formed teams might be carefully and fully designated by the instructor (a cooperative approach) who then leaves the room (a collaborative approach)", (ibid. p7)

Most faculty find that students, even adults, welcome the structure provided by a cooperative approach. In fact, most find that the structured nature of cooperative learning results in both efficiency and accountability in the classroom. According to Mills and Cottell (ibid. p7), "Cooper (1990) regards the key to successful cooperative learning as "Structure! Structure! Structure!" (p.1). The end goal should be a smoothly operating classroom, but not one that runs with clockwork-like precision".

The argument that cooperative learning only applies to school-based classes - as much of the research in the last decades has been conducted at these levels - understates its benefits, according to Natasi and Clements (1991); they seem to be universal: "Cognitive-academic and social-emotional benefits have been reported for students from early elementary through college level, from diverse ethnic and cultural backgrounds, and having a wide range of ability levels. Furthermore, cooperative learning has been used effectively across a wide range of content areas, including mathematics, reading, language arts, social studies, and science" (p. 111)

Integrated studio teaching, the pedagogy described and evaluated in this thesis, is a perfect example of cooperative learning at tertiary education level.

1.3 Piaget

It is probably true to say that the ideas formulated by Piaget in the first half of the 20th century have had a most profound impact on current educational concepts. Virtually all students of education in the past 50 years have had to study his work, and have come to know, if not understand, his four major concepts. Most educational reforms over this period of time have also paid lip-service to his ideas. However, it is only over the past twenty years or so that Piagetian concepts have moved from the schoolroom into college and universities.

This is especially true of his concept of formal operations. Piaget studied early adolescents. At this age, many can deal with hypothetical situations and their thought processes are not tied down exclusively to what is immediate and real. According to Beard (1969), "At the beginning of adolescence social life enters a new phase of increasing collaboration which involves exchange of view-points and discussion of their merits before joint control of the group is possible". (p97)

As Beard continues, "This obviously has the effect of leading children to a greater mutual understanding and gives them the habit of constantly placing themselves at points of view which they did not previously hold. Consequently, they progress to making use of assumptions". Beard then goes on to pose the question "Could this development of formal operations occur without co-operation and discussion? Evidently Piaget believes that it would not".

Although college and university students are generally in their late teens or early twenties, even at university level the quality of students' thinking in their own subjects may still only partly attain the level of formal operations, despite Piaget's finding that thinking at this level is normally more fully achieved at sixteen years.[2] According to Beard (1969);

> "Observations and experiments by Abercrombie (1960), with first-year university students in London showed that although they were well-grounded in the facts of biology, physics and chemistry they were often unable to use their information to solve slightly unfamiliar problems or to defend a view in argument, and they tended to observe what the textbook said should be there rather than what was actually on a slide or X-ray" (p117).

Piaget (1926) held that "social-arbitrary knowledge – language, values, rules, morality, and symbol systems (such as reading and maths) – can be learned only in interactions with others" (Slavin, 1996, p29). According to Slavin, "many Piagetians .... have called for an increased use of cooperative activities in schools. They argue that interaction among students on learning tasks

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[2] There is some evidence to show that this does in fact occur, with reference to more fully achieved, at 16 and older. For example, Shayer and Adey (1981).

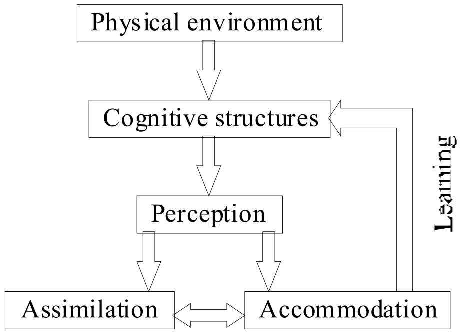

Figure 1.1 Diagramatical representation of the Piaget's theory of equilibration (from Hergenhahn and Olson, 1993, p 280)

will lead in itself to improved student achievement. Students will learn from one another because in their discussions of the content, cognitive conflicts will arise, inadequate reasoning will be exposed, and higher-quality understandings will emerge" (ibid., p29).

Piaget introduced the concepts of assimilation and accommodation, two functional invariants that occur at all levels of intellectual development. Assimilation refers to a kind of matching between the cognitive structures and the environment. As the cognitive structure changes it becomes possible for the child to assimilate different aspects of the physical environment. Accommodation, on the other hand, is the process by which the cognitive structure is modified. According to Hergenhahn and Olson (1993, p279), "It should be clear, however, that early experiences tend to involve more accommodation than later experiences because more and more of what is experienced will correspond to existing cognitive structures, making substantial accommodation less necessary as the individual matures".

Piaget assumed that all organisms have an innate tendency to create a harmonious relationship between themselves and their environment. He defined the concept of equilibration as the continuous drive toward equilibrium or balance. The dual mechanisms of assimilation and accommodation, along with the driving force of equilibrium, provide for slow but steady intellectual growth. Hergenhan and Olson (ibid., p280) construct a diagram, Fig. 1.1, to explain the interaction between these mechanisms. This bears a close relationship to the concepts behind the integrated teaching studio.

Many researchers following Piaget believe that, in many ways, learners construct their own knowledge. If one accepts this, then Meyers, (1986, p. 13) for example, finds that Piaget's concept of mental structures is particularly helpful in thinking about education. Piaget maintains that "children do not receive knowledge passively but rather discover and construct knowledge through activities. As children interact with their psychological and physical environments, they begin to form ...... structures of thought. These structures help to organise the child's experience and direct future interactions" (Piaget, 1976, p. 119)

Meyers and Jones (1993, p 20), commenting about Piaget's concepts in their book, *Promoting active learning : strategies for the college classroom*, state that while "we are not committed to the specific forms of intellectual development Piaget defined, we do agree with him about a basic principle of education: students, no matter what their age, need opportunities to engage in activities – with teachers, fellow students, and materials – that help them create their own mental structures and test them, thus making better sense of the world around them".

In this regard, they identify four key elements associated with active learning that are used to create new mental structures: talking and listening, reading, writing, and reflecting. These elements involve cognitive activities that allow students to clarify, question, consolidate, and appropriate new knowledge. "Each teaching strategy discussed (in this book) incorporates one or more of the key elements, or activities, as building blocks for constructing new knowledge. Nevertheless, we would be the first to admit that nothing is gained by simply having students talk, listen, write, read, or reflect-unless those activities are well structured and guided by teachers. There are sound pedagogical reasons for adopting active-learning strategies, and we are more likely to encourage students in those activities if we better understand how they work and how we can use them effectively" (ibid., p21).

In many ways, it can be seen that the work of Piaget is central to any discussion of small group interactive learning. Coupled with developments of his work in the use of computing as an interactive learning tool, as developed by Papert, for example, Piaget's concepts form one of the theoretical basis of integrated studio teaching.

1.4 Papert

Seymour Papert was an American mathematician who spent the early sixties at Piaget's Centre for Genetic Epistemology. He then went to MIT, where he was one of the founders of the Artificial Intelligence Laboratory. In 1980 he published the seminal book "*Mindstorms; children, computers and powerful ideas*" (Papert, 1980). In this book he details the development of the LOGO computer language as well as the concepts of turtles, dynaturtles and microworlds. Papert's work became the basis for much of the following two decades' development of educational computing. This was based upon two premises. First, that it is possible to design computers so that learning to communicate with them can be a natural process, and that children can learn to use computers in a masterful way, and secondly, learning to communicate with a computer may change the way other learning takes place. In this book, Papert also propounded a computer on the desk of every child. His book "sent shockwaves throughout the education and psychological communities, both of which accused him of pushing an educational pill that would induce psychosis in our children" (Schwartz, 1999).

He also took the cultural interpretations of Piaget, where learning amongst urban children in Europe or the USA and those in African tribal cultures are considered to be different, although both valid, and changed them to look at the difference between pre-computer cultures (whether urban Western or African tribal) and the "computer cultures" that may (and have) develop over

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[3.] In 1984 I set up a company in UK to design and manufacture educational robots. The first model we designed was a LOGO turtle based upon Papert's ideas. Over 200 of these were sold worldwide. The company developed many extensions and sub-routines based around the LOGO language, in consultation with teachers using LOGO in their classroom, which enabled students to enhance many of Papert's original ideas. Many discussions were held over a number of years with Papert himself, as well as with my fellow members of the British LOGO Users' Group, which has evolved into the EuroLOGO series of meetings and conferences. Papert's ideas were also instrumental in me setting up a programme for teachers as part of a community access computer project at the then Polytechnic of North London. This led to the publication of the journal "Educational Computing", which I edited for a number of years.

the decades following publication in 1980. As *Mindstorms* was published before the world wide web was invented, many of Papert's observations have proved prescient especially in the area of person-to-person communications.

The LOGO environment, "instead of the computer programming the child, the relationship is reversed: the child, even at pre-school ages, is in control: the child programs the computer" (ibid., p 19). The turtle is a computer-controlled cybernetic animal existing in the "cognitive minicultures of the LOGO environment". It serves no purpose other than to be good to program and good to think with. Some turtles exist solely on the computer screen; others have a physical manifestation that can move about the floor or desk, and may have a pen and lights or sound [3]. The idea of programming is introduced by the metaphor of teaching the turtle a new word. Very powerful learning takes place. Children working within a LOGO environment are "learning a language for talking about shapes and fluxes of shapes, about velocities and rates of change, about processes and procedures" (ibid., p 13).

What Papert, and those who applied his ideas, developed was a completely new way of using the computer in the classroom, one that eventually found its way into the integrated teaching studio. As they discovered, "the computer is not a culture unto itself but it can serve to advance very different cultural and philosophical outlooks. ….Of course, the turtle can help in the teaching of traditional curriculum, but I have thought of it as a vehicle for Piagetian learning, which to me is learning without curriculum" (Papert, 1980, p31).

In relating this to his experience with Piaget, Papert goes on to say:

> "There are those who think about creating a "Piagetian curriculum" or "Piagetian teaching methods". But to my mind these phrases and the activities they represent are contradictions in terms. I see Piaget as the theorist of learning without curriculum and the theorist of the kind of learning that happens without deliberate teaching. To turn him into the theorist of a new curriculum is to stand him on his head.
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> But "teaching without curriculum" does not mean spontaneous free-form classrooms or simply :leaving the child alone". It means supporting children as they build their own intellectual structures with materials drawn from the surrounding culture. In this model, educational intervention means changing the culture, planting new constructive elements in it, and eliminating noxious ones. This is a more ambitious undertaking than introducing a curriculum change, but one which is feasible under conditions now emerging" (ibid., p32)

Papert goes on to enunciate three concepts of what he calls "approbriable mathematics". (Although his work was primarily concerned with learning mathematics, it applies to many other subjects, especially science and engineering, two disciplines traditionally with a mathematical basis). First there is the principle of continuity; the mathematics must be continuous with well-established personal knowledge from which it can inherit a sense of warmth and value as well as "cognitive" competence. Secondly, is the power principle; it must empower the learner to perform personally meaningful projects that could not be done without it. Finally, there is the principle of cultural resonance; the topic must make sense in terms of a larger social context. Although these three principles were originally applied to turtle geometry within a LOGO environment they equally apply to all learning which is computer-based.

Another concept which Papert introduced related to Bruner's influential classification of way of knowing (Bruner, 1966a, 1966b). In this classification some knowledge is represented as action, some as image, and only the third category as symbols. According to Papert "Bruner has asserted that "words and diagrams" are "impotent" to represent certain kinds of knowledge which are only representable as action. …My perspective is more flexible because it rejects the idea of the dichotomy (between) verbalisable and nonverbalisable. No knowledge is entirely reducible to words, and no knowledge is entirely ineffable" (Papert, 1980, p96) [4].

In developing an integration between computers and Piagetian concepts of learning, Papert essentially developed a new paradigm of learning, one which became more and more influential as the computer became more ubiquitous in classrooms, educational institutions and homes. As he says "Out of the crucible of computational concepts and metaphors, of predicted widespread computer power and of actual experiments with children, the idea of Piagetian learning has emerged as an important organising principle. Translated into practical terms this idea sets a research agenda concerned with creating conditions for children to explore "naturally" domains of knowledge that have previously required didactic teaching; that is, arranging for the children to be in contact with the "material" – physical or abstract – they can use Piagetian learning" (ibid., p187).

Unfortunately, although Papert suggests that this type of discourse is welcome in schools of education and in science departments, "funding agencies as well as universities do not offer a place for any research too deeply involved with the ideas of science for it to fall under the heading of education, and too deeply engaged in an educational perspective for it to fall under the heading of science. It seems to be nobody's business to think in a fundamental way about science in relation to the way people think and learn it"(ibid., p 188)[5].

To summarise Papert's thinking; he saw the popular idea (at the time) of designing a "Piagetian curriculum" as "standing Piaget on his head. Piaget is par excellence the theorist of learning without a curriculum" (ibid., p 216). As a consequence he formulated two ideas; a) significant change in patterns of intellectual development will come about through cultural change, and b) the most likely bearer of potentially relevant cultural change in the near future is the increasingly pervasive computer presence" (ibid., p 216).

In the twenty years or so that *Mindstorms* was published Papert, and his colleagues, have continued to work on the development of LOGO. However, his original ideas have inspired a whole range of projects which do not in themselves involve simply writing LOGO programs to produce geometric

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[4] It is interesting to note that much engineering education is based on this dichotomy, which Papert's work tries to undermine!

[5] Many of us involved in science and engineering education would not necessarily agree with this point of view. But then Papert always aims to be nothing if not controversial in these type of statements!

figures. One of these was the development of a new use of programming by interfacing LEGO constructs to the computer. (Resnick et al, 1988). LEGO constructs are interactive, physical objects built with LEGO plastic blocks, gears, pulleys, etc., which are then controlled by a LOGO program on the computer.

> "Giving children the opportunity to program behaviours into vehicles, robots, dinosaurs and other constructs of their own design opened a new horizon onto the possibility of engagement: many children who were mildly interested in the graphics programming showed high degrees of enthusiasm in this new sphere. At the same time many kinds of program structure that were not spontaneously picked up in the old context now seemed obvious to the children. The conclusion to be drawn was not that LEGO constructs were better objects for programming than graphics. But that variety offered more chances for more children to relate to more concepts" (Papert, 1997).

Harel (1991) and Kafai (1995) developed the concept of developing real products with LOGO, with children working for an hour a day over most of the school year instead of for a few hours at a time on isolated projects. The first round had students producing a piece of educational software, the second a complete video game with all the supporting materials. In the past twenty years the LOGO environment has become an important, but not determining, part of computer learning culture. The LOGO environment was one of the first stages of a continuing evolution.

In 1996 Papert published *The Connected Family* (Papert, 1996) where he developed the idea that the computers that will be the pivotal force for change will be those outside the control of schools and outside schools' tendency to force new ideas into old ways. One of the basic assumptions behind integrated studio teaching, for example, is that students are computer and internet aware and competent. Whether this assumption is correct will be considered in later chapters of this thesis.

Finally, Papert writes:

> "It is 100 years since John Dewey began arguing for the kind of change that would move schools away from authoritarian classrooms with abstract notions to environments in which learning is achieved through experimentation, practice and exposure to the real world. I, for one, believe the computer makes Dewey's vision far more accessible epistemologically. It also makes it politically more likely to happen, for where Dewey had nothing but philosophical arguments, the present day movement for change has an army of agents. The ultimate pressure for the change will be child power" (Papert, 1996).

<u>1.5 Small group interactive learning</u>

Although most of Papert and Piaget's writings are concerned with school-based children, many of their ideas have application to adults, and especially those in the early years of tertiary education. As cited above, Abercrombie recognised in the 1960s that many young adults are still at the stage of formal operations, at least in some areas of their learning process. Abercrombie also recognised that the group system of teaching focuses attention on the interaction between all participants, students and teachers, not on the polarised interaction of a student with a teacher.

Since the early 1960s many researchers have followed in Abercrombie's footsteps, and there is a burgeoning literature on the subject. As Abercrombie noted, "man is essentially a social animal and that he has to undergo an exceptionally long period of development" (1970, p6). Slavin (1996) notes that, based on Piaget's theory of *conservation,* i.e. the ability to recognise that certain characteristics of objects remain the same when others change, there is a great deal of support for the idea that peer interaction can help nonconservers become conservers. Although this was directed at children aged between the ages of five and seven the principal can be extended to older students.

As Mills and Cottell (1998, p170) point out, the power of groups is well documented, but groups "functioning well only under structured conditions where there is a clear, compelling task and where...... the team performance requires both individual accountability and mutual accountability". In this scenario "the members hold themselves accountable for their individual contributions to the team, their collective contributions to the team, and the team's overall result" (Katzenbach and Smith, 1993, p277). Within a computerised environment, the challenge, as Salomon (1995) points out, is to create electronically genuine interdependence:

> "For genuine collaboration to take place, you need genuine interdependence. In its absence, teams do not function the way they ought to, regardless of how wonderful the computer tools they are given to work with are. In other words, computers can support collaboration provided it entails interdependence, but the computer is not likely to produce this interdependence all on its own" (ibid., p3).

Meyers and Jones (1993, p 20) believe that, in many ways, learners construct their own knowledge. In this context, they find Piaget's concept of mental structures particularly helpful in their thinking about education (Piaget, 1976, p119). Here,

> "Piaget maintains that "children do not receive knowledge passively but rather discover and construct knowledge through activities. As children interact with their psychological and physical environments, they begin to form ...structures of thought. These structures help to organise the child's experience and direct future interactions"" (Meyers, 1986, p13).

Although Meyer and Jones (ibid.) are not committed to the specific forms of intellectual development Piaget defined, they do agree with him about a basic principle of education: students, no matter what their age, need opportunities to engage in activities – with teachers, fellow students, and materials – that help them create their own mental structures and test them, this making better sense of the world around them.

In this regard, they identify four key elements associated with active learning that we all use to create new mental structures: talking and listening, reading, writing, and reflecting. These elements involve cognitive activities that allow students to clarify, question, consolidate, and appropriate new knowledge.

The concept of 'structured and guided cooperative learning' is fundamental to the understanding of studio teaching, along with the use of some sort of 'incentive', usually based upon group assessment rewards for innovative work. Slavin has attempted to define effective instruction in a more general context, based on the work of John Carroll (1963, 1989), which focuses on the alterable elements of Carroll's model, those which teachers and schools can directly change (see Slavin 1984; 1987; 1994). The components of this model are as follows:

> "1. Quality of Instruction. The degree to which information or skills are presented so that students can easily learn them. Quality of instruction is largely a product of the quality of the curriculum and of the lesson presentation itself.
>
> 2. Appropriate Levels of Instruction: The degree to which the teacher makes sure that students are ready to learn a new lesson (that is, they have the necessary skills and knowledge to learn it) but have not already learned the lesson. In other words, the level of instruction is appropriate when a lesson is nether too difficult nor too easy for students.
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> 3. Incentive: The degree to which the teacher makes sure that students are motivated to work on instructional tasks and to learn the material being presented.
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> 4. Time: The degree to which students are given enough time to learn the material being taught". (Slavin, 1996, p5)

Slavin (ibid., p9) also shows that forms of cooperative learning that have consistently increased student achievement have provided rewards to heterogeneous groups based on the learning of their members (Slavin, 1995). "This incentive system motivates students to encourage and help one another to achieve. Rewarding students based on improvement over their own past performance has also been found to be an effective incentive system (Natriello, 1987; Slavin, 1980)".

Again, according to Slavin (1996, p9), in addition to being a product of specific strategies designed to increase student motivation, incentive is also influenced by quality of instruction and appropriate levels of instruction.

> "Students will be more motivated to learn about a topic that is presented in an interesting way, that makes sense to them, that they feel capable of learning. Further, a student's motivation to exert maximum effort will be influenced by their perception of the difference between their probability of success if they do exert themselves and their probability of success if they do not (Atkinson and Birch, 1978; Slavin, 1977; 1994). That is, if a student feels sure of success or, alternatively, of failure, regardless of his or her efforts, then incentive will be very low. This is likely to be the case if a lesson is presented at a level much too easy or too difficult for the student. Incentive is high when the level of instruction is appropriate for a student, so that the student perceives that with effort the material can be mastered, so that the payoff for effort is perceived to be great".

Research on cooperative learning methods has indicated that team rewards and individual accountability are essential for basic skills achievement (Slavin, 1983a, b, 1989). It is not enough to simply tell students to work together; they must have a reason to take one another's achievement seriously.

Further, research indicates that if students are rewarded for doing better than they have in the past, they will be more motivated to achieve than if they are rewarded for doing better than others, because rewards for improvement make success neither too difficult nor too easy for students to achieve (Slavin, 1980).

1.6 The learning environment for small group teaching

Whilst developing the concepts of the studio teaching environment, a number of parallel initiatives were taking place in other teaching concepts. One, The Foundation Coalition, a programme sponsored by the National Science Foundation, (Foundation Coalition, 2001) developed and implemented an Active and Collaborative learning technique that prescribes the following five principles:

1. Positive Interdependence: Tasks are structured to encourage team members to rely on each other in order to accomplish team goals. Each team member should perceive that his/her individual success depends on the success as a team;

2. Individual Accountability: Tasks are structured to encourage team members to be held accountable for doing their share of the work, as well as mastering all material. Each team members should perceive that he or she must be able to demonstrate mastery of the material on an individual basis;

3. Group Processing: Encourages each team to reflect on its performance as a team. Teams should periodically reflect on what they do well as a team, what they could improve, and what they might need to do differently.

4. Interpersonal and Social Skills: Team members practice and receive instruction in leadership, decision-making, communication, and conflict management.

5. Face-to-Face Interaction: Structure team tasks so that members spend all or some of their time working together. Encourage physical arrangements so that team members can see each other as they are working. For example, with teams of four persons, encourage teams to arrange themselves so that they are all facing each other instead of sitting in a row.

Others, such as Kolb (1984) connect the concept to its intellectual roots, Dewey, Lewin and Piaget; and call attention to the important role that experience plays in the learning process, and use the term "experiential learning".

Kolb (ibid.) suggests that the most effective learning process requires the four different learning steps outlined in Lewin's experiential learning model, i.e. concrete experience, observations and reflections, formation of abstract concepts and generalisations, and, testing the implications of concepts in new situations.

Kolb explains this cycle as follows: The immediate concrete experience is the basis for observation and reflections. After that, the observations are assimilated into a theory from which new implications for actions can be deducted. These implications then serve as guides in acting to transform new experiences in knowledge in a learning spiral process. The sequence - experiencing, reflecting, generalising, and applying - is called the experiential learning cycle or Kolb's learning cycle. Experiencing involves sensory and emotional engagement in activity. Reflecting involves watching, listening, recording, discussing, and explaining the experience. Generalising involves integrating theories and concepts into the overall learning process. Applying involves engaging in a trial-and-error process in which the accumulation of sensory experience, reflection and conceptualisation is tested in a particular context (from Malave and Figuerdo, 2002).

Millis and Cottell (1998, p.172) discussing the literature on deep learning, state that

> "Woods (1994) recommends that instructors "create an environment that encourages and rewards, and allows sufficient time for "deep processing." Another way of viewing "deep processing" is: "Don't try to learn everything from the first activity. Build up your subject knowledge successively" (ibid., p7.)". This progression by "deep versatile" learners cannot occur, according to Entwistle (1981), when surface learning is encouraged by: (1) work overload; (2) stress; (3) examinations that emphasise memorisation and "regurgitation"; (4) an environment that rewards surface learning".

When addressing the role of technology in the learning environment, Millis and Cottell (ibid., p.172) say that using technology in ways that promote sequenced learning within groups can lead to more in-depth processing of course content and, hence, more retention of information, whether students are interacting within a classroom setting or interacting through out-of-class electronic networks.

Millis and Cottell (ibid., p. 179) also quote Alexander (1995, p6), who puts learning with the World Wide Web in the broader context of deep, not surface learning, citing work by Biggs and Telfer (1987) and Laurillard (1993). With this framework, she (Alexander) states:

> "The challenge for educational developers is to use this knowledge of learning, together with an understanding of the features of the WWW, to design learning experiences which promote a deep approach to learning so that 'what' students learn is a deep understanding of the subject content , the ability to analyse and synthesise data and information, and the development of creative thinking and good communication skills".

The connection between cooperative learning and technology is long-standing. Light and Mevarech (1992) point out that

> "Since the early 1980s there has been a growing interest in the potentialities of both cooperative learning and of computers as facilitators of student learning. In

> some respects, the claims made for each are rather similar. They are both based on theories in the area of social cognition and they both emphasize the role of student interactions in enhancing a wide range of school outcomes, including academic achievement, cognitive processes, metacognitive skills, motivation toward learning, self-esteem, and social development (p. 155)". (from Millis and Cottell, ibid., p171)

Millis and Cottell (ibid., p172) conclude that if technology is to be seen as a tool rather than as a driver or an "add-on," then it must simplify the learning process for students, not complicate it. Too often, early innovators worked out convoluted ways to incorporate technology into the classroom which built in resentment if students were required to use it or apathy if they considered it a complex option.

Unfortunately many applications of technology in the classroom have not made allowances for the incorporation of Piaget's insights about the need for reflection to be supported. As quoted in Meyers and Jones (1993), Piagetian scholars Lawson and Renner (1975) stress disequilibrium and equilibrium as important processes in forming new mental structures. So long as new knowledge fits into our present mental structures, we are pretty much in a state of equilibrium. But when experiences and new knowledge do not fit within these structures, we encounter disequilibrium - a challenging and sometimes painful situation. Then, through a process of integration and appropriation, we either incorporate the new knowledge in our existing mental structures or construct new ones, thus returning to equilibrium. In a sense .... the process of education is an ongoing dialectic between equilibrium and disequilibrium. For it to work, that dialectic must include some quiet time for reflection so that students can integrate and appropriate new knowledge. Successful application of technology must allow time for students to discuss and reflect, both inside and outside the formal class situation.

As Meyers and Jones (1993, p.29) continue:

> "If this Piagetian scenario is valid (and it makes sense to us), then we need to make room for reflection in our classes, especially following the presentation of new, challenging information that creates disequilibrium. By structuring opportunities for pondering and reflection, we can help students sort things out as they restructure old ways of thinking and move on to new understandings. In any significant learning experience, we cannot help profiting from time specifically set aside for reflection. At least that is what our personal experience as students and teachers suggests".[6]

<u>1.7 The studio teaching paradigm</u>

Although the practical implementation of studio teaching, that is, small group teaching based around a problem-based learning strategy, aided by technology, such as internet and World Wide

[6] For further discussion on this point, see the work of Shayer and Adey (1994), for example, in their CASE project (Cognitive Advancement in Science Education) where they deliberately induce cognitive conflict in the children starting secondary school and propose that this has an impact later on. Unfortunately, there is little room here to consider these ideas further.

Web access, with course materials therefore easily accessible, was originally implemented in an empirical manner, it is possible to summarise some of the ideas in the preceding section as follows (after Wilson and Mosher, 1994)

• Learning is a highly interactive process. Teacher and students become involved in a learning "conversation" in which both parties clarify messages, test for understandings and are both transformed by the experience (Pea, 1992).

• Teachers are not simply the delivery mechanisms of the content of a curriculum. Although good lecturers may be inspirational, the lecture is not efficient in stimulating student learning (Laws, 1991; Hestenes et al, 1992; Redish et al, 1992). The model used by a number of educators when working in collaborative learning situations is one where the teacher is a "coach" of their students' learning process (Pea, 1992; Laws, 1991)

• Education, especially for scientists and engineers, must not be too far removed from the context of its meaning. If learning is to be viewed as a process that has meaning beyond the classroom, the students must be able to reach beyond the classroom. Either practitioners from the field of study must be brought to the classroom – which is not always possible - or the students must be able to access this information in other ways, for example, via the World-Wide-Web.

• Learning can be enhanced by providing students with access to powerful computing tools that can allow them to interact with real data and solve open-ended problems. Learning-by-doing has been shown to be a successful pedagogical model to enable students to solve real-world problems. (Laws, 1991; Redish et al, 1992). This approach also has the advantage of supporting individual differences in learning styles. Students bring to the classroom a diversity of interests, levels of preparation, cultural backgrounds and learning styles.

• Cooperative learning is a highly structured, systematic instructional strategy in which students work in small groups toward a common goal. This strategy has been shown to promote active learning, positive student attitudes towards learning, and increase student interdependence. Increased interdependence is a positive goal for students because of its effects on students interpersonal skills, teamwork capability, and self esteem. While working in teams on a project, it is difficult for students to be passive onlookers; the contribution of each team member is important (Millis, 1991). Teamwork is also becoming a widely implemented organisational strategy in many work settings, including manufacturing, services and government. Instructional practices should prepare students for working in this type of environment.

Drawing on some of these ideas, starting in the early 90s, a number of educators started rethinking the whole process of teaching and learning with respect to science and engineering education, especially at university level. There was clearly a need for new teaching materials and methodology that encouraged different modes of learning. Also, as networking, multimedia, mobile technology, and better software converged, educational institutions tried to discover new ways to improve learning, increase information access - and save money! Rubinstein (1994), in the introduction to a seminal edition of *Science* (Nov. 1994) on the subject, writes:

> "In small and large schools alike, individual teachers are developing innovative curricula – and novel pedagogical techniques as well – to address the problems created by disaffected (and fearfully unprepared) undergraduates". (p843)

At the same time, course feedback has shown that traditional courses were not preparing graduates for the 'real' world, especially in science and engineering:

> "Traditional courses, some will tell you, don't prepare (students) for the real world, and traditional teaching methods don't engage their interest. The world has changed, many say, and their universities haven't" (Rubinstein 1994, p843).

This sense of seeming irrelevancy of traditionally taught courses to a graduate's eventual employment needs affects all aspects of the learning process. Jack Wilson, one of the pioneers of this new paradigm, and who implemented the studio teaching approach at Rensselaer Polytechnic Institute (RPI), is quoted as saying, "We pretended to teach them, and they pretended to learn" (Culotta, 1994, p875).

Massy and Zemsky (1995) tried to summarise many of the arguments for the introduction of these new techniques based on information technology, especially its impact on productivity, as follows:

> "Economists define productivity as the ratio of outputs to inputs, or more generally as the ratio of benefits to costs. Productivity can be improved by:
>
> 1. Producing significantly greater benefits, encompassing quality and well as quantity, at modestly greater unit cost ("doing more with more")
>
> 2. Spending significantly less money while limiting benefits reductions to modest levels ("doing less with less")
>
> 3. Producing greater benefits while spending less money ("doing more with less")"

Productivity also can be increased by improving quality at the same unit cost - a result we consider a limiting case of "doing more with less." (ibid., p5)

However they then try to relate these general criteria to academia, mostly without considering the history of using technology to aid teaching and learning.

So far, most IT-based academic productivity improvements have involved doing more with more. With labour - especially faculty labour - considered to be fixed, IT becomes a quality-enhancing add-on. This fits the faculty culture but suffers from at least two serious deficiencies.

> "First, scarcity of add-on funding limits IT's rate of adoption. While colleges and universities might like to pour money into more-with-more productivity

enhancement, most are not in a position to do so. Funding scarcity constrains the courseware market, thus inhibiting would-be developers from making the large front-end investments needed to exploit fully IT's potential advantages.

Second, and more fundamentally, the more-with-more approach does not address the institution's need for cost containment. One can imagine a scenario where widespread IT add-ons produce a situation like that found in medicine, where technological breakthroughs produce a spending race that eventually threatens the system's affordability. Tight financial circumstances currently inhibit such scenarios, but even if today's constraints could be relaxed, more-with-more productivity growth would eventually encounter new financial limits." (Massy and Zemsky, 1995, p6)

1.8 Studio teaching in practice

Studio teaching was initially implemented by scientists and engineers as a pragmatic and practical answer to questions raised concerning undergraduate teaching of scientists and engineers. Those conceiving the idea did so from many years of experience in teaching, and not from any pre-defined educational theories. For the purposes of this study, studio teaching is defined as that teaching methodology that combines the traditional, and usually disconnected, elements of engineering education into an integrated whole. In other words, lectures, tutorials and laboratory work, are not differentiated, or allocated different time slots or different physical space in the time table. As mentioned above, a studio class, usually lasting two hours, may contain elements of lecture, laboratory and tutorial, but they are presented holistically. This is designed to reinforce learning in the students, hopefully to enable a deeper form of learning to occur. As assessment is also continuous, with emphasis on project-based, interactive, small group learning, there is less opportunity for strategic learning, aimed at 'playing the system' to take place. However, there has to be a commitment from both the institution and the staff members concerned to make it all happen!

Studio teaching was first introduced at Rensselaer Polytechnic Institute (RPI), in the USA, in the early 90s. RPI is a research-oriented university with a strong reputation for quality undergraduate education and innovative teaching. Most of RPI's first year courses have now been converted to studio teaching format, not only in science and engineering, but also across the whole university curriculum (Wilson and Jennings, 2000). The changeover started initially in the Physics Department as described by Wilson (1994), and then in other science and engineering disciplines as detailed by Iannozzi et al (1997), Maby et al (1997), Jennings (1998) and Carlson and Makedon (1996). Other universities quickly picked up on the approach and introduced studio teaching into the curriculum, City University of Hong Kong (CityU) being especially vigorous in its adoption, where it was labelled ITS - Integrated Teaching Studio.

The reasons and methodology behind CityU's decision to take this approach, and its subsequent implementation, are given by Yu and Stokes (1998a), Leung et al (1996) and Bradbeer (1998).

One of the main changes in tertiary education in Hong Kong in the 1990s, as earlier in most of the western world, was the rapid growth in the number of students undergoing university education. Inevitably this has resulted in a more diverse and larger student intake, and the traditionally accepted entrance skills base changes. For engineering and science this poses major problems. At the same time language skills, especially where a subject is taught in a language other than mother-tongue, as in Hong Kong, have been shown by Flowerdew and Miller (1995) to be generally low by world standards.

> "To gain entrance into the university (CityU), they must have at least a grade E in their Use of English paper. The students' entry levels ranged from E to C. An E correlates to around 450 on the TOEFL test, whereas a C correlates to around 530 (Hogan & Chan, 1993). As a point of comparison, most US universities have an entry level of about 550." (p349)

Pennington et al (1992) already noted that in 1992 CityU students' language abilities were restricted.

> "... the present research with City Polytechnic students uncovered ... the occurrence of English was found to he highly restricted, used primarily with Westerns and with Chinese in the academic context. A mixture of Cantonese with English lexis was found to be relatively common at City Polytechnic, used both with other students and with Cantonese-speaking teachers. With both of these groups, (pure) Cantonese was also used, particularly when speaking about non-academic topics." (p69)

Studio teaching has been welcomed by many faculty as one answer to these problems. The philosophy behind the studio teaching format and its ingredients may be summarised as follows. Learning is more effective (a) by doing (mini-labs, exercises), (b) by interactive and cooperative techniques (discussion and group activities), (c) if more of the senses are engaged (interactive multimedia courseware), and (d) by immediate application and follow-up (in-class assignments).

Essentially the methodology replaces the traditional large-group lecture, small-group tutorial and separate laboratory format with an integrated studio approach, that is claimed to be both economically competitive and educationally superior. The focus is on student problem-solving rather than presentation of materials.

A typical ITS session would be two hours long and consist of up to 30 minutes of presentation, possibly a short mini-lecture or interactive demonstration, followed by a question and answer session. Again, this may be either pencil-and-paper type or interactive using the workstation available to each individual or pair of students. This may also develop into a small-group discussion, especially when workstations are grouped around each other, as at CityU in Hong Kong.

Yu and Stokes (1998b) describe the situation where this small group interaction leads students to teach students, drawing on the work of Mazur, at Harvard University (Mazur, 1996, p13). The "students teaching students" approach, was proposed by Mazur and modified and adopted for the Multimedia Integrated Teaching Studio (Yu and Stokes 1999b, p282). Under this approach, students are expected to learn through discussions within a group of students. This is different from the "teacher teaching students" approach in traditional classes, in which students are expected to learn through listening to the teacher. “Problem-based learning” and “interactive learning” are also incorporated in the studio teaching classes.

Many studio sessions allow the students to work with some physical equipment or parts and this will allow them to carry out short experiments that are based on the previously presented material. At CityU, the introductory electronics and physics classes are able to carry out experiments where the instrumentation is represented on the workstation screen, although real parts and components are used on the bench as noted by Bradbeer (1999a) and Bradbeer (1999b). At RPI most of the studios have fixed bays of standard laboratory equipment that can be accessed by the students by turning their chairs through 180^{o} as described by Millard et al (1997).

Owing to the flexibility inherent in the studio environment it is possible for the teacher to modify the structure of the session to take into account feedback from the students. For example, they may request more time for discussion or investigation of one particular aspect of the material being presented. This, of course, means that those teachers more accustomed to a more structured approach may have problems, and this will be addressed below.

Most ITSs have projection screens that can show presentation graphics, animations and web pages, as the instructors’ desk, as well as all the student workstations, are not only connected to a local area network (LAN) but also the Internet. There will also be a visualiser that can be projected onto the large screen(s). This inherent interactiveness, associated with access to the Web, and even video on demand (VOD), allows the ITS to be very flexible. At CityU, for example, a management or biology class may follow an electronics class.

Of course, normal lecture material, especially that based on overhead projector slides and/or ‘chalk and talk’, does not fit into an ITS environment. Consequently much thought, effort and money must be put into the preparation of material. Owing to the ubiquitous nature of multimedia there is much material available commercially that can be easily modified for ITS use, although some investment will still be necessary. At CityU a special authoring unit was established to aid preparation of such courseware - Klassen and Morton (1999).

There is also an initial investment in constructing the studio itself. Many universities have either private or public funds available for improving their teaching infrastructure and these have usually been used. However, some studies, especially those by Massy and Zemsky (1995), Wilson (1994) and Ianozzi (1997) have shown that the efficiencies in staff use and student performance more than compensate for this initial financial investment.

The studio teaching paradigm has shown itself to be robust. It is now ten years since the methodology was first introduced, and not only is it established in those institutions where it was initially introduced, but is gradually “working its way through the system”. A number of examples from these other institutions now using studio teaching will be referred to in later chapters.

However, a number of problems have been identified; many teaching staff do not like to take studio classes and a small minority of students do not like working in a studio environment. Others have criticised the reliance on technology as detracting from the teaching and learning process.

1.9 A cautionary tale

However, a potential problem associates with studio teaching is the possibility that the technology may 'hijack' the whole idea. At this point it may be instructive to look at the example of the introduction of some of Papert's ideas as put into practice in British primary and secondary schools., and the way that the learning pedagogy was eventually lost in the obsession with the technology used. Noss and Hoyles (1996) have written an insightful account of this, especially as it comes from two educationalists who have been involved with assessing the impact of Papert's ideas, especially the use of LOGO and turtles, for over 20 years[7].

They introduce the subject by looking at one of the first attempts at computer-assisted teaching, PLATO. As they note:

> ".....a few decades ago, it was generally accepted that a combination of good ideas, money and energy from external agencies could quickly and easily transform schools and curriculum. One example was the introduction of the computer-assisted teaching system, PLATO, into some community colleges in the U.S.A.[8] In a fascinating case study, House (1974) traces the gradual disintegration of this innovation under the combined influences of a multitude of factors: lack of clarity of the change process, naivety in thinking about the translation of objectives into practice, internal politics and conflict between groups, technical problems, lack of resources and limited teacher preparation. This was one of many spectacular failures at that time - all well-resourced and arising from sound educational ideas. (p 156)

They go on to say that "conventional wisdom asserts that the computer has not achieved the radical effects that its proponents believed it would some ten or twenty years ago". As Becker (1982) has put it:

> There were 'dreams' about computer using students. ..dreams of voice-communicating, intelligent human tutors, dreams of realistic scientific simulations, dreams of young adolescent problem solvers adept at general-purpose programming languages - but alongside these dreams was the truth that computers played a mini-

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[7] Celia Hoyles and I worked at Polytechnic of North London in the late 70s before she moved to the Institute of Education, London. We were both active in the British Logo Society at that time, and she continues to be so, as well as EuroLOGO.

This section, focusing on the experience of introducing LOGO into British schools is given as an extended case study into how an enabling technology - ubiquitous low cost computing - was considered an educational objective in its own right, and the software that actually had the potential to give rise to a new teaching paradigm - LOGO - was basically ignored, then distributed widely in schools in a form that meant that change was not necessary. Unfortunately, that attitude is still current today, where the introduction of an enabling technology, such as Blackboard, is seen to be a useful tool for administering the tasks of teaching, but is generally ignored when it comes to implementing changes in teaching methodology. The studio teaching concept basically takes the enabling technology of ubiquitous web access, and does attempt to change the teaching methodology - hence the cautionary tale expanded on here.

[8] I had a chance to look at PLATO in action on a visit to Control Data Corps. HQ in Minneapolis in 1982. It seemed a dinosaur of a system even then!

mal role in real schools. ..” (ibid. p159)

Noss and Hoyles (ibid.) note that in the late seventies, the programming language BASIC was popular .

> “There were claims for the importance for learning mathematics through writing algorithms to make procedures and structures clear and explicit. By the mid-eighties, the rhetoric had changed with the introduction of the notion of ‘mathematical programming’ -a compromise formula to allow discussion of Logo, a new and apparently more radical alternative to BASIC, without actually having to name the language! Eventually Logo came into its own, quickly followed by spreadsheets, then databases. Now, in the nineties, dynamic geometry software and computer algebra systems are fashionable. Yet Logo survives in two forms: as an elementary drawing program in primary schools, and as a medium for mathematical exploration in some secondary schools.” (ibid., p161)

To understand how this has come about, they begin with a little history. When Logo arrived on the educational scene at the beginning of the nineteen-eighties, there was a surge of interest which, although more measured than that in the U.S.A., gave rise to substantial conferences organised to provide a forum for researchers and teachers to meet and discuss the implications of this new software for curriculum and policy. There was enthusiastic curriculum development together with a burgeoning of research projects.

> “Excitement spread throughout the community, although it must be said this was matched by cynicism and opposition from two sources; from those who still advocated BASIC, and those who wanted schools to remain immune from computer use altogether. Provision of computers in schools was entrusted to the Microelectronics Education Programme (MEP), a government agency; in common with many countries at the time, the U.K. government saw their role as equipping schools with machines first, and only, secondarily to aid in the process of deciding what to do with them. On the hardware front schools were exhorted to ‘buy British’ , and substantial subsidies were handed out to, in particular, the ‘BBC’ computer.[9] As a result, there was little incentive for the company who manufactured it to develop a viable Logo - after all, it had invested heavily in its own ‘improved’ variety of BASIC.” (ibid., p161)

As Noss and Hoyles continue:

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[9] I was a member of the committee established by the BBC and the Department of Industry to come up with the design specifications of the BBC computer. We had many discussions on the appropriate roles of both Logo and BASIC in the classroom. The Sinclair machine was rejected partly because it already had a very well established Logo package for the Spectrum. One reason given was that this would ‘confuse’ teachers! When I co-authored the book of the tv series, BASIC was the only language we could refer to, and Logo was not even mentioned!

> This mildly interesting accident of marketing and economics had some surprising outcomes. It created a serious gap between the sudden flash of interest in Logo's potential, and the ability of children in schools to actually use it. Into this gap stepped a number of 'turtle drivers': simple programs (usually written in BASIC) designed to draw graphics using a screen turtle: the most successful of these was DART. All of these programs allowed the child to drive a turtle using FORWARD and RIGHT, but none had recursion, list processing, proper control structures, arithmetic operations or serious screen editors. Yet some (not, thankfully, DART), happily packaged themselves with the title 'Logo'". (ibid., p162)

In one form or another, 'Logo' was rapidly taken up in the U.K. As early as 1984 the MEP commissioned a report on classroom experiences by an experienced primary specialist and computer 'non-expert' (Anderson, 1986). Anderson's report showed that 'programmable toys, such as Milton Bradley's 'Big Trak', were not distinguished from Logo-turtles; turtle graphics programs such as DART were not distinguished from Logo; and Logo itself was viewed as difficult, expensive, and (possibly) not necessary for doing 'Logo' (Doyle, 1993, p24).

> "It would be simplistic to argue that it was merely an accident of software availability that led to the Logo programming language being reduced to turtle graphics - with little emphasis on any aspect of mathematics or even geometry , let alone on programming as a means of mathematical expression. It is more a question of teasing out the factors by which an innovation like Logo changes so that it becomes deemed as acceptable to teachers and to the system. Which aspects take hold and which wither away?
>
> In this case two contradictory processes were at work. On the one hand, the child-centred approach which had come to characterise English primary schools resonated with cut down 'Logo': teachers, parents and head teachers could view 'Turtling' as happily fitting into the wide variety of 'child centred' activities which could be found in many primary classrooms. On the other hand, the very success of Logo's assimilation led to its being viewed as 'an activity' in its own right - not a way of expressing mathematical ideas, but a way of operationalising existing priorities by an 'added on' school topic rather than one integrated into the educational setting. (Noss and Hoyles, 1996, p162)

There is thus a possibility that studio teaching, as an implementation of interactive learning, may also fall into the same trap. However, the way that it has been implemented in practice, seems to point otherwise.

1.10 Does studio teaching really work?

The main thrust of this thesis is to determine whether studio teaching delivers what it promises to. Does it make the learning experience not only more enjoyable for the students, but also stimulates them to better achievements than traditional methodologies? What do students think of the studio based approach? Do they in fact learn more? Can they apply what they've learned to other courses that follow? What type of learning takes place? These, and other questions will be addressed in later chapters.

The first task, therefore, is to split a class of students into two groups, and then determine whether they are similar - in entrance qualifications, previous knowledge of the subject taught, and interest in the course. Next, can a set of instruments be devised to measure any differences between the groups at the end of a course, without prejudicing the assessment procedures set down by the university? Finally, what conclusions can be drawn from the results? And, once these conclusions have been drawn, what changes need to be made to the course so that it can be made more effective?

The next chapter addresses the splitting of the groups, and assesses whether they are similar. This is then followed by a chapter that looks at the assessments used in two, consecutive and related, courses. The first is analysed in great detail; the second only superficially. Then, a more qualitative approach is taken, where student responses are considered, both on the two courses under study at CityU, and also one at RPI. The results from the quantitative and qualitative analyses are then compared to results from other studies at other universities where studio based teaching has been introduced. A number of recent developments on learning styles and strategies are then considered to see if they may point to better course design, and if they give some insight into why studio teaching works. Finally, some conclusions are drawn.