Research and Development of Internet-Based Courseware in Higher Education

Submitted in fulfillment of the degree MSc (Computer Based Education and Multimedia).

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Project Duration

January 1998 - December 1999

Submitted
January 2000

Project URL

http://www.nu.ac.za/bioped/edutech

Preface

The following study was undertaken by Sarvalogan Naicker between February 1998 and December 1999 at the University of Natal, Durban, South Africa under the supervision of Professor Alan Amory. Results presented here reflect accurate and true observations as recorded by the authors.

Acknowledgements

The author would like place on record sincere thanks to his family, close friends and fellow colleagues:

Alan Amory (Carbohydrate Metabolism subject expert and Project Supervisor), Glen Campbell (Lipid Metabolism subject expert) , David Baxter, Joseph Osodo, Jacky Vincent, Jillian Adams (bioped research group), Cell Biology 2 Class (1999) and demonstrators, Robert Slotow, Dhiven Naicker, Lynn Greeff, Ronella Govindasamy, Quinton Potgieter and Norman Pammenter.

The following study was funded by the National Research Foundation (NRF) and University of Natal.

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1. Abstract

Curriculum experts, instructional technologists and teachers are looking at computer technology to address many of the inadequacies that plague traditional teaching. These inadequacies include practical limitations and outdated educational philosophies that encourage rote learning and passive transfer of information from teacher to student via the typical lecture-based classroom. Often educational technology is used as an add-on to make content available to students. However, technological tools should rather be used to facilitate productivity and communication in the modern classroom. In addition, the introduction of technology into the classroom can be used to completely transform the traditional lecture into interactive computer-based learning environments. Provided that innovation can be sustained and supported over a period of time, the creative use of technology should enhance sound pedagogical principles rather than replace it.

This project reports on the development and evaluation of two, second year, Biology Internet-based software packages used by students in a computer-based constructivist environment that replaced the traditional lecture based model. The first part of the project involved the evaluation of a number of Internet-courses to identify appropriate design and development criteria. This information was then used to create an Educational Software Evaluation Tool (ESET). The courses on carbohydrate and lipid metabolism were then developed in conjunction with subject experts. Evaluations of these learning environments were conducted via paper-based questionnaires, student interviews and student evaluations using ESET. Additional quantitative data was obtained by comparing examination results with the previous year to measure the impact of the technology on learning outcomes.

The results of the software evaluation indicated that students found the user interface of the software products easy to use and navigate. Students also rated construction of information from a searchable databased highly. This project showed that student learning was improved by self-paced, user-controlled, non-linear software usage. The results also showed that personal information construction by students improved understanding of concepts and led to deeper learning and acquisition of specific skills such as problem solving, information navigation and self-management. Giving

students responsibility for their own learning was also shown to be beneficial to them as a life-long learning skill.

Evaluation of the learning environment by students indicated that they valued the permanent availability of Internet-based information highly and felt that having assistants (demonstrators and the subject expert) helped them to direct and guide their learning. The results also revealed that students learnt better in groups and that members of the group participated in communicating and constructing shared knowledge. The role of the teacher in this project was transformed from information provider to information facilitator, as the teacher became an additional resource and had more time to spend answering specific questions and problems.

Evaluation of student behaviour via interviews revealed that student attitudes were improved and that they enjoyed working with the software. Students found the environment comfortable to work in, were motivational and thought the system was a highly effective way of preparing for the examinations. Students also regarded this active form of learning as far more effective than traditional lectures, although they felt that introductory lectures could still play a role in providing them with direction and focus. Quantitative analysis indicated that students understood key concepts in both the courses, and examination performances revealed that students performed better in both the computer-based courses than in the lecture-based courses for this particular year. Further analysis showed that students performed better than the previous year with respect to the Carbohydrate Metabolism course, but not for the Lipid Metabolism Course (no significant difference).

Quantitative and qualitative comparisons between the Carbohydrate and Lipid Metabolism course identified that the Carbohydrate Metabolism course offered students with dynamic content that fostered knowledge construction from a searchable database with easy navigation tools, whereas the Lipid Metabolism course consisted of pre-structured static content that students found difficult to search. This result indicates that interactive components foster constructivist based learning skills are an essential part on on-line learning environments.

The results of this study include a model for designing, developing and evaluating education software and concluded that technology based on sound pedagogy can be successfully and effectively integrated into the classroom and form the basis for future prolonged development and learning.

2. Literature Review

2.1. Introduction

The following study covered three main categories of research into educational software (a) designing, (b) developing and (c) evaluation of Web-based instructional material. The scope of the research included curriculum development in higher education and instruction technology (use of technology in education). Traditionally all research pertaining to education is contained within curriculum studies. This field focuses on the goals of higher education as well as the skills and content. With the recent advancements in technology however, conventional practices are being transformed to include the use of technology.

The field of Instructional Technology blends traditional curriculum research with modern information technology. It focuses on structures and procedures that allow technology to be used successfully and efficiently in education. In order for technology products to enhance learning however, researchers need to focus on knowledge building and associated learning processes, deep learning and development of higher order skills and abilities. Instructional design also needs to include modern educational theories such as constructivism where knowledge is built individually rather than passively transferred from teacher to students.

The development of software to achieve the goals of the modern classroom should be based on sound developmental models and sound pedagogical dimensions. Evaluating such products should include both qualitative and quantitative results that cyclically improve the software and provides guidelines and foundations for further educationally sound software.

This review will focus on curriculum studies, in order to understand how traditional theory can include technology as a well as a discussion of instructional technology, theories of knowledge and learning, software development, technology enhanced learning, assessment and remediation, and finally educational software evaluation.

2.2. Curriculum Studies

Higher education is undergoing tremendous change with much research being directed towards characterizing and optimizing the model of learning. According to MacFarlane (1992), the aims of higher education must be to develop students' critical faculties, understanding and independence of thought. In order to characterize the model, Dwyer (1995) argued that a paradigm shift of education and training is long overdue from the factory model (with its roots in the industrial era) to a social and critical thinking model with its future in the global information age.

This change in educational settings and directives are the main focus in the field of curriculum studies that has undergone intense debate during the 21st century. Priorities such as citizenship demands, personal development and vocational training pressures have all been put forward as steering factors in curricular trends (Schubert, 1986). There has also been considerable pressure to include practical, school-focused approaches, theoretical perspectives and technical, scientific management approaches. In order to present a definition for 'curriculum', there must be accommodation for different values and perspectives. Walker (1990) outlined the definition of curriculum according to: matters that teachers and students attend together, matters that students, teachers and others recognize as important to study and learn, and the manner in which these matters must be organized. Gumport (1988) presented a formal working definition of curriculum:

"...curricula may be seen as that part of the cultural life of academic organizations in which faculty, administrators, and students construct and revise their understanding and in which they negotiate about what counts as valid knowledge in particular historical and social settings "

Walker (1990) listed fundamental concepts such as content, purpose and organization of learning, while Tripp (1994) included determining characteristics such as: intentions, planning, explication (the extent to which details are made explicit), harmony, and relations in curricula designs. Curriculum on the whole is constructed by society which includes: teachers, principals, parents, university specialists, industry and community groups, and government and political agencies (Schubert, 1986). According to Baijnath and Hendricks (1993), curricula needed to be constantly reviewed in order to provide coherency. These authors state that a coherent curriculum is important for the development of student learning and for improved teaching, without which, leads to confusion and fragmentation.

2.2.1. Curriculum Paradigms

"Paradigm" in recent years has been used to describe the change in philosophy and represents a well-established, clearly defined approach to conducting inquiry in a field (Reeves and Hedberg, 1998). In curriculum studies, paradigms are used to explain and describe different ways in which curricula are viewed, researched and implemented. For more than 20 years scientists have been concerned about paradigms of inquiry (Schubert, 1986) who presented a comparative model (Table 2.1.) that outlined the three most common curriculum paradigms: empirical, hermeneutic and critical.

The empirical-analytical model is technical in nature, which admits no value to or ideological orientation, is based on the social organization of work where workers are there to do their work within a controlled hierarchy. In this model, researchers search for laws and propositions based on universal probabilities. The hermeneutic paradigm, on the other hand, is practical in nature and is concerned with the cultural and historical circumstances within which persons are embedded. Researchers here look for meaning that enhances interaction with others and events that place emphasis on communication. Finally, the critical sciences paradigm goes beyond the first two and emphasizes emancipatory political interests. Here, the search for meaning is accompanied by social organization that empowers human beings to transcend constraints imposed by socio-economic class and controlling ideologies. In this paradigm, pedagogy has to provide for socioeconomic equity and justice.

Reeves and Hedberg (1998) described a fourth model, which they termed "Eclectic-Mixed Methods-Pragmatic Paradigm". This model incorporates the previous three and is capable of handing the complexity that is the hallmark of contemporary society and technology (Casti, 1994; Sedgwick, 1993).

Table 2.1: Habermas's Comprehensive Theory of knowledge (Schubert, 1986)

Type of science of inquiry	Empirical/ Analytical	Hermeneutic	Critical
Interested Server	Technical	Practical	Emancipatory
Social Organization	Work	Interaction	Power
	Mode of rationality		
	Posits principles of control and certainty Operates in the interests of law-like propositions that are empirically testable. Assumes knowledge to be value free Assumes knowledge to objectified Values efficiency or parsimony Accepts unquestioningly, social reality as it is	Emphasizes understanding and communicative interaction Sees human beings as creators of knowledge Looks for assumptions and meanings beneath texture of everyday life Views reality as intersubjectively constituted and shared within a historical, political and social context Focuses sensitively to meaning through language use.	Assumes the necessity of ideological critique and action Seeks to expose that which is oppressive and dominating Requires sensitivity to false consciousness Makes distorted conceptions and unjust values problematic Examines and explicates value system and concepts of justice upon which inquiry is based

This model is thought to incorporate the strengths of all three paradigms to provide flexibility and openness for multi-perspective problem solving facing educators and trainers.

2.2.2. Curriculum Frameworks, Integration and Implementation

The previous section outlined the different philosophies and ideals governing the field of curriculum studies. Determining the correct ideal/s to employ, however, represents only "half the battle" Curricula need to be implemented in real-life situation and this requires a highly structured and carefully thought out process involving analyzing the environment and its embedded activities within appropriate frameworks.

According to Marsh (1997) frameworks can provide an important springboard and focus for teachers in terms of curriculum planning. They serve as tools for control and direction as well as stimuli for creative ideas and activities. Marsh defines frameworks as groups of related subjects, or themes, that fit together according to a predetermined set of criteria to appropriately cover an area of study. Frameworks provide a structure for designing subjects and a rationale and policy context for development and may potentially improve student access, curriculum coherency, quality, content areas and important skills (language, numeracy, problem solving). However, care must be taken to avoid frameworks becoming too directive and controlling.

Once the framework has been constructed, educators need to relate the various skills inherent in different subjects and disciplines. Marsh (1997) describes how teaching has become too subject specific with each subject being packaged on its own, with its own presentation, focus and skills. Students fail to see the inter-connectivity of subjects and fail to integrate and adapt skills from different subjects. Marsh proposed presenting students with inter-disciplinary skills that span across different subject matter and produces a more worthwhile permanent experience rather than subject specific, narrowly focussed learning outcomes (Choi and Hannafin, 1995) that satisfy rigid and temporary assessment methods. Integration enables teachers to focus on many skills, which are often neglected also or taken for granted, in single subject teaching (Jung, 1994). Marsh (1997) argues that with integration, subject specific content and skills are not abandoned, but are simply repositioned in relation to broader concepts and activities leading to more meaningful contexts for students.

Implementation refers to actual usage of products or activities and is the result of the decision made by the educator to accept a particular curricula model or framework. Once the framework and developmental model has been decided, developers need to consider method/s, level of coherency required by student, choice of assistance, and desired effects on learning (Marsh, 1997).

Implementation practices improve with experience as teachers becomes more familiar with their environment and resources, refining and optimizing them with each cycle. Although power may swing between the teacher and authority, specific settings dictate the ratio between the two groups as an optimal solution (Marsh, 1997). Fullan (1982) presents factors that affect implementation (Table 2.2).

Table 2.2: Factors affecting implementation (Fullan, 1982, p. 56)

A Characteristics of change	
1	Need and relevance of the change
2	Clarity
3	Complexity
4	Quality and practicality of programme (materials etc.)
B Characteristics at the School District Level	
5	The history of innovative attempts
6	The adoption process
7	Central administrative support and involvement
8	Staff development (in-service) and participation
9	Time line and information system (evaluation)
10	Board and community characteristics
C Characteristics at the school level	
11	The principal
12	Teacher-Teacher relationship
13	Teacher characteristics and orientation
D Characteristics External to the Local System	
14	Role of the government
15	External assistance

These factors refer to the attributes of the innovation or change, characteristics of the school district, characteristics of the school as a unit, and factors external to the local school system (Marsh, 1997). In characteristics of change (A), factors listed in the table above determine the practical outcomes of the implementation, whereas factors at the school district level (B) stem from logistical and background considerations such as the history and process of implementation, as well as the composition of staff, community and time considerations. At the school level (C) behaviours of and between teachers play a role in implementation. Finally, external systems (D) such as government and external parties may also influence the level and degree of implementation.

2.2.3. Goals of Education

As mentioned earlier, new curriculum models are aimed at enhancing student critical thinking and problem solving skills. The South African Education Department hopes to introduce critical thinking and problem solving skills in the new curriculum as opposed to old style memorization of content (de Lisle, 1997). According to Dwyer (1995), the social and critical thinking model reflects the way we naturally learn and encourages teachers to accept that every person is capable of learning and understanding. The author supports the blending of various disciplines (integration that make meaningful connections which learners are faced with in their everyday lives).

What are the ideal goals of tertiary education? In Australia, calls for the broadening of university goals have come from national government, employers, professional associations and educational theorists (Nightingale *et al.*, 1995). Council bodies refer not only to acquisition of a body of knowledge, but the mastery of technical skill, development of problem solving abilities, critical thinking, effective communication as well as development of attitudes towards working in groups and to ethical practices within one's discipline (Higher Education Council, 1992).

2.2.4. Curriculum Content and Skills

Much attention needs to be placed on 'what' students need to learn. Baijnath and Hendricks (1993) stated that content plays a role in curriculum structure and development. These authors described how different subjects infer different knowledge structures (example, History is chronologically structured). Stark *et al.* (1998) proposed that knowledge is commonly arranged into concepts and operations, and this is the basis for which teachers expect students to integrate ideas from the discipline into abstract principles. Content remains the foundation from which curricula are developed where knowledge transmission results in implicitly and explicitly learned skills (Baijnath and Hendricks, 1993). These authors argued that the structure and articulation of content greatly affects the level of skill and ability achieved by students. Stark *et al.* (1998) suggested that student learning theories reinforce the importance of how academic courses are planned in order to facilitate broader pragmatic change. Student skills and abilities are thought to enhance the quality of work, and increase the employability of students (Baijnath and Hendricks, 1993). Hitchcock (1990) provided six useful skill categories that students need to possess: general, self-managing, social and communicative, adaptive, creative and intellectual. These generic skills are easily transferable to other subjects and contexts.

2.2.5. Strategies and Planning Curriculum

Based on the concept of 'holistic' approach to change, Dwyer (1995) stated that strategies needed to incorporate professional practice, curriculum, classroom arrangement and implementation of the curriculum. This involves support from stakeholders as well as inter-disciplinary teaching between different subjects. The author also introduced the concept of technology integration into curriculum that would allow learners greater time to develop and use high levels of critical thinking skills.

Planning is the first and most important step in any process. The first attempt at providing formal approaches to curriculum planning was made by Ralph Tyler in the 1940s. His book has been widely used, yielding the 'Tyler rationale' or 'Tyler's Planing Model'. Tyler's (1949) model stated how to build a curriculum. The author argued that there are four main issues that curriculum developers need to address. These principles (illustrated diagrammatically in Figure 2.1) provide teachers with a general outline, or methods, for developing curricula.

The first step in the model is concerned with educational goals. Only when one has decided what one wants to teach can one select and organize content (Marsh, 1997). Selection of content can include input from various sources (e.g. students, society and subject specialists). Tyler (1949) stated "no single source is adequate to provide a basis for wise and comprehensive decisions about objectives of the school". Although this can rise in considerable incongruencies, Tyler also stated that such dilemmas can be resolved by identifying potential objectives from each of these sources and to then use educational philosophy and psychological principles to produce a final set of objectives.

Tyler (1949) was referring to more than just content when he referred to selecting learning experiences. His concern was with learning experiences and behaviours that reach specific objectives. In organizing learning experiences, Tyler mentioned coherent programs, efficiency of instruction, and effective organization. In evaluation he stated that educators needed to compare objectives with results actually achieved. He also stated that evaluation should be conducted throughout the process, and not just at the end. Examples of evaluations include observations, interviews, questionnaires as well as evaluation instruments that emphasize scientific testing.

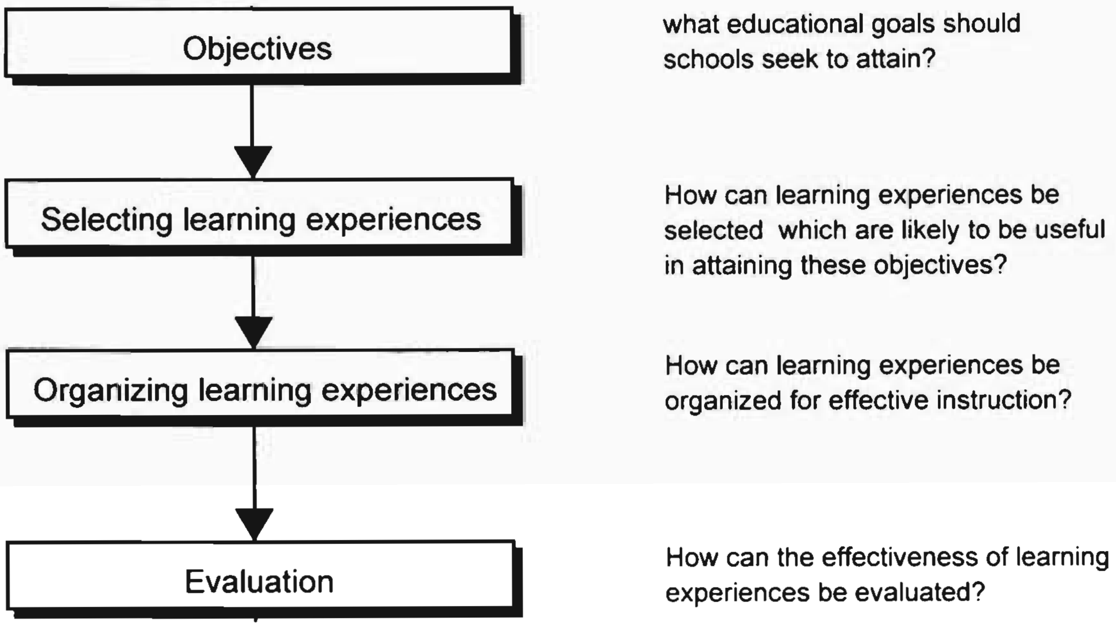

Fig. 2.1: Tyler's Planning Model (Tyler, 1949).

2.2.6. Transformation of Conventional Teaching practices

Tyler's model was very loosely defined and gave educators a lot of options in terms of change and innovation. In South Africa, research into curriculum and educational theory is relatively new (Baijnath and Hendricks, 1993) forcing many to adopt mainly British, North American and Australian models. These authors further added that there is a need for curriculum change in response to student needs and relationship between various economic, social and political factors that have come to hallmark 'the new South Africa'.

When change is made to educational and training systems it should not disrupt the present system. Instead, it should provide enhanced learning outcomes which are cost-effective (Dwyer, 1995). Collis (1997) introduced examples of transforming conventional profiles such as 'pedagogical enrichment' and 'pedagogical re-engineering'. In the former, educators focus on new techniques of teaching focussing on efficiency, enrichment, or flexibility. The latter, however involves changing the entire profile of a course, which may include the use of technology, group work and collaborative projects. These changes must also be accompanied by changes in mental attitude. Teachers need to rethink their assumptions about teaching, and students need to confront their entrenched expectations about classroom learning (Graziadei and McCombs, 1995).

2.3. Instructional Technology

The previous section described how ideas and models of conventional learning systems needed to adhere to structure, integration and implementation guides. The following section describes how "modern day" technology is integrated into curricula paradigms, a field which has become known as 'instructional technology', otherwise referred to as telematics, education technology, learning technology or educational media. Although proponents of each school may argue substantial differences, all center on the use of technology in education, the main focus of this project.

According to Seels and Richey (1994) Instructional Technology is "the theory and practice of design, development, utilization, management, and evaluation of processes and resources for learning". Albright (1996) maintained that instruction technology is not synonymous with information technology nor is it a euphemism for academic computing. It is a complex field that is concerned with learning and its products. The field focuses on equipment, material, skills, development and environmental conditions that influence the quality of learning. Reiser and Ely (1997) stated that the modern definition has evolved its focus towards learning rather than teaching.

There seems to be problems facing integration, or implementation, of technology in education, since it is a fairly new field with little experience, and administrators are still understanding the role of technology in education. Caution must be adopted in with new technology, since the history of the field has seen many high hopes with limited successes (Anderson, 1997). This author argued that if technology is to be integrated successfully it must be tried and tested with conventional teaching methodologies. Furthermore, developers must choose technologies and techniques appropriately to the situation at hand, making note of their strengths and weaknesses. Also, Miller and Olson (1994) suggested that successful integration of instructional technology in education occurs in the context of "an awareness of the role of the teacher and the existing curriculum". Debates on the value of technology often arise as a consequence of differing and conflicting conceptions of curriculum.

2.3.1. Instructional Technology and the Curriculum

How and where is technology integrated into modern day curriculum? Richards *et al.* (1997) proposed that the following practical areas need to be addressed: use of electronic lectures, mechanisms to facilitate lectures-on-demand, the use of tele-teaching, tele-tutoring, electronic libraries and collaborative and distance learning. On a theoretical level, White and Purdom (1996) stated that conceptualization of the 'modern curriculum' is a product of different mind sets which, if understood, can generate different proposals. These authors provided a brief description of different mindsets that have helped shape modern instructional technology.

One of the first examples described is 'academic rationalization', where the starting point for curriculum development is the subject matter, which is refined by a subject expert and usually is the foundation for technology use. Unfortunately this mindset is very highly conventional and rigid with practitioners afraid of technology replacing the teacher (White and Purdom, 1996).

The second mindset is 'self-actualization' where the aim is to develop specific individual skills, abilities and interests rather than a given body of content. Such skills are in most cases content independent and desirably transferable. Here, there is tremendous potential to develop individuals who constantly seek to explore the environment around them. This approach also endorses 'open learning environments' where students are given control over their own learning. There is also no distinction made between conventional textbooks and technology, since both are regarded as resources, which students may choose to use at their own disposal.

Thirdly White and Purdom (1996) described curriculum mind-sets with respect to modern social settings, in which group outcomes are more valued than individual outcomes. Here, teachers prepare students for a future in which there is an awareness of social problems that are solved by democracy in a just society. Finally, the authors focused on students' abilities to think, i.e. cognitive processes. Here, value is placed on intellectual process rather than content and proponents of this mindset believe that virtually any content can be used to facilitate problem solving, critical thinking and higher order thinking processes applicable to any field. Evidently, it is these practitioners who have mainly embraced the potential of IT. Technology here fosters innovative and creative ways of problem solving abilities.

Although the above mindsets are presently separately in time-scales and backgrounds, modern technology utilization can possibly be greatly improved by absorbing each of their strengths to provide a modernistic, evolved mindset, which in itself, is not static but is constantly and cyclically shaped by current needs, ideas and technologies.

2.3.2. Technology use in education

Dwyer (1990) stated that education change has traditionally been very poor, providing a partial solution at best, which is mainly motivated by budgetary or political pressures. In describing the various symptoms of educational crisis, Greening (1998) stated that traditional instruction inhibits reflection, experimentation and even play with application of knowledge, which usually occur with ill-structured domains or problems. The author also argued that very few lifelong learning skills are incorporated into graduates' list of personal attributes with little emphasis being placed on student-centered learning. In terms of methodology, higher education is normally distributed in very non-interactive formats such as books, journal articles, handouts and other print base resources (Richards *et al.*, 1997). Although no attempt is made to de-value these resources, they are usually "dished out" to a very large number of students making educational practices that much less efficient. In other words, students are led to believe that the knowledge is contained within the content, and that's where it will remain. The practical nature which dictates forms of content (books etc.) cannot be denied, however, rich knowledge can be achieved by transforming the way in which we interact with content via structured active student participation in some form of pedagogical activity.

Traditional lectures being the dominant mode, although highly valuable, do not promote active student participation (Anderson, 1997). Furthermore, lectures on their own promote surface learning and do not provide the appropriate context for deep learning (Ramsden, 1992). These practices and others like it have failed to keep pace with changes in society and has failed to change the learning environment to reflect the way we naturally learn (Dwyer, 1995), the extent of which is due to lack of control over environment rather that lack of ability or talent. Wilson (1995) referred to modern education as a 'pill' and emphasizes the dangers on packaging instruction to students. The author states that as learning is packaged and simplified, its richness is lost, an example that also applies to learning outside the context of natural settings.

Computers have been heralded as the solution to our educational crisis, and not without good reason. Attempts in the 1980s to bring technology into the classroom involved the creation of computer literacy classes at elementary and secondary levels (Moersch, 1995). Students learned about computer architecture, operating procedures, basic software applications and introductory programming. In the last 20 years, technology has certainly come a long way, it impacts our economy and helps shape our culture, becoming part of the human environment and society. Therefore, in reflecting society, it must become part of the learning process (Dwyer, 1995).

Technology carries an expectation that it will transform many aspects of learning including the content and body of knowledge taught, delivery, and the types of facilities required to support delivery (Kook, 1997). Learning environments are becoming more creative and diverse with schools becoming, not only information centers for specific content, but also arenas for technology development and innovation in obtaining all types of knowledge and skills (Kook, 1997). Technology, if well utilized, can be used to complement the process of formal education or can even be used to acquire some concepts, skills and interactive behaviours that would otherwise be difficult to realize in real life situations.

Technology however, is not a process, mindset, or a global solution, it is merely a tool. Mankind is well noted for it reliance on tools which have over the centuries evolved to support, for example, an ever growing demand for diverse knowledge (Richards, *et al.*, 1997). With the onset of the 21st century, it is undeniable that the computer, as a tool, has by far made the biggest impact on human endeavor. "Technology, be it a writing system, a media system, or a computer system, has been proven to be an effective tool to realize the interrelated goals of learning, teaching and cognitive growth" Chen (1993). Although some teachers have used technology to promote 'intelligent behaviour' in students, others have used it to facilitate the mastery of essential knowledge and skills in the classroom that go beyond traditional instructivist goals. Moersch (1995) stated that computers are used as tools that supports and extends student understanding of concepts, processes and themes. The author mentioned technological usage of databases, telecommunications, multimedia, spreadsheets, and graphing applications in which traditional verbal activities are being replaced by hands-on interfacing within authentic problem based environments. On a global scale technologies such as electronic mail, bulletin board systems, listservs, newsgroups and more recently the World Wide Web has enable rapid exchange of ideas and feedback between people worldwide (Lake, 1995).

In addition to its inherent use as communication tools, technology may also play a direct role in educational activities. Richards *et al.* (1997) introduced the concept of "electronic performance support systems" which provides mechanisms, techniques, technologies or tools that augment, or facilitate, individual (or group) performance within a given task domain. In other words, technology presents us with "tools" that make us work faster and better. These authors maintained that the use of technology is two-fold: it accelerates skill and knowledge acquisition and enhances the ability levels of both staff and students. In classroom settings, McDonald and Ingvarson (1997) stated that computer applications free students from laborious tasks of rewriting and copying notes in a highly prescribed format. They stated that technology also allows students flexibility, pace and focus that frees both students and teachers from traditional classroom constraints. The above authors do not identify distinct pedagogical functionality, but argued for the practical nature of technology to improve our speed and quality of learning. Providing the pedagogical perspective however, Dorfler (1991) stated that cognitive tools amplify human ability as "information re-organizational devices" that extend activity and reflection to a (higher) meta-level.

Although the instructional technology focuses on technology as a "learning tool", its potential as a developmental tool (for teachers and students) is equally appreciable. There are many development tools available for creating multimedia for example

(Hypercard, Toolbook, Macromedia Suite [Director, Authorware, Flash]) and a host of web (HTML) and platform based languages, although many "in-house" developmental products are currently being created (Ward and Tiessen, 1997). These authors also described tools that allow students to construct text, graphics and any other type of media that can be incorporated into Web pages.

Although computer technology presents higher education with means of providing an increasing student population with adequate resources, the focus should still lie with educational issues (Hämäläinen *et al.*, 1996) and user needs (Brown, 1995) first and technology second. This point is further stressed by Collis (1997) who added that central to its evolution is not technology for its own sake, but technology as a tool to make concrete an educational philosophy. Greening (1998) stated that theory should drive the application of technology within educational contexts rather than technology itself. It is important to note that technology does not guarantee fundamental change in teaching-learning processes and consequential learning outcomes. Other variables such as organizational structure, the role of the teacher and the curriculum itself may also play a role in determining the effectiveness of technology (Thomas and Knezek, 1991).

In order for any new system to succeed, educators need to be aware of the problems that occur as a result of incorrect technological use. Maus (1998) argued that there are tremendous contradictions between institutional assumptions and classroom realities. The author listed problems with student experience, student interest and quality of work, which may not necessarily be enhanced by technology. Clearly all institutions are being presented with a myriad of new learning and teaching technologies, but much scientific/educational research is required to deal with possible problems and to steer technology use in the right direction.

2.3.3. Development of Instructional Technology

Instructional technology, developed since the early 20th century is been based upon systematic and scientific development and delivery of education. It has been developed to provide scientific input into traditional educational structures transforming it into modern education, as we know it today. Barker (1990) stated that advances in technology have seen expected and unexpected development with designers nowadays having access to tools that are much cheaper and more powerful. Barker also identified processing speed and storage space as *the* most fundamental improvement areas. The author further mentioned exciting innovations in 3D interface design, optical media, communication technology and artificial or virtual technologies. Its hard to imagine that this was envisaged by Barker nearly ten years ago, in which he proposed that innovation would significantly impact interactive learning systems.

Development, however, requires considerable investment of time and energy as well as support from management (Taylor, 1996). It is important to build a society rich in information handling skills. The technology on its own won't change society overnight. Students need to be taught responsibility and skills to handle and manage learning from interactive technology, as well as making decisions on appropriate use of various different resources. There is tremendous hope that technology will become part of the day-to-day curriculum and although there is tremendous hype, technology is still just an add-on rather than an integral part of education (Horgan, 1998).

2.3.4. The World Wide Web

The WWW presents us with the latest platform for taking education into the future. Communication networks have made possible the development of "information superhighways" which allow users to browse, or search, through vast amounts of information and resources in a wide range of forms (Richards *et al.* 1997). Starr (1997) argued that the superhighway is a term popularized by the media, referring to the vast amount of data transmitted by the Internet and by telecommunications facilities in general. The World Wide Web is one of several services on the Internet, one of which is most responsible for the increase in Internet users (Richards *et al.* 1997).

Whether it arose as the result of booming markets, or competitive telecommunication giants and Internet service provides, the WWW today has become a 'colossal money-spinner' that risks engulfing everything including education (Trentin, 1996). The Internet as we know it today was originally developed in the late 1960s (Starr, 1997) and was funded by the US Department of Defense. Research that focused on sending information packets over electronic networks first went live on December 1969 linking four US universities. Development, which was then supported by the National Science Foundation, culminated in technologies such as file transfer protocol (FTP), electronic email (Email) and even remotely logging into computer systems (TELNET). Pretty soon computer workstations (information nodes) became linked all around the world leading to the development of the World Wide Web in 1990 (World Wide Web Consortium, 1996). The first Internet 'browser' Mosaic capable of viewing text and images from host machines was developed by the US National Center for Supercomputing Applications (NCSA). After Mosaic supported 2 million free downloads, the market became flooded with fierce competition between the Netscape Navigator and later Microsoft's Internet Explorer browser.

Despite it being a relatively new technology, the WWW has made a tremendous impact on providing continuously available resources (Anderson, 1997; Collis, 1997). The dynamic nature of electronic content makes expanding and updating information quicker and easier than conventional means (Starr, 1997). Lake (1995) regarded it as a place to do three things: a place to talk, a place to get organized information and a place to organize and place information. In other words, it is a global computer network that allows communication with millions of computer users with access to resources from around the world. Despite the fact that the Internet has become so massive that finding the *right* information becomes problematic (Greening, 1998), the Internet presents tremendous value to students. According to Ward and Tiessen (1997) the WWW has the potential to impact the social dimensions of learning by providing extensive computer-based information resources for students to explore their own understanding. In recent years technological possibilities have become more refined with the Internet becoming more robust offering flexibility and multimedia options. Simply 'putting lecture notes on the internet' are encouragingly being replaced by more constructivist, open-ended learning programs (Greening, 1998).

Trentin (1996) argued that even though not necessarily based on specific teaching approaches, the most powerful function of the WWW lies in its basic function as tool for navigation through distributed information and interpersonal communication. He stated that the educational implications lie in the very processes of learning to take advantage of powerful communication systems. The author also mentioned technology use in specific teaching approaches and commented that it is a key factor in adopting new teaching and learning processes. Collis (1997) for example, stated that the WWW could be used to change the pedagogical profiles, which can lead to flexibility and efficiency. In other words, not only is technology set to improve existing learning, but it may also change the way in which we ultimately learn.

2.4. Knowledge and Learning

The following section provides a background into students learning and understanding and identifies sound conventional pedagogy that can provide future technologies with foundations for producing highly educational learning resources. The section provides non computer-based appreciation for fundamental learning activities, how information is built and the skills and theory that underlies knowledge construction.

"As human beings knowledge is just one of a number of different commodities that arise and develop as a result of the events and processes that occur with ourselves and with our environment" (Richards *et al.*, 1997). According to Eisenstadt (1995) knowledge is not information but an emergent property, a dynamic process, a 'vibrant living thing', resting on shared assumptions, beliefs, and complex perceptions. Furthermore it is an entity that is not transferred from one person to another, but is actively built by the learner (Driver *et al.*, 1994).

2.4.1. The basis of structuring new knowledge

According to Jean Piaget (1937) cognitive schemas (knowledge structures) are formed and developed through the co-ordination and internalization of a person's actions on objects in the world or, in other words, the organization and representation of ideas and information in the form of schemas (Jonassen, 1988). These schemes evolve as a result of a process of adaptation to more complex experiences, i.e. new schemes come into being by modifying old ones. All our experiences in life are made sense of by previous experiences, but themselves are used to shape the cognitive framework upon which we build called 'knowledge'. Driver *et al.* (1994) introduced the concept 'resolution of disequilibration' where original schemas are changed via internal mental activity and results in previous knowledge schemes being modified. Learning thus seems to involve a process of conceptual change. Dwyer (1995) described the process as "observing new information into their present understanding or schema, reflecting on how their present perception and understanding differs from their new understanding". Hill and Hannafin (1997) defined this process as "information integration". Bruner (1966) stated that the process that follows these initial encounters with information involves expanding and relating ideas in order to form an overall, or general, picture from detailed information. The author explained that understanding does not only involve learning a specific thing but a model for understanding other things like it that one may encounter, i.e. forming generalization and discerning patterns.

In introducing this topic, it was stated that knowledge is vibrant and dynamic. This presents the idea that knowledge is not constant and may vary in composition from learner to learner. Knowledge can be viewed from different perspectives. This is important as students who learn from multiple perspectives can better understand why, when, and how to use knowledge in various situations and are able to analyze problems and settings from different points of view (Choi and Hannafin, 1995).

Cognitive psychologists generally speak about two types of knowledge, declarative and procedural i.e. knowing-that and knowing-how (Ryle, 1949). Perkins (1996) expanded this theory by arguing that knowledge is "...having a sense of orientation, recognizing problems and opportunities, perceiving how things work together, possessing a feel for the texture and structure of the domain...". Other categorizations of knowledge include either verbal and propositional or visual and spatial (Tweney, 1987; Rouse and Morris, 1985). Verbal knowledge is abstract in nature, spoken or heard knowledge. It is usually related to students by the teacher and usually has sequential, biographical property. Visual knowledge, however, is more representational and graphical. Visual information has no necessary sequence and is usually best related by pictures and diagrams, which according to Bruner (1966), is the way in which the brain usually stores information.

2.4.2. Building information

Knowledge has a fundamental purpose. Be it for the purposes of application or furthering knowledge, it takes us into the future. The physical activity of building knowledge serves to create skills and instill attitudes and principles, which ultimately broadens and deepens knowledge (Bruner, 1966).

The first step in building information is thought to involve determining aims and objectives of the current activity (Taylor, 1996). In this sense, information needs a place and context within which to belong, a starting place. From this, students need to be aware of, not only what they are learning, but why, how, and to what end the knowledge will serve them (with the aid of appropriate guidance). In doing so students start the process of personal information development which serves themselves and not necessarily the course objectives or assessment. Piaget (1970) argued that personal construction of meaning results from learner's personal interaction with physical events in their daily lives. Driver *et al.*, (1994) added that learning from this perspective requires well-designed practical activities that challenge learner's prior conceptions and personal theories.

2.4.3. The learning process

In describing a basic model of learning, Richards *et al.* (1997) stated that students *gather* information from various sources including: 'the universe of disclosure' (the world around us), scholars and researchers, and teachers. According to Anderson (1997) "...presenting students with information in some way and through some medium, while a necessary step, is by no means sufficient to define an effective teaching and learning strategy". The author argued that learning is a by-product of understanding, which occurs best while performing tasks and reflecting on them alone and with others.

Dwyer (1995) described learning as a sequence of events for teaching any topic or a subject that allows learning to unfold in a meaningful and natural way that arouses curiosity and gains attention of the learner. The authors further added that providing the 'big picture' attains effective learning and providing students with a context and framework for new learning to take place. In other words, learning is only affected by some sort of activity or procedure, which while fostering certain practical skills, may ultimately affect deep learning. Richards *et al.* (1997) stated that learning is facilitated by providing students with working knowledge (to address current problems and tasks) or to provide deep understanding in the long run (applicable and personal knowledge).

An important activity that affects learning is social interaction (Driver *et al.*, 1994). This focuses on roles played by peers and teachers in bringing about the social engagement of learners transferring experience and building an appreciation for the learning domain. Such settings provide highly intellectual environments in which problems are solved by different perspectives from learners who progressively restructure overall underlying theories and beliefs (Driver *et al.*, 1994).

Learning is thought to occur in phases. Needham and Hill (1987) present, what they termed, the 'phases in teaching schemes' in which they described a linear sequence in which students need to learn. Phases I consists of orientating students (i.e. setting the scene). Although this is a linear sequence, learning itself, may not necessarily be sequential in nature. Activities include practical problem solving, demonstrations and familiarization with background information. The next step involves the teacher eliciting ideas from students so that they become aware of their personal and prior ideas. Thereafter students can restructure alternative and newly learned viewpoints in small discussion groups. In addition to reflecting on new ideas and integrating new ideas into older ones (discussed earlier), Needham and Hill (1987) introduced an additional step where students are given the opportunity to test validity of old an new ideas in a practical context. Thereafter knowledge is applied to problem solving situations, in some form of activity, which then leads to a final review and consolidation of what has been learned in the form of reports or tasks.

2.4.4. Deep learning and successful transfer

Learning activities, albeit well structured and planned, need certain mental processes to effect deep learning. Anderson (1997) argued that deep learning involves students applying analysis, attempting synthesis of concepts and evaluating what has been done. This involves largely subjective and tacit knowledge, which comes mainly through experience, dialogue and interaction with the learning material. According to Bruner (1966) deep learning is dependant on detail being placed within a structured pattern, without which information is forgotten. The author also added that detail is reserved in memory by very simple ways of representing it such as formulae and patterns. Land and Hannafin (1997) argued that pattern formation in learning is crucial in formulating conclusions and predictions and making generalizations. These authors argued cataloguing successful actions enhances the process. Furthermore, this allows for the successful organization of observations, which lead to consolidation and refinement of knowledge. Land and Hannafin (1997) argues that this process strengthens personal intuitive theories against orthodox views.

Deep learning is also fostered when we reflect and relate knowledge to ourselves, and more so, to others (Dwyer, 1995). Reflection implies an interaction with information without which knowledge transfer could not take place (Richards *et al.*, 1997). In order for knowledge to be successfully transferred, processes need to go beyond simply viewing information (Richards *et al.*, 1997). These authors list several issues that facilitate knowledge transfer which includes mechanisms that assist in the actual conversion process, facilities for students to assess their progress and remediation for discrepancies that arise. Taking into account that activities have been well prepared and learning has ultimately been achieved, educators also need to be aware of skills that are acquired either intentionally, or as a by-product of learning activities.

2.4.5. Knowledge Skills and Abilities

The main aim of higher education, besides teaching students a body of content, is to instill them with valuable learning and performing skills. The goal here, is to process information deeply and restructure knowledge accordingly, and to apply knowledge and skills across different problems (Choi and Hannafin, 1995). White and Purdom (1996) believe that skills are valuable intellectual processes that can be achieved independently of the content studied.

Based on research in higher educational goals, Nightingale *et al.* (1995) described the primary skills required by students at a tertiary level: (a) thinking critically and making judgement, (b) solving problems and developing plans, (c) performing procedures and demonstrating techniques, (d) managing and developing oneself, (e) accessing and managing information, (f) demonstrating knowledge and understanding, (g) designing, creating, performing, and (h) communicating ideas to others.

With respect to inquiry-based learning, Taylor (1996) argued that it is important to be able to ask questions and recognize answers. The author stated that learning anything useful is heavily dependant on how well developed our information inquiry and handling skills are. Placing students in problem solving environments best fosters these skills. Problem solving is probably one of *the* most important and widely used skill both in the working world and everyday life. According to Young and Kulikowich (1992), it is viewed by cognitive psychologists as acts of knowledge construction rather than mere reproduction. Also, Barker (1990) stated that problem solving environments foster creative thinking in students. Choi and Hannafin (1995) state that "formal education contexts are comparatively unfamiliar and impoverished compared with the real-life experiences of an individual...". The authors added that academic cognition is too formal and needs to incorporate everyday problem solving where knowledge is applied practically and routinely.

2.4.6. Constructivism

Constructivism as the term indicates is the science of constructing or building knowledge, as opposed to knowledge being merely transferred from the teacher to the student. Constructivism is a school, which has spurred a whole new field of research in education. Reeves and Hedberg (1998) defined constructivism as "...the process of how we construct meaning and knowledge in the world..", "..based on our previous experiences and how we organize those experiences into knowledge structures such as schema and mental modes, and the beliefs that we use to interpret the objects and events we encounter in the world".

In offering a formal definition, Fosnot (1996) stated that constructivism is "... a theory about knowledge and learning; it describes both what 'knowing' is and how one 'comes to know'... the theory describes knowledge as temporary, developmental, non-objective, internally constructed, and socially and culturally mediated. Learning from this perspective is viewed as a self-regulatory process of struggling with the conflict between existing personal models of the world and new insight, constructing new representations and models of reality as a human meaning-making venture with culturally developed tools and symbols, and further negotiating such meaning through co-operative social activity, discourse and debate."

On a practical level Needham and Hill (1987) stated that constructivist learning involves students constructing their own knowledge through personal interaction with natural phenomena and through social interaction with members of the community and peers. These authors share the belief that knowledge is constructed by both the teacher and student.

Fosnot (1996) stated that constructivism is a whole new paradigm that has evolved in the last 20 years from the previously mainly "behaviouristic" school of learning. Behaviourists see knowledge as objective, pre-determined and finite, which they break up into content and skills and sequence these into packages for students to learn. Learners are then simply "tested" to see whether they fall into this curriculum continuum or not. Progress by learners is assessed by measuring observable outcomes-behaviours on pre-determined tasks.

Another extreme in the continuum of learning paradigms is Instructivism. This school presents knowledge to students as 'instruction'. Reeves (1992) argued that this tutorial style of teaching assumes that all students learn the same way. Similar to behaviourism, instructivists stress the importance of objectives that exist apart from the learner. Once objectives are identified, they are sequenced into learning hierarchies (Fosnot, 1996), after which instruction is designed to address each of these objectives behaviouristically. Although setting goals and addressing them is a crucial exercise in education, its should by no means be definitive, i.e. attainment of goals in a behaviourist fashion does not guarantee that students have learned anything, or that they have acquired problem solving or higher order thinking skills. Instructivism places no emphasis on learners and regards them as passive recipients with no prior knowledge.

Greening (1998) stated that constructivism is context dependent rather than content dependant. It focuses not on the content or its objectives, but on the diverseness and richness of the learning environment (Reeves, 1992) and the skills and competencies in learning that may not be directly monitored via behaviouristic assessment methods. Reeves stated that in constructivism, knowledge does not exist outside the human mind and that what we know of 'reality' is individually and socially constructed based on prior experience.

Constructivism is a theory about learning, not a description of teaching (Fosnot, 1996). The author stated learning *is* development and not a result of it. Teachers allow students freedom to explore, raise their own questions, and test their own assumptions (inquiry based learning). Errors and misconceptions are welcome since they are seen as possibilities to test existing beliefs with new perceived notions and strengthen ultimate learning via known mistakes. Activities allow students to reflect and relate their information to others, creating dialogue and discourse in social settings. Fosnot (1996) stated that constructivist learning culminates in the formation of learner constructed mental (and physical) structures containing principles that apply to broader ranging learning experiences.

In conclusion, this section focused on the principle nature of knowledge in which learning is accomplished by forming, structuring and integrating new ideas into older or existing ideas. In cases where there are misconceptions, students can test these ideas and consolidate their knowledge in a socially constructed environment. Knowledge is therefore dynamic and subject to change, rather than being constant and absolute. Furthermore knowledge building activities should accommodate deep learning, which results in acquisition of easily transferable skills, and competencies that are independent of the content from which they were fostered. This model for learning is referred to as "constructivism" in which knowledge is built rather than being read from a book, or heard from a teacher. In the next section constructivist knowledge building sets the scene for developing software that fosters visual learning, organization of knowledge and non-linearity in its design and use.

2.5. Software development

The following section presents the pedagogical nature of developing software that is usually absent in commercial software development. Inherent processes included defining the pedagogical nature of the software to be developed and educational activities that need to support the software. This section also presents theoretical developmental models and focuses on constructivist models for learning, as well as the phases involved in developing software.

2.5.1. Defining course profile and pedagogy

Before any attempt is made to develop software, one needs to establish course fundamentals irrespective of the technology used. Collis (1997) stated that focus should always be placed on pedagogy first and then technology, irrespective of its importance in the course structure. This presents developers with two possible options of technology use where (a) technology is supplemental and rests on existing structures, and (b) technology is mandatory and changes the course structure completely.

In order to better introduce the two type of technology use, the author uses the terms 'enrichment' and 're-engineering'. In the first case, technology is used as an add-on or as an alternative method to teaching a particular aspect within the course. Here, the course structure remains the same in terms of 'balance of percentages of intended pedagogical events' (Collis, 1997). The rationale for technology use here is improving efficiency, enrichment, or flexibility that would replace more traditional means. On the other hand, re-engineering, as the term implies, changes the course profile completely. Traditional structures are disassembled completely and technology plays a more fundamental role as a educational tool. Classroom settings, activities, assessment methods, and even intended outcomes may change completely to reflect more constructivist views of learning. Anderson (1997) offered an example in which the author describes shortening lecture periods, maintaining practical and group activity and using computer technology to speed up the rate of which students experience the learning materials. According to this author, re-balancing in this form should reduce lecturing time without sacrificing quality of exposition or motivational impact.

2.5.2. Developmental Models

Models, constructed to conceptualize reality, are simple representations of more complex forms, processes and functions of physical phenomena or ideas (Gustafson and Branch, 1997). Educationally they serve to reproduce theoretical prototypes in terms of mental pictures or images, the popularity of which serves the ubiquitous desire for an intuitively satisfying account of any theory (Lachman, 1960). Although Lachman argued that models may become too prescriptive, it is not wrong to assume that models may assume a certain flexibility in order to suite the needs of the user. In other words models can be a recipe, or they can be a guideline for development, provided that the author is aware of the degree of flexibility allowed by the model.

Dick (1997) stated that models are useful in terms of summarizing research and procedures of many contributors to the field of instructional design. Models themselves are rarely absolute and may be subject to constant appraisal and modification in order to provide refined models or multiple instances of the same model. According to Dick (1997), theory is revised via evolution of models to reflect outcomes that are being achieved with its current use.

The basis for instructional design models embodies both the educational (pedagogical) and psychological (learning) theories (Yang *et al.*, 1995). Models can guide the planning and development of instruction by reminding designers of the important instructional factors and processes. "They require ways of thinking about processes, procedures, and decision criteria that can be used to describe and prescribe appropriate, yet flexible, responses to situated learning" (Gustafson and Branch, 1997). Dick (1997) argued that modern technology is developing at such a rapid pace, that it precedes theory and hence refines and redefines theory. Barker (1990) introduced the concept of 'openness' to education technology, in which he argued that almost any subject is amenable to the use of technology, the ease of which is determined by individual difficulties in a particular subject. The field is still young though. Yang *et al.* (1995) stated that instructional design models suffer from a lack of practical examples that are well described and documented.

The first documented model in 1967 began with development of large-scale curriculum projects and teacher-training packages (Gustafson and Branch, 1997). Thereafter, models were influenced by the military, which in the early 1980s, gave rise to models created mainly for classroom teachers rather than professional developers. This was followed by focusing on content and objectives and gathering data and strategies. Thereafter, ASSURE (Heinich *et al.*, 1996) (analyze learners, state objectives, select media and materials, utilize materials, require learner participation, evaluation/ review) became a popular text devoted to the concept of systematic design and emphasized selection vs. production of material. Since then, Dick and Carey's (1996) model became most widely used and is, according to Gustafson and Branch (1997), well known almost anywhere instructional development was taught. Their model is praised for their very readable text and continual updating of the model by emerging developmental philosophy.

For the purpose of this study however, Yang's Generic Model (Fig 2.2) was chosen (Yang *et al.*, 1995) as a basis, since it evolved from a generic model of instructional design that best suited constructivist ideas and flexibility of introducing and integrating computer software into the curriculum. Yang's model is broken down in three main phases viz. I. Analysis, II. Development, and III. Evaluation, and is similar in nature to the previously discussed models, all of which possess the same three general phases. This model was also found to be highly constructivist in its philosophy.

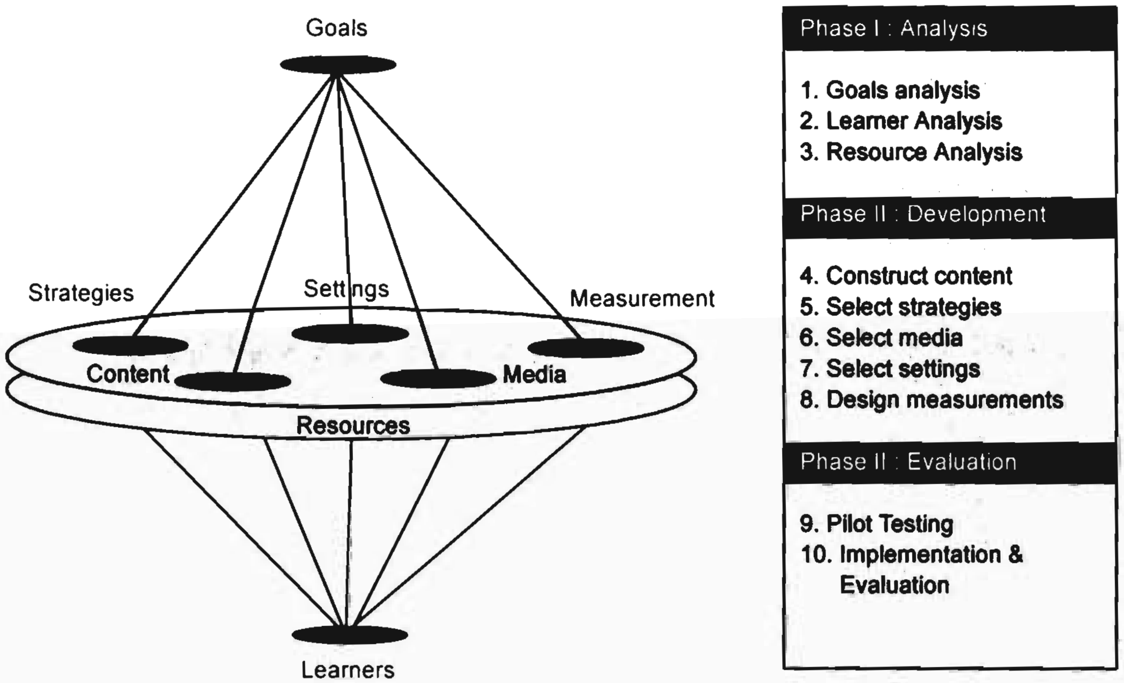

Figure 2.2: Yang's Instructional Design Model (Yang *et al.*, 1995, pp. 62)

Good technology design begins with the same principle as designing conventional curriculum, in which it is suggested that constructivist models are more suitable than its predecessors (McManus, 1996). As an example given earlier, constructivist models of development serve to inform the gathering of information about students, the learning context and the performance context (Dick, 1997). It can suggest components to be included in the learning context and ways in which learning can be particularly useful for integrating software into curriculum. Starr (1997) stated that constructivist models using technology provides a higher level of student involvement such as problem solving and increased learner control.

2.5.3. Phases of Software Development

Although the general software design model consists of design, development and testing (Barker, 1990), developing educational software is thought to consists of analysis, design, implementation and evaluation. In Persico's (1997) breakdown of the developmental phase, the author indicated 'requirement definition' and 'specification definition'. Data pertaining to requirements is usually a product of analysis of several variables including problems (weakness with current settings), needs, contexts and resources. Specifications on the other hand, includes clarifying aims, choice of media, instructional strategies and evaluation of cost and benefits.

In presenting 'analysis' as the first developmental activity, Persico (1997) stated that analysis to address weaknesses in the system should be conducted in areas such as teaching methodology, subject matter, student motivation, student numbers, or combination of these factors. Once weakness of the curriculum have been assessed, developers need to analyze requirements and constraints e.g. resources, available tools and even costs involved (Chen, 1993) and document proposed specifications such as aims, subject area profile, strategies. Curriculum developers and teachers also need to analyze learner goals and resources (Yang *et al.*, 1995) and in many cases this will involve collecting information about learners and their environment.

Software design, or formal production, consists of the actual building of the software once the initial analysis; strategizing and planning are complete (Yang *et al.*, 1995). The process usually begins with the content, and as mentioned earlier, content is usually supplied (for the developer to work with), or content is created directly in an electronic format. Content design created from new or modified from existing material is usually affected by the instruction design model chosen (e.g. constructivist model). Once the content has been synergized with the model, the process is followed by graphical artwork, information structuring formatting, and final media production (Yang *et al.*, 1995). Thereafter, content, graphics and the 'technology enhanced' pedagogical interface (discussed later) are integrated and are usually pilot-tested (Persico, 1997) with accompanying manuals.

Once software has been developed and tested, it has to be implemented. Richards *et al.* (1997) stated that implementation should fulfil three important pedagogical activities viz. assessment, remediation and the provision of student performance support tools that facilitate effective and efficient skill development. During the intense pedagogical activities that are expected to occur during implementation (discussed later), developers need to play a role in maintenance and testing. Often enough, problems will occur that need to be dealt with immediately to prevent unpleasant experiences for students. Brown (1995) listed specific examples such as: adapting to a changing environment, responding to user requests for improvement (hardware, software), and correcting bugs. Finally, the developer needs to ensure that the entire process is managed fluidly and efficiently. Management includes meeting tasks and deadlines, coordinating resources such as hardware, software, assistants, time, materials and space settings (Brown, 1995) as well as documenting and collecting evaluation results (discussed later) of the project.

2.6. Technology enhanced learning

Of the four main phases of development (analysis, design, implementation and evaluation), design is about *the* most important, since it requires skills and proficiencies of many different players including curriculum developers, content builders, artists, programmers, teachers, and students. It is a process that involves the crucial blending of pedagogical, psychological and technological philosophies. In this section components of successful technology enhanced learning are presented together with associated aspects that support the cognitive and practical processes that take place in learning.

The main purpose of developing technology-based learning software, is to engage learners in practical activities that allow them to apply what they've learned. Richard *et al.* (1997) argued that technology promotes an active style of learning. McDonald and Ingvarson (1997) stated that the aim of technology is to provide an environment, which removes constraints and enables teachers to implement new goals which address the needs of the modern day classroom and offer skills that are otherwise not available in conventional settings.

2.6.1. Specific components of technology enhanced learning

Often in research authors focus on specific learning activities or components related to software development and the learning environment that have come to hallmark good educational software use. The following section describes software and environmental components which include information navigation, searchable database knowledge, simulation learning, interactivity, self-paced learning, motivational features, feedback, guidance and support, communication (dialogue) and collaboration (group-work). These components are what are believed to offer technological advancements over conventional teaching, particularly when used in combination.

Computer technology presented tremendous advantages over conventional books, due to its potential for information navigation. Navigation is the process whereby students move through or explore (Greening, 1998) different places within the information system. Information is traditionally sequentially and rigidly (Starr, 1997) presented, although its true nature is more dynamic and cross-linked.

In the modern classroom, students can view information in a non-linear constructivist way (Greening, 1998) via a myriad of navigation tools offered by computer technology. These non-linear capabilities can provide students with a range of possibilities to explore patterns of regularity or concepts (Kumar and Helgeson, 1994). Students can move uniquely from place to place at their own speed, reviewing, assessing, and obtaining feedback where necessary and explaining in more detail on items based on their own personal intuition and interests (Graziadei and McCombs, 1995). This gives them the potential to develop their own personal learning pathways (Starr, 1997) and elaborate on specific content areas at their own discretion.

On the Internet, for example, this is made possible by hyperlinks, which may link students from one section to another, or to a completely different site all together. Because we learn by association (Graziadei and McCombs, 1995), hyperlinks are logical ways of relating similar information (i.e. information that may posses hierarchical or related properties) that may often not be, traditionally speaking, in the same physical place.

On a practical level, this immediate linking of information saves students the tedious task of having to search for information (in an index for example) thus loosing focus. Starr (1997) stated that this basic level of interactivity allows students valuable control over their own learning, which can be uniquely traced or logged. This information can be valuable to students who wish to retrace or assess and consolidate their learning (Greening, 1998). Students can use this information to recap or review those sections that they encountered difficulty with, as well as discover the 'larger picture' of the knowledge system.

There is a danger, however, associated with too much navigation, or open consultation (Jarz *et al.*, 1997) where students have access to all the information. Jih and Reeves (1992) argued that learners interacting with highly navigable systems may become confused and loose track of what they are locating in the program and may result in frustration and inefficient use of the software. It is here, where a compromise between navigation and guidance (Jarz *et al.*, 1997) both in the program and externally (i.e. assistants) may prevent students from becoming disorientated (discussed later).

Knowledge in many cases comprises of distinct pieces, or components, that relate together. When stored on a computer system, they can be put into a database, which can be easily searched via an alphabetical index or via powerful keyword search engine (Jih and Reeves, 1992). Databases are traditionally designed to store information in one place so as to reduce redundancy. Having information in one place makes updating and adding content much effective thus fostering integrity of the knowledge base. Electronic databases that utilize network technology can make vast amounts of information easily and globally accessible to more than one user simultaneously.

The value to students, however, is that that specific information can be found immediately and incorporated into their own learning strategies. In other words, the way information is stored does not have to make sense to the computer, but must be readily sourced by the students to integrate into their own knowledge structure. The speed at which information can be retrieved may determine the ease and comfort of learning experienced by the learner. The database knowledge model can easily be incorporated into constructivist philosophy, since it allows students to actively build their own knowledge quickly and effectively.

Computer technology has an made immense impact with respect to simulation capabilities. It has been used since the early 1960s in military, medicine and aviation sectors for example. Theoretically all electronic hardware can be simulated reducing the cost of using actual equipment for training and teaching purposed. Simulation technology has also made its way into education. It can be used to teach students about concepts and systems that are otherwise expensive or difficult to obtain and demonstrate in the classroom. Simulations are primarily used in education to run experiment and tests (Brown, 1995). Students can test their hypotheses and input values and get immediate feedback and make immediate alterations. Simulations have also shown to be useful in 'hands-on' assessment and studying student decision-making (Kumar *et al.*, 1994). Even computer games have been shown to foster constructivist-learning skills by simulating "problem based" virtual worlds (Amory, *et al.*, 1999).

Interactivity is probably one of *the* most commonly used buzzwords in educational software yet it's meaning still remains unclear to many. Wills (1996) related the various assumptions of the term as: "simple electronic page turning, hierarchical menu choices, point and click browsing systems, or testing and tutoring on black and white facts". True interactivity, however, goes beyond static pages and page linking. "Typically, the term interactivity is directed at the level of the interface – the user takes some action and the computer responds to that action" (Aldrich *et al.*, 1998). Starr's (1997) definition is along the similar lines where the user transmits data and receives response from the system immediately. This implies a two-way relationship between the user and the software in an active environment where "learners engage in problem based manipulation of information" (Wills, 1996).

Aldrich *et al.* (1998) argued that proper interactivity is synonymous with cognitive activities such as learning, problem solving and memory tasks. Although all types of media offer some form of interactivity, technology based interactivity is specifically designed to engage the learner in external behaviours such as making choices, answering questions, and solving problems (Jih and Reeves, 1992). From a practical and software design point of view, Aldrich *et al.* (1998) stated that the following components are desirable in developing 'two-way' interactive software: visibility and accessibility, manipulation of information and note-taking, creativity and combination of thoughts, and experimentation and testing (simulation). Also, the two-way nature of interactivity between the student and software can be individualized, adaptive and personal to provide individual unique experiences (Price, 1991). Aldrich *et al.* (1998) argued that this type of interactivity (i.e. different navigation and control mechanisms) is useful in catering for different learning styles that exist amongst students.

According to Ward and Tiessen (1997) however, such technology is still in its infancy with respect to the Internet, since many web sites are passive with interactivity being limited to 'point and click' with very little intuitivity (i.e. students knowing what to do). There is also the danger of 'assumed interactivity' where software may contain fancy trimmings, but may included instances of bad pedagogical design (Greening, 1998).

Another valuable aspect of technology-enhanced learning is the ability of learners to engage software at their own pace and be placed in control (freedom to inspect or ignore any or all of the information) in a mature and scholarly way (Taylor, 1996). This form of self-directed (Berge, 1997), non-linear persual of knowledge is in keeping with the constructivist model of learning (Kumar and Helgeson, 1994) in which self sufficient and self-regulatory behaviour sees students becoming less dependant on external support (Choi and Hannafin, 1995).

Students are expected to manage their own time and deadlines (McDonald and Ingvarson, 1997) and work without constant intervention or supervision. The teacher-student model undergoes change with the teacher engineering situations to place control and decision-making with students, resulting in personal exploration of knowledge (Taylor, 1996). Student become responsible for learning (Needham and Hill, 1987) and ownership of tasks (McDonald and Ingvarson, 1997) and control becomes less of an issue. Teachers are transformed from directors to trouble-shooters and monitors.

Technology may also offer a intrinsically motivational and enthusiastic environment that is not otherwise attainable by conventional means. Almost any subject matter expert has the potential to create and present exciting interactivity learning experiences. Using technology can invigorate the way we teach and the way students learn (Graziadei and McCombs, 1995). If software is designed to promote constructivist knowledge building and interactivity, students become more aware of changes in their ideas and review their learning (Needham and Hill, 1987).

During the life cycle of learning, (i.e. interaction with the knowledge system), students require feedback when performing tasks and engaging in cognitive activities. In most cases, this feedback is provided long after students have interacted with the information. Feedback, by definition, helps to minimize confusion and misconceptions during learning which may be normal when students build knowledge. Conventional feedback is usually slower and takes the form of written comments or marks at the end of the course, i.e. exists as a separate phase after interaction with learning material (Anderson, 1997).

In group-settings however, feedback becomes a reality since, students can discuss problems or bring to attention misconceptions of others immediately (often in the form of healthy debate). Anderson (1997) argued that feedback in this form may serve to highlight, or focus problematic areas that can be rectified immediately.

Technology too is being deployed to provide real-time feedback which improves skill acquisition (Richards *et al.*, 1997) and the overall learning process time. Technology can effect both the quality, i.e. unique to each user (Graziadei and McCombs, 1995) and speed of response that ultimately fosters a more fluid passage by students through the learning system. Remediations by students are then carried out during the learning process (Richards *et al.*, 1997) and are more likely to be transferred to deep memory (Anderson, 1997). Richards *et al.* (1997) provide an example of web-based tests and tutorials that can provide students with tools that can test, mark and remediate their knowledge almost instantly providing feedback to both students and teachers.

It was mentioned before that too much navigation in software could leave students with a sense of information overload and confusion. Students therefore need a substantial amount of guidance over and above that provided by the software. Assistance can be provided by the teacher, the software developer, or assistants that have been trained in the use of the learning software. Students who are given generous access to information resources are most likely to learn something if they are given proper support and guidance (Wilson, 1995). The author stated that the learning environment is transformed from the conventional 'controlled and directed' form to the fostered and supported 'learning environment'.

The author also mentioned that guidance needed to be managed in order to maximize the functioning of the learning environment, which by now consists of the student, the teacher (facilitator), the learning software and the support staff (guides). Brandt *et al.* (1993) stated that guidance involves observing and helping individuals while they attempt to learn or perform tasks. It includes directing learner attention, reminders, hints and feedback and challenging learners with additional problems. Guides themselves can also assist in identifying misconceptions and providing verbal explanations and examples where deemed necessary, thus maximizing the learner's use of cognitive resources and knowledge, in other words, guides themselves, become an additional resource that students may, in directing their own learning, choose to use.

Learning is about communication, being able to translate and transfer an experience or concept of what one has just learned. It is probably *the* most powerful way humans interact and transfer personal knowledge and views. McDonald and Ingvarson (1997) maintained that people strengthen their own learning when attempting to relate to others. By communicating information, learners help to correct misconceptions and provide other ways of perceiving information to form powerful memories. Communication in technology enhanced learning environment may take two forms. Firstly it can involve placing students in groups working with the software, or technology itself, can be used to link students and teachers that are geographically displaced.

Students communicating in groups become more aware and critical of each other's views, ideas and inputs (Collis, 1997). McDonald and Ingvarson (1997) argued that putting students in groups, particularly one where technology use is involved, produces a varied amount of reactions and behaviours depending on individual interests, abilities and initiative. These authors stated that the range of such outcomes are itself a valuable result since it allows individual the scope to achieve individually, yet undergo stronger learning from the group experience through the process of constructing shared knowledge. Here, problem solving and creation is a shared and consolidated process which forms quicker and possibly more accurate that individual attempts.

With respect to technology-based communication, Lake (1995) stated the that Internet presents students with the perfect communication medium and regards the Internet as a 'place to talk'. The author listed early examples such as text exchange and conferencing forums. According to Lake, communication, particularly technology based, itself becomes an acquired skill. Trentin (1996) added that this form of 'interpersonal communication' makes it possible to organize conferences, on-line distance courses and co-operative production. The Internet today has provided people worldwide with a host of communication tools including electronic mail, bulletin board systems (BBS) and even on-line databases for class projects (Collis, 1997).

In communicating information in the classroom, it becomes part of a community, rather than part of an individual. Although it is possible to learn without discussion, there is a great need to support deep learning through peer-group dialogue (Anderson, 1997). While communication is a component of collaboration, collaboration is different from communication in that it involves people working together to build new understandings that would not otherwise be achieved working individually (Schrage, 1990).

Collaboration is inherent in everyday activity, problem solving and interacting with others (Choi and Hannafin, 1995). Students negotiate meaning with others, share responsibility for learning and consolidate their learning (Dwyer, 1995; Trentin, 1996). Students clarify, elaborate, describe, compare, negotiate, and reach consensus on the meaning of various experiences (Hooper, 1992). Anderson (1997) stated that grouping students leads to increased cohesion and social integration compared with conventional forms. Furthermore, the total workload can be reduced by assigning different tasks to people (Graziadei and McCombs, 1995) thus forming a collaborative, harmonious learning environment (Dwyer, 1995).

Although various ways of exploiting technology in education have been appraised above, McNaught *et. al.* (1994) raise a critical point concerning the ultimate adoption of technology. These authors maintain that in order for technology to offer long-term benefit, it needs to be supported and nurtured over a sustained period of time. They further argue that this requires dedication from project members who possess vision; commitment and innovative thinking that can maintain high levels of energy, work and enthusiasm.

2.7. Assessment and Remediation

Assessment is another facet of education that can be enhanced by the use of technology. According to Choi and Hannafin (1995) assessment is a multi-dimensional process involving diverse measures and standards related to student thought, behaviour, or performance. Good assessment practice allows teachers to demonstrate the quality of their students and encourages students to engage in meaningful and in depth learning by testing the limits of their understanding (Nightingale *et al.*, 1995). Traditional assessment however, is very problematic. According to Kumar *et al.* (1994) it is very didactic in that it tests knowledge recognition (memorization) and recall (Choi and Hannafin, 1995) rather than problem solving skills. Furthermore it can become very time-consuming with large class groups.

The use of technology in assessment has thus far been restricted to automated multiple choice question marking (Kumar *et al.*, 1994), but with the use of technology interfaced with cognitive psychology, these authors believe that it can be used to assess the process of learning and problem solving in science education. Together with a style of interaction, Richards *et al.*(1997) believe that assessment activities can engage learners to apply what they have learned. Research into computer-based assessment, however, is still in its infancy and relates to much research on 'artificial intelligence' and similar monitoring systems.

2.8. Evaluation of Education Software

With the multitude of educational packages being offered today (both multimedia and Internet), teachers are faced with tough decisions on what packages to choose. The decision process is twofold. Teachers need to (a) decide between competing packages, and (b) determine the extent to which the package they have chosen will fulfil their curricula and learning needs. Often enough there is not enough time to use and evaluates more than a few packages before they need to be used by students. Also, from a developmental point of view, teachers who produce their own learning resources need to evaluate its usefulness in order to qualify the use of the technology and to provide both quantitative and qualitative data on its strengths and weaknesses, thus making the process of evaluation and development cyclic.

The following section presents theory behind software evaluation. It focuses on the problems and needs and purpose, types of evaluative research, evaluation models, and finally a description and nature of some of the criteria used in evaluation. Evaluation, however, like development is not a recipe. Instead, developers need to analyze their unique needs, students and environments in order to decide the best way in which to evaluate the entire learning process.

Zahner *et al.* (1992) posed several questions asked by evaluation in general. Is the software accurate? Does it match curricular objectives? Is it instructionally sound? Is it technically adequate and most importantly, do students learn the skills that the program is designed to teach? Furthermore, *when* does evaluation occur? During learning or at the end? Castellan (1993) believes it is continuous, ranging from immediate feedback during software use to long-term assessment. The entire process of evaluation however, is thought to include more than just this. It may also include student performance data and attitude data (interviews with students) that contribute towards the overall evaluation of not only the software (Zahner *et al.*, 1992), but interaction with it as well. Although transformation of education via technology cannot occur without evaluation (Castellan, 1993), its will ultimately come down to outcomes, i.e. the quality of student learning, which is thought to be these most important component to evaluate.

2.8.1. Problems, Needs and Functions of Evaluation

A need exists for criteria and procedures to help students and teachers to evaluate the quality of information that they using as learning resources (Wilkinson *et al.*, 1997). In evaluating commercial resource guides, the above authors found that there were no guidelines or criteria for evaluating the "quality" on-line content, with many of the main guides rating sites along aesthetic criteria. Also, many teacher are being disappointed with software packages that look appealing but fail to deliver pedagogically (Aldrich *et al.*, 1998). This author stated that many CD-ROMs for example, are just a 'mishmash' of images and sounds that offer little more than light entertainment.

With respect to evaluating such material, most evaluation instruments are concerned primarily with accuracy and scope of content and neglect interactivity advantages over traditional materials (Aldrich *et al.*, 1988). Teachers are busy people, with little time for conducting evaluation and most tools are often long and time-consuming to use (Zahner, 1992). In these cases, teachers often rely on judgement by commercial evaluation services, whose evaluations are often different (Reiser and Kegelmann, 1994), each based on their own varied interpretations.

Teachers traditionally conduct evaluation, but with the development of new technologies, students, teachers and even other educational parties may play a role in evaluating software. According to Persico (1997) subjective evaluation of software involves presenting initial prototypes and/or documents to impartial experts other than the authors, who include subject experts, computer science experts and instructional technologists, each of whom provide a different angle of feedback to evaluating the product. Persico (1997) also described "house testing" software with a small group of users in a controlled environment under supervision of the authors, as a form of evaluation. Thirdly, the author described "pilot test" in which a complete version of the software is used with a significant sample population. Such experiments are carried out in real environments yielding results such as attractiveness and suitability of the adopted approach, feasibility in real conditions, time and resources effectively required. The results of this evaluation are usually re-routed back in the development phase to improve the product for the next set of learners.

2.8.2. Quantitative vs. Qualitative Research

Evaluation is generally broken up into qualitative and quantitative methods. Quantitative analysis asks "Have the goals been achieved?" whereas qualitative analysis more openly analyses "What has been going on?" (Rowntree, 1992). According to Persico (1997), qualitative analysis is based on observation of formative dynamics and the study of everything that occurs during the learning process, as well as the analysis of variables and the results obtained. Qualitative analysis is very detailed and usually performed with a small sample, the results of which are usually open to interpretation (Jones, 1997). The focus here, is the study the system as a whole rather than measure change. Conversely, the quantitative approach gives priority to objectives and measurable data (Persico, 1997). This form measures values and applies statistical analysis to them.

Although both schools are far from compatible, Persico (1997) believes that a compromise between the two, although costing extra effort, may produce a wider range and depth of research. Jones (1997) described them as blending the human-psychological approach with the scientific objective approach. Jones argued that the synergy provides the overall picture, yet supplies behavioural and descriptive information, confirms theories, and illuminates reasoning and understanding behind observed phenomena.

2.8.3. Evaluation Tools and Models

Similar to developmental models, researchers have over the years worked on suitable evaluation models for education software. Thomas Reeves is considered to be the leader in the field of educational software evaluation. This author has published on the Internet (Reeves, 1997) several evaluation tools that allow teachers to evaluate software. Included in this set of tools are: an evaluation matrix (measuring software components on a 10-point scale), anecdotal records, an expert review checklist, focus group control, formative review log, implementation log, interview protocol, questionnaires, user interface rating form, and an example of an evaluation report. Reeves makes available these wide range of tools that serve to collect different forms of data between the qualitative and quantitative range, depending on the requirements by the developer.

Reeves evaluation model is based on ten learning dimension of interactive education (Reeves, 1992). In this tool (evaluation matrix), these dimension include: pedagogical philosophy, learning theory, goal orientation, task orientation, teacher role, meta-cognitive support, source of motivation, accommodation of individual differences, co-operative learning and structural flexibility. Reeves (1992) stated that this model, which can undergo further upgrade, addresses fundamental problems among educators. The author stated that the model has applicability in research, design, implementation and evaluation.

Other models include Zahner's simplified model (Zahner *et al.*, 1992). These authors presented a model, which is concerned with decision-making concerning software. The model prescribes that teachers should review software, identify objectives the software is designed to teach, and develop objectives-based tests and attitude questionnaires. This model however, is more technical is nature and does not describe the actual criteria or pedagogical founding behind choices made by teachers. It does however provide a very useful schematic of practical procedures involved in decision-making by students. The model also lacks explicitness and measurable values in the decision making process.

2.8.4. Evaluation Criteria

A well-developed evaluation tool is one which is explicit, quick to use, and delivers the maximum amount of information about the software. In development of evaluation tool Reeves (1997) used the concept of criterion-based checklists. Criteria chosen by this author (listed above) asks specific questions of the software, to which, users can response to from a scale of one to ten thus creating a profile of the software. In an effort to develop strategic evaluation, Castellan (1993) described a set of criteria, which the author believes can be used in evaluating instructional software and education technology in general. These criteria include technical accuracy, pedagogical soundness, substantive fidelity, integrative flexibility and cyclic improvement.

As powerful and pedagogically sound as these criteria may be, it may present significant difficulty to teachers who do not posses a background in education theory. Many common evaluation tools these days take the form of evaluation checklists utilizing questions based on the Likert scale (Reiser and Kegelmann, 1994). Teachers can grade questions from a good to bad scale or mark the absence or presence of particular components. Despite this practicality, however, there are still two problems that exist. Firstly, not all criteria are of equal importance (Wilkinson *et al.*, 1997), and secondly, questions asked may leave too much of interpretation to the user. There is a need therefore to make questions more simple and understandable to 'everyday' teachers, yet be powerful enough to provide a solid evaluation of the software.

2.9. Aims and Objectives of Study

The following study was divided into three main aims which included (a) developing an evaluation model and then using this model to (b) develop and (c) evaluate educational software.

The aim of the evaluation model in the first part of this project was to provide educators with a tool that allowed them to evaluate educational resources quickly and accurately. This included producing a tool with high-resolution criteria (specific, clear questions that did not require too much interpretation by the user) that was simple and easy to use, even by teachers who did not necessarily have a background in instructional technology. The tool consisted of two sections, the Technical and Anecdotal sections. User Interface and Pedagogy & Interactivity were included in the technical section, while Planning, Management, Implementation and Curriculum Incorporation formed part of the Anecdotal Section.

With the use of the evaluation model developed in the first part of this study, the next aim was to design, develop and evaluate educational resources for second year Biology students.

This involved evaluating the software and learning environment. The aim in this part of the study was to provide students with interactive learning material (based on sound pedagogical models) that fostered construction and building of information by students on their own. This also included analyzing the advantages of students working at their own pace and being responsible for their own learning. Furthermore, the study attempted to provide students with permanently available resources that were easy to navigate and in which students could find information easily and logically. In addition to this, the feasibility of placing information in a database was tested. This involved placing different types of information or knowledge units into a searchable database that students could easily search and construct information with.

This project also placed students in small groups in an effort to measure the advantages of communication and collaboration in groups as well as communication with assistants (guides), subject expert and courseware developer who were present during software usage. In doing so, the role of the teacher was re-examined as a facilitator rather than information provider.

In addition to evaluating the software and learning environment, this project also aimed at evaluating student behaviours, performances and attitudes during the course. Observational behaviors were obtained by placing students in challenging situations that fostered self-paced and self-directed learning experiences. By engaging students in active learning processes, the study aimed to evaluate specific skills learned by students as well as the amount of understanding (as opposed to rote learning) achieved by students. The study also intended to measure student comfort and compatibility with technology use, as well as the level of enjoyment and motivation offered by the software developed. Student performance included measuring amount of knowledge obtained in both courses as well as performance in exams.

This study attempted to characterize the difference between (a) interactive software that promoted students building their own information, and (b) software that presented students with information that was already pre-formatted according to a known structure. This involved carefully characterizing components that made dynamic, searchable content more feasible than static information.

Finally, this study aimed to use the developmental, implementation and evaluation procedures to construct a model for developing software. This model included persons involved, as well as the products of each of the development phases.

3. Materials and Methods

The following project investigated current trends and components in educational software and included the development of an evaluation tool that can be used by educators to evaluate learning resources. The theory and model behind the evaluation tool was subsequently used to develop Internet based learning resources for two undergraduate Biology courses. The resources were implemented in a computer-based environment as an alternative to conventional teaching and included pre- and posttest evaluations, paper based evaluations, evaluation via the tool, student interviews, and exam performance analyses per course.

3.1 Evaluation Model

The first part of the project was aimed at developing an evaluation tool that is both easy to use and requires no "in depth" knowledge of education theory. The "Educational Software Evaluation Tool", or ESET, was designed to enable educational practitioners to effectively evaluate multimedia and Internet-based material easily but provides understandable and comprehensive evaluations.

While many evaluation models exist, as cited above, many are difficult to use and usually require specific knowledge of instructional design and education theory. Also there is a need for quality evaluation (Zahner *et al.*, 1992; Reiser and Kegelmann, 1994). Wilkinson *et al.* (1997) stated that "A need exists for criteria and procedures to help students, educators and other Internet users evaluate the quality of information that they have located through electronic searching". Besides the general lack of reliable tools (Aldrich *et al.*, 1998), specific problems of such tools include (a) poor construction with little pedagogical thought (Aldrich *et al.*, 1998), (b) "lack of guidelines or criteria evaluating quality online" (Wilkinson *et al.*, 1997), (c) conflicting paradigms and models (Reeves and Hedberg, 1998), and (d) difficulty of use by ordinary teachers (Zahner *et al.*, 1992).

Examination of current evaluation models reveal that the nature of interrogation is, in most cases, too open ended to serve as accurate evaluation criteria and causes considerable variation in analysis (Reiser and Kegelmann, 1994) as well as problems with interpretation of results (Zahner, *et. al.*, 1992).

3.2 Tool Development

ESET was developed in the form of a checklist and aimed to increase the resolution of the interrogation by breaking down evaluation criteria into basic components that were easy to understand and evaluate. Questions pertaining to aesthetics, for example, were broken down into concrete questions that could be answered within multiple choice (4-point-Likert) or checklist (yes/no) mode (Fig. 3.1) and are usually employed to rate individual program features (Reiser and Kegelmann, 1994).

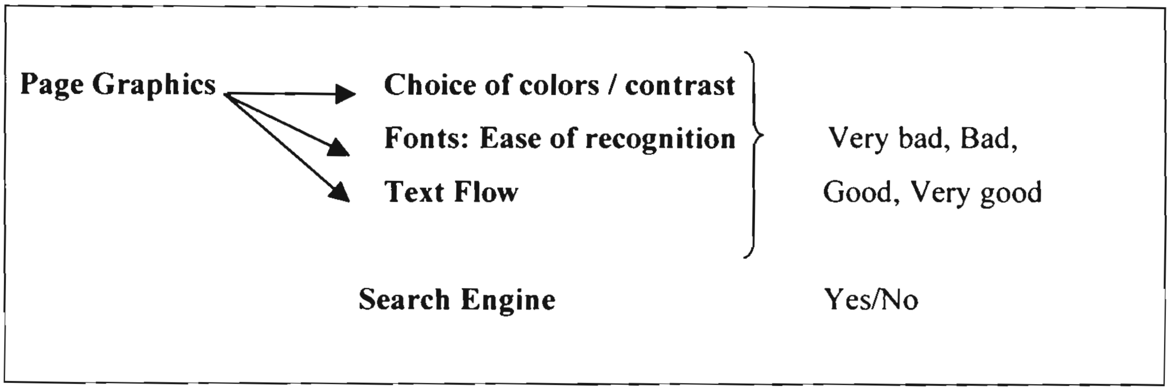

Figure 3.1: Component Based Evaluation Criteria

ESET is divided into two sections, the Technical and Anecdotal sections. User Interface and Pedagogy & Interactivity were included in the technical section, while Planning, Management, Implementation and Curriculum Incorporation formed part of the Anecdotal Section.

The first part of the tool is concerned with the User Interface design and includes criteria such as screen design and layout, navigation and interaction, instruction availability, information presentation, multimedia options, and special features. Pedagogy and Interactivity included criteria such as content, self paced learning, time management, learning styles and customization, knowledge structure and transfer motivational features, presentation of learning goals, assessment features, feedback and communication and collaboration features. A complete list of criteria used in designing ESET is found in Appendix I.

Many of the evaluation models originally consulted (Reeves, 1993 Zahner *et al.*, 1992; and Yang *et al.*, 1995) contained many aspects relating to user interface and interactivity, but did not sufficiently include "anecdotal" or "implementation record" criteria (Reeves, 1997). In the ESET model, these sections are not analytical in nature, but serve as a guide for designing, developing, implementing and managing new software and take into account actual problems and scenarios that may occur in a classroom setting. Anecdotal records and recommended practices include: logistical and technical considerations; known problem areas; data collection and processing; software considerations and; security. The Curriculum Incorporation section includes software role; improvement rating; integration; value; re-used and economic viability; expert review; and overall impressions.

The Internet was chosen as a platform to distribute the tool, as it provides worldwide accessibility and ease of use. The tool was constructed in HTML (Microsoft FrontPage) and made use of database technology (Access Database and Active Server Page, ASP technology).

To use ESET a user enters a login name and password before gaining access to the evaluation tool. The login process is used to uniquely identify each user and associated data. The evaluation tool consists of multiple choice and checklist questions and also includes form text input for additional notes (see Appendix I). After answering all the questions the inputs are analyzed using a numerical rating system and results are then presented to the user. Results are presented as total scores for each section and as well as scores for each individual component.

3.3 Software Design and Development

The second part of the project saw teaching material being converted into resource-based educational material and aimed to promote self paced, user-centered, learning resources within dynamic, socio-constructivist learning environments. Software developed in this part of the study was based on components found in the ESET model. The software was designed to improve: flexibility in design and delivery; quality; student attitude; enjoyment; and performance; integration with curriculum; and collaboration working groups.

Two second year Biology courses were selected for this part of the study. Course material included notes, diagrams and overhead slides from subject experts, as well as content from prescribed textbooks. Critical analysis of the content structure revealed that these topics needed to be presented in an highly visual format which fostered user controlled, self paced usage of resource based material, rather than sequentially presented information.

Conceptualization of the project activities was based on constructivist learning strategies rather than on behavioral modes, i.e. students had to build the knowledge from the resources provided. Although behavioral psychology continues to underline the design of most instructional technologies, including web-based learning, cognitive psychology places more emphasis on internal mental states than on behavior (Reeves, 1992).

The first topic, Carbohydrate Metabolism aimed at teaching carbohydrate utilization and energy production in cells. The course consists of a number of pathways and reactions, and requires an in depth understanding of compounds involved (their relationships), as well as control and regulation systems of the metabolic pathways. The content building blocks consisted of molecules, reactions, biochemical terminology, processes and actual pathways. These knowledge units were individually constructed using Macromedia Flash

2.0 (figures and charts) and their linking information was stored in an Microsoft Access database. These building blocks provided the material for students to construct their own representation of the pathways according to problems presented in the workbooks. The functionality of the searchable database ensured that students could find any piece of information (of various types) immediately based on their own search strategies. The glossary provided students with immediate clarification of unfamiliar terminology. The software was also designed to respond quickly and easily to student searches. The database therefore contained different views into a single knowledge domain (i.e. directly from the database search facility or from within the main text).

The interface (constructed in HTML using Microsoft FrontPage and Macromedia Flash 2.0), provided students with a series of notes, which, although static in nature, contained links into the database bound knowledge units. Information was also dynamically accessible via the database, where objects (terms, molecules, pathway slides) could be immediately viewed in separate browser windows. The process of knowledge navigation and construction was guided by on-line guides (Course Outline and Objectives) and problems posed in the course workbooks.

The second topic, Lipid Metabolism based on essays, with short topics and molecular data, was aimed at describing mainly lipid breakdown, in the human body. Notes were pre-prepared by the subject expert and converted into HTML using FrontPage 98 and Flash 2.0 for graphics and diagrams. Resources (notes, diagrams, pathways and data) were made available through an interface that grouped the information in the categories: essays, structures, processes, and transport. Students answered questions posed in workbooks by searching for information according to these categories.

Implementation of the software involved resource utilization and class activities in the computer laboratory. Resources including software, workbooks, textbooks, assistants and subject expert were made available. Activities included: personal information building, peer clarification and feedback, online testing, and problem solving in workbooks. The learning environment also promoted group collaboration and communication, active feedback and remediation from student demonstrators or subject expert, and self paced content usage.

Both courseware products were made available on the student LAN consisting of sixteen computers (Intel Pentium 233MHz) running Microsoft Window NT, with Internet Explorer 4.0 browsers and the Macromedia Flash plug-in installed. Forty-nine students working in groups of between two to three used the web-based courseware to answer questions posed in workbooks over a two-week period. Student demonstrators, the courseware developer and the subject expert were available during contact time to provide assistance and feedback to students.

3.4. Courseware and Software Evaluation

In order to qualify the benefits and value of the courseware packages, evaluation of the entire implementation process was conducted and included: pre- and post- testing of content; paper-based course evaluations (Appendix II); ESET evaluation of software by students (Appendix I); informal interviews (Appendix III); and assessment of student performance (evaluation of examination results). Anecdotal records of the entire project involved: project development, implementation logs, and Table of Specification (Dills, 1998) project evaluation to match objectives to design elements.

Anonymous pre- and posttests were constructed by the subject experts and took the form of short questions (one word and short paragraphs) that tested the understanding of the course content. These tests were administered prior to, and after, each of the courses to identify what students had learned. In addition to identifying correctly answered questions, independent Mann Whitney tests were conducted using SPSS (SPSS inc.) to determine if students had gained knowledge from the course. In order to ascertain misconceptions, students were asked to rate their confidence (a four point scale) for each test question. Regression analysis between answers and confidence responses were also conducted using SPSS.

Paper based evaluations were conducted to measure student attitudes with respect to enjoyment and benefit from the course, types of skills learned, as well as the suitability and feasibility of integrating technology into the classroom. Students were asked specific questions pertaining to: content structure; environment and learning activities; software usage; course structure; and skills and competencies. These evaluations were conducted at the end of the course and analyzed qualitatively using the software package QSR N*U*D*I*S*T (Qualitative Solutions and Research).

The evaluation tool (ESET) developed earlier, was also used by the students to provide a quantitative assessment of the software itself. Students completed and submitted sections B (User Interface Design) and C (Pedagogy and Interactivity) of the ESET tool. In addition to providing evaluations for each course, Wilcoxin Signed Ranks tests were use to compare the Carbohydrate Metabolism evaluations to Lipid Metabolism (both for sections B and C).

Performance data (examination results) was analyzed using Wilcoxin Signed Ranks tests to identify significant differences between computer based and non-computer for the current year. A combination of the Mann Whitney and Wilcoxin test was use to compare results of the two computer based topics with the previous year's results, as well as comparing each of the computer based course performances to the rest of the course. These results were computed using the statistical software package SPSS.

Finally, a sample of thirteen students, who volunteered and represented each group, were informally interviewed. Interviews, which served as "attitude data" (Reiser and Kegelmann, 1994) were conducted to probe more deeply student opinions related to the use of web-based courseware and their use of the learning resources. Students answered questions in the following categories: personal use, perspectives of higher education, the learning environment, personal value, and learning outcomes and understanding. Interviews were recorded using a tape recorder, transcribed and analyzed using QSR Nudist.

4. Results

A number of qualitative and quantitative techniques were use to evaluate the different aspects of the project (Table 4.1.). Also, the course design, development and evaluation phases are presented as schematic charts.

Table. 4.1: Matching evaluation techniques to course aspects

	Pre- and post-testing	Paper based Evaluation	ESET Evaluation	Interviews	Exam Performance
Student					
• Performance	♦				♦
• Opinion		§		§	
• Skills		§		§	
Environment					
• Physical space		§		§	
• Interaction and Guidance		§		§	
Software					
• User Interface		§	♦	§	
• Pedagogy and Interactivity		§	♦	§	

♦ (quantitative) § (qualitative)

4.1. Pre- and Post- Testing

Pre- and post- tests were used to determine student understanding of the basic course content before and after using the developed materials.

4.1.1. Carbohydrate Metabolism Courseware

In the Carbohydrate Metabolism course, students (n=49) scored an average of 15.8 ±1.4% which increased to 34.7±1.4% in the post-test (n=44). Using a 95% confidence level, there was a significant difference (Mann-Whitney test) between the pre- and post test (asymp. sig. < 0.005, $z=-6.841$) indicating that students had gained knowledge during

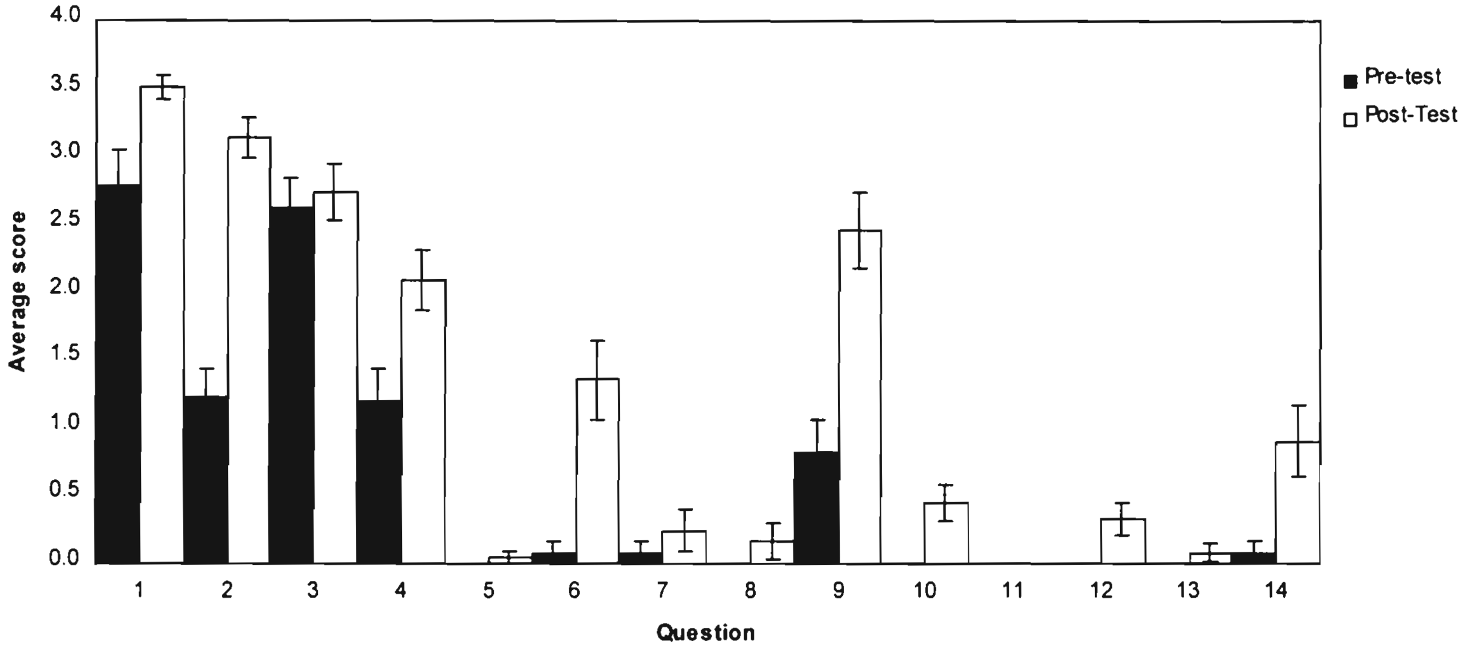

Figure. 4.1: Student performance in pre-(n=49) and post- (n=44) tests in the Carbohydrate Metabolism course (bar= SE).

the course. Students scored higher in all questions (except questions 5 and 6) in the post-test (Fig. 4.1.). In the post-test students scored the highest for questions 1,2,3,4,6 and 9 (Fig. 4.1., Table 4.2.)

Table 4.2: List of high scoring questions for the Carbohydrate Metabolism course pre- and post-test.

Question Number	Question
1	What compound is glucose converted into during glycolysis?
2	Under anaerobic conditions glucose is metabolized into which compounds?
3	Which three pathways are involved in the breakdown of glucose to oxygen and energy?
4	How many moles of ATP and NADH are produced in the conversion of glucose to pyruvate?
6	What are the two phases that make up Glycolysis?
9	What pathway is responsible for the metabolism of pyruvate?

In order to identify misconception students were asked to rate their confidence in their answers. There was a strong correlation between correctly answered questions and student confidence (pre-test r^2=0.861, post-test r^2=0.818).

4.1.2. Lipid Metabolism Courseware

In the Lipid Metabolism course students (n=39) scored an average of 26.1±1.6% for the pre-test and 34.0±2.2% in the post-test (n=30). The Mann-Whitney test showed a statistical difference between pre- and post test (asymp. sig. = 0.009, z=-2.596) indicating that students had gained knowledge during the course. Students improved in 14 of the 20 questions posed and performed worse in 6 questions. High scoring questions are shown in Table 4.3.

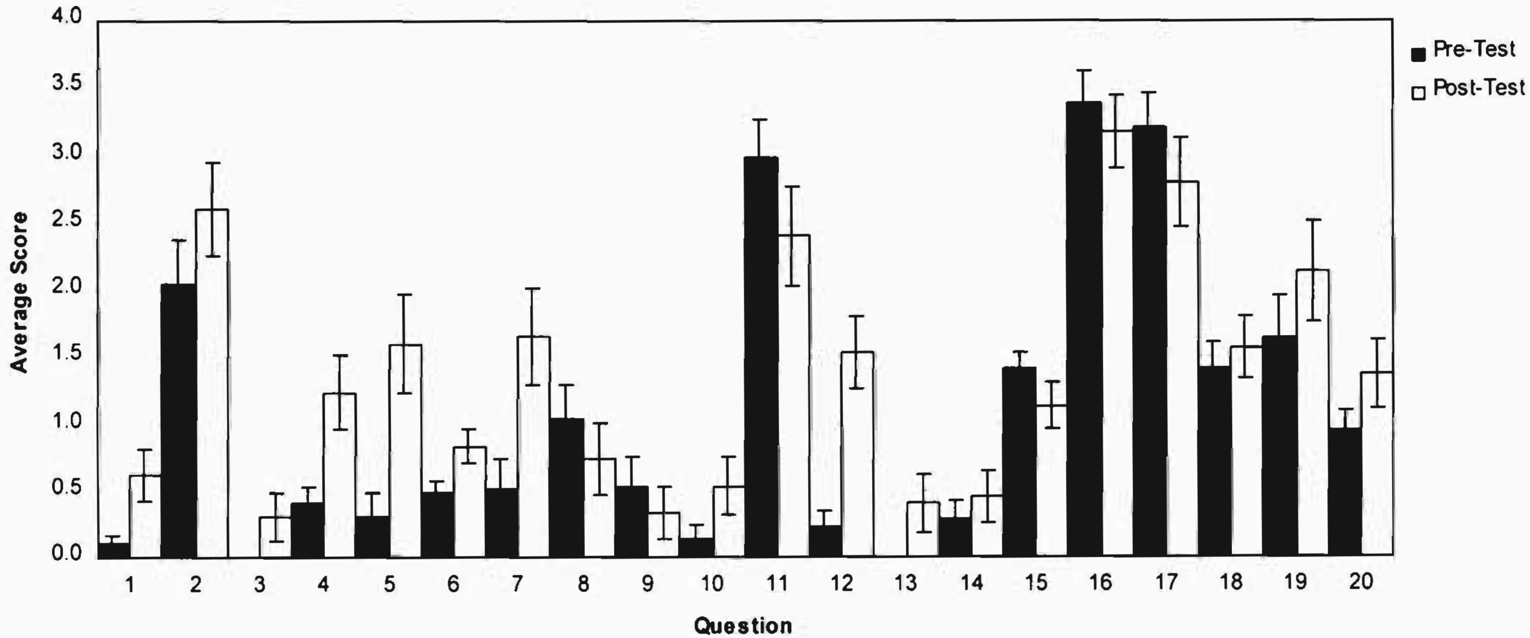

Figure. 4.2: Student performance in pre-(n=39) and post- (n=30) tests in the Lipid Metabolism course (bar = SE).

Table 4.3: List of high scoring questions for the Lipid Metabolism course pre- and post-test.

Question Number	Question
2	Name the two hormones responsible for metabolic inter-conversions
5	Which pathway is said to operate in opposite to Gluconeogenesis?
7	The Glyoxylate cycle is a short-cut of which pathway
11	In which organ does fatty acid biosynthesis occur?
12	What is the function of lipoprotein?
16	Name the compound that builds up in muscle tissue, when not enough oxygen is available during a strenuous exercise
17	Name the important eating strategy a marathon runner should employ 6 days before a race
18	During fasting or starvation, which is the first reserve to be depleted, and which reserve is the last?
19	Which organ in the body most critically requires a constant supply of glucose, since it cannot directly utilize large fatty acids.

Regression analysis indicated a poor correlation between student performance and their confidence of answers in both tests (pre r^2=0.363, post r^2=0.285). Although incorrect answer confidence limits varied, no clear misconceptions could be identified (high confidence in wrong answers).

4.2. Paper-based Evaluation

Conventional paper based evaluation were conducted to evaluate student opinion to the learning environment and use of the software (see Table 4.1.) The questionnaire was divided into six categories, which included: content structure; course structure; software usage; environment and learning activities; online testing (carbohydrates only) and skills and competencies. Responses were converted to scores (ranging from 1 to 4) and totals were derived for each category.

4.2.1. Carbohydrate Metabolism Courseware

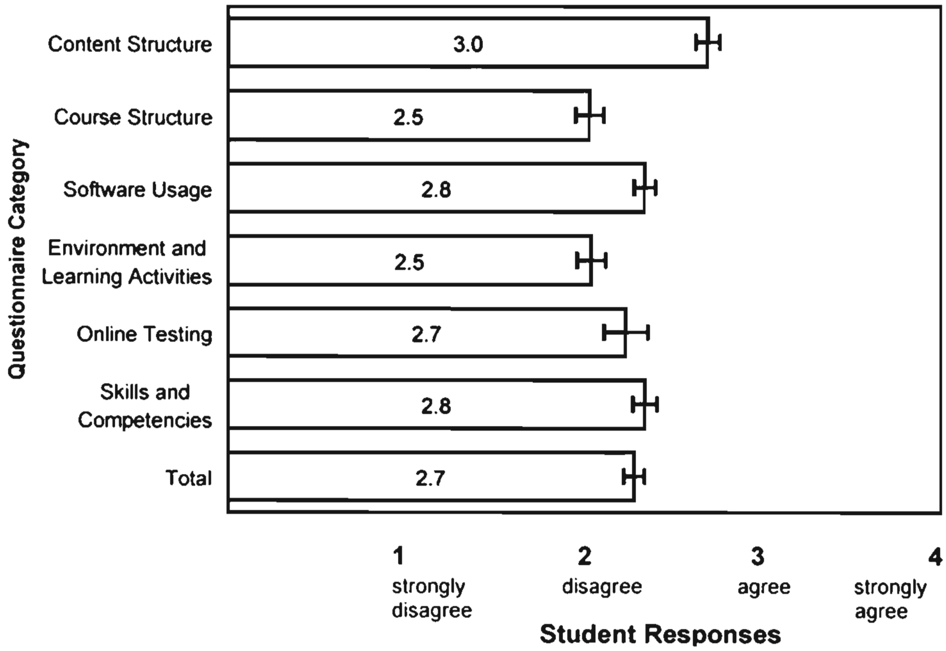

Figure 4.3: Paper-based student evaluation of the Carbohydrate Metabolism courseware (n=44, bar = SE).

Students rated content structure as the most favorable part of the course followed by software usage and skills and competency components (Fig. 4.3.). Course Structure and Learning Activities were rated the lowest.

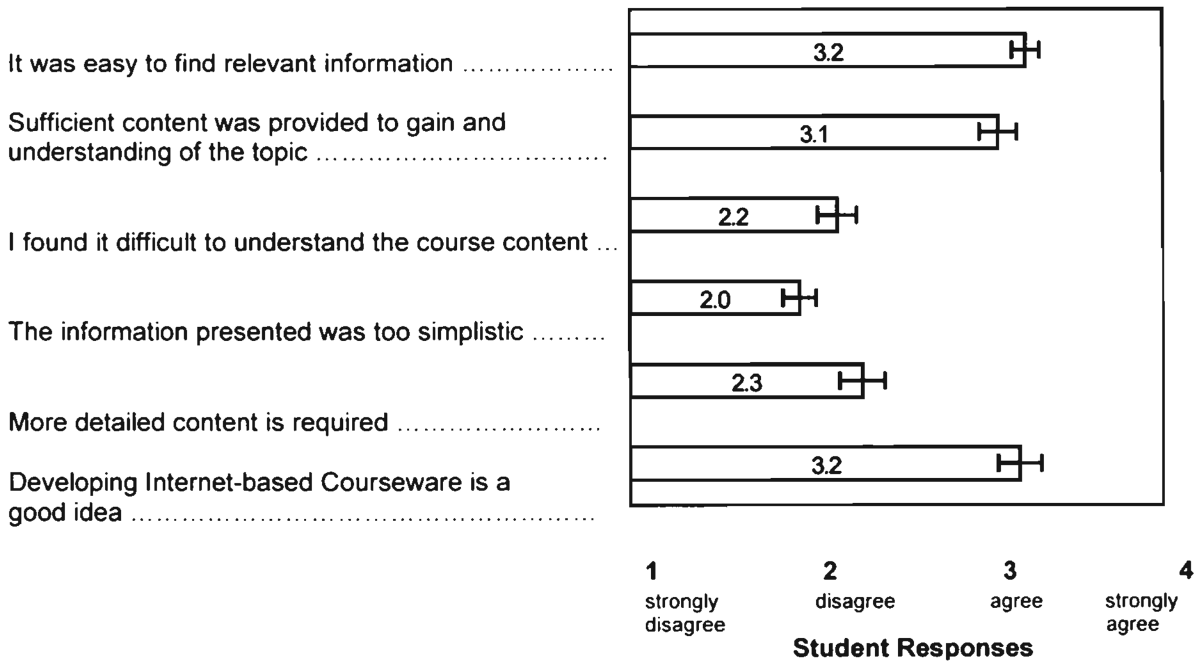

Figure 4.4: Paper-based student evaluation of Content Structure for the Carbohydrate Metabolism courseware (n=44), bar = standard error.

With respect to Content Structure, students felt it was easy to find relevant information, that sufficient content was provided to answer questions in the workbook and that the development of Internet-based software was a good idea (Fig. 4.4.). They also felt it was easy to use the software.

Although students enjoyed working with the Internet-based software, their response varied with respect to the difficulty of problems presented in their workbooks (Fig. 4.5.). Students appeared to want written notes and lectures in addition to the resources provided. They also liked working in groups.

Students regarded the workbook as their primary source of knowledge, but many of them used textbooks and library books to learn for examinations.

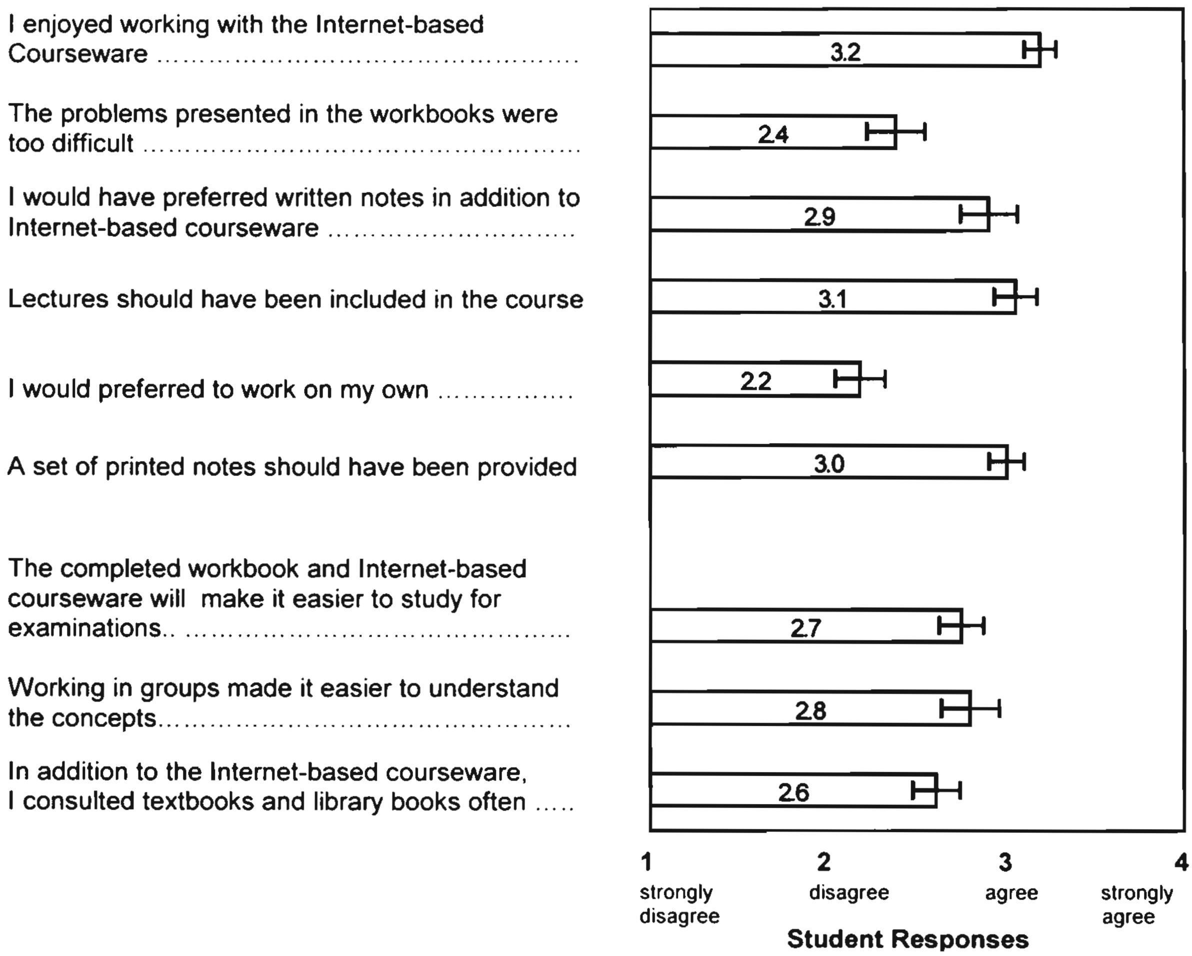

Figure 4.5: Paper-based student evaluation of Course Structure for the Carbohydrate Metabolism courseware (n=44, bar = SE).

Students commented favorably on the visuals and navigation tool of the software (Fig. 4.6.). With respect to resource types, students used the database module more the online course notes. They also referred to the pathways more than the individual molecules, but stated they used the different resources equally. Students rated both the glossary and search engine very highly. Most students found the tasks in the workbook to be slightly difficult to group and answer.

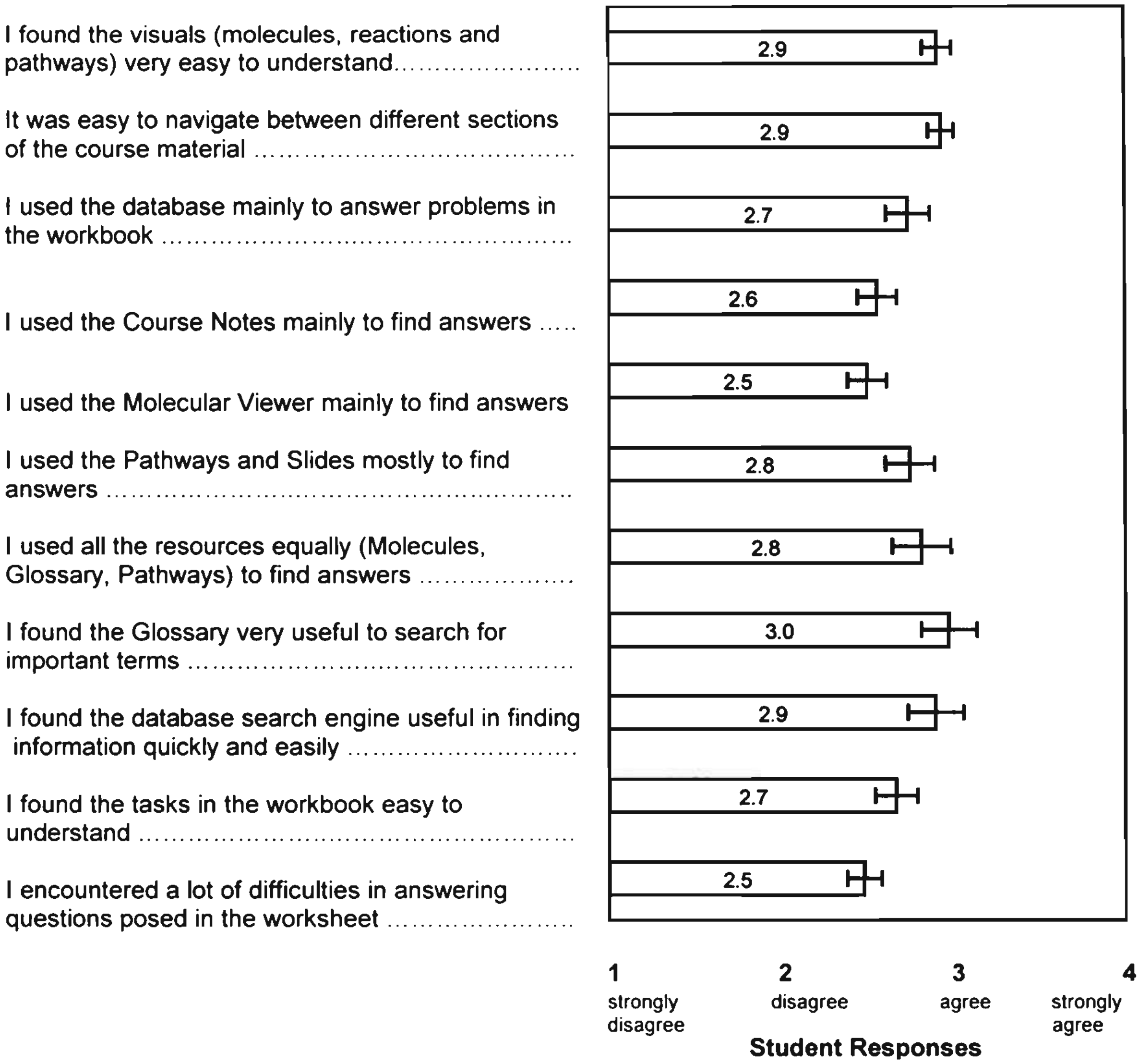

Figure 4.6: Paper-based student evaluation of Software Usage for the Carbohydrate Metabolism courseware (n=44, bar = SE).

Students found the demonstrators helpful but felt that more time should have been allocated to the course (Fig. 4.7.). They also felt comfortable working with the material in the computer laboratory, and maintained that there was sufficient communication between members of the group and with the demonstrators but did not always get answers they expected from the demonstrator and lecturers, who were asked to help students solve problems and not supply correct answers.

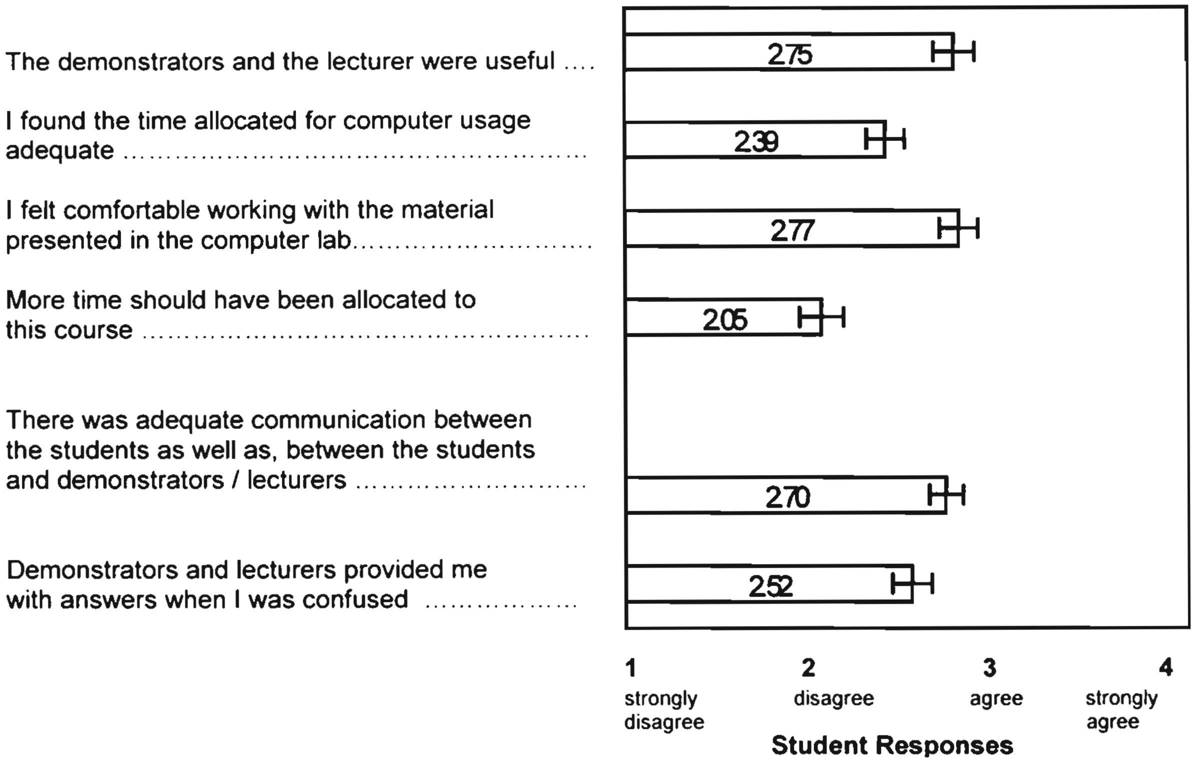

Figure 4.7: Paper-based student evaluation of Environment and Learning Activities for the Carbohydrate Metabolism courseware (n=44, bar = SE).

An online testing section was developed for the carbohydrate metabolism courseware. This included multiple-choice questions that were immediately responded to as well as short questions with model answers provided to students. There was no strong indication whether students would have preferred not to be marked, i.e. given a test score at the end (Fig. 4.8.). They did however; respond favorably to the immediate response and links to related content when answering problems in this section. They found the short questions section very helpful and not boring. A significant part of the class, however, did not make use of the testing section.

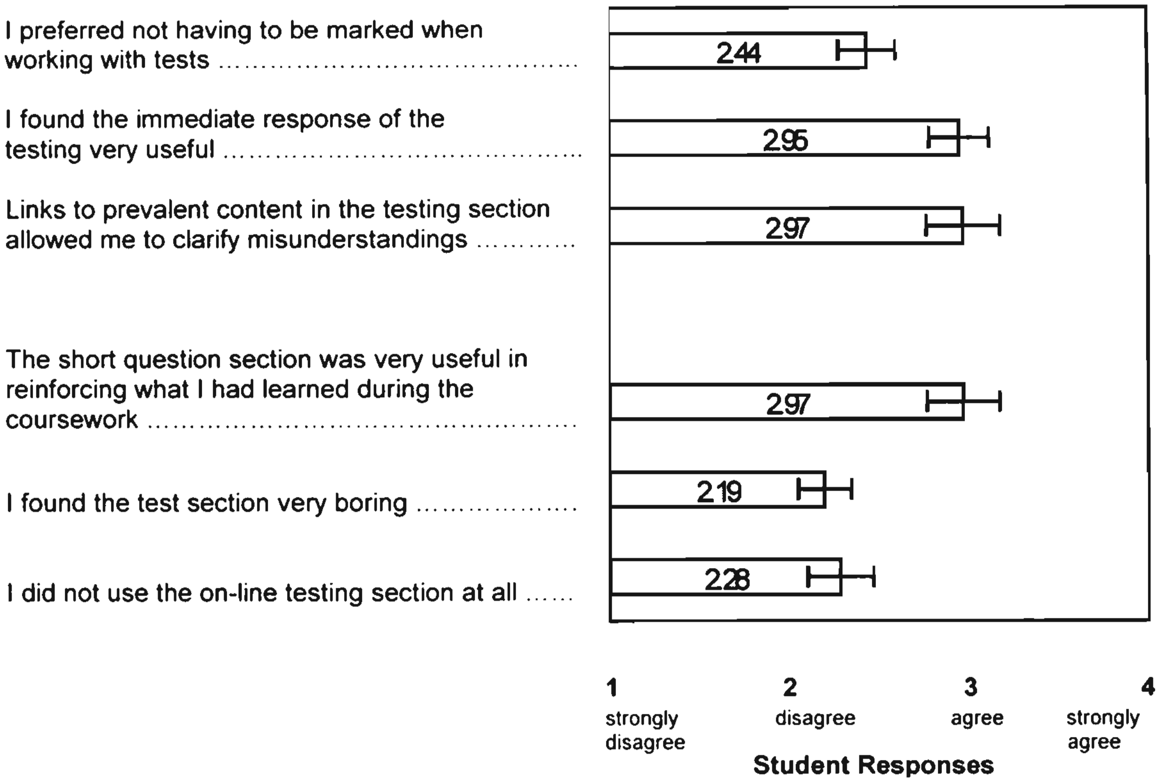

Figure 4.8: Paper-based student evaluation of Online Testing for the Carbohydrate Metabolism courseware (n=44, bar = SE).

Students confirmed earlier findings (Fig. 4.5.), commenting very favorably that they enjoyed using the software (Fig. 4.9.). They enjoyed searching for and constructing knowledge for themselves using different learning sources. Students disagreed that memory from the previous day/session's work helped them to maintain focus. There was no clear indication of whether students made use of mathematical or logical thinking skills. Response towards problem solving and the testing module was fairly moderate, although students thought that the course improved their groupwork skills. The highest rating was given to improvement of their computer skills.

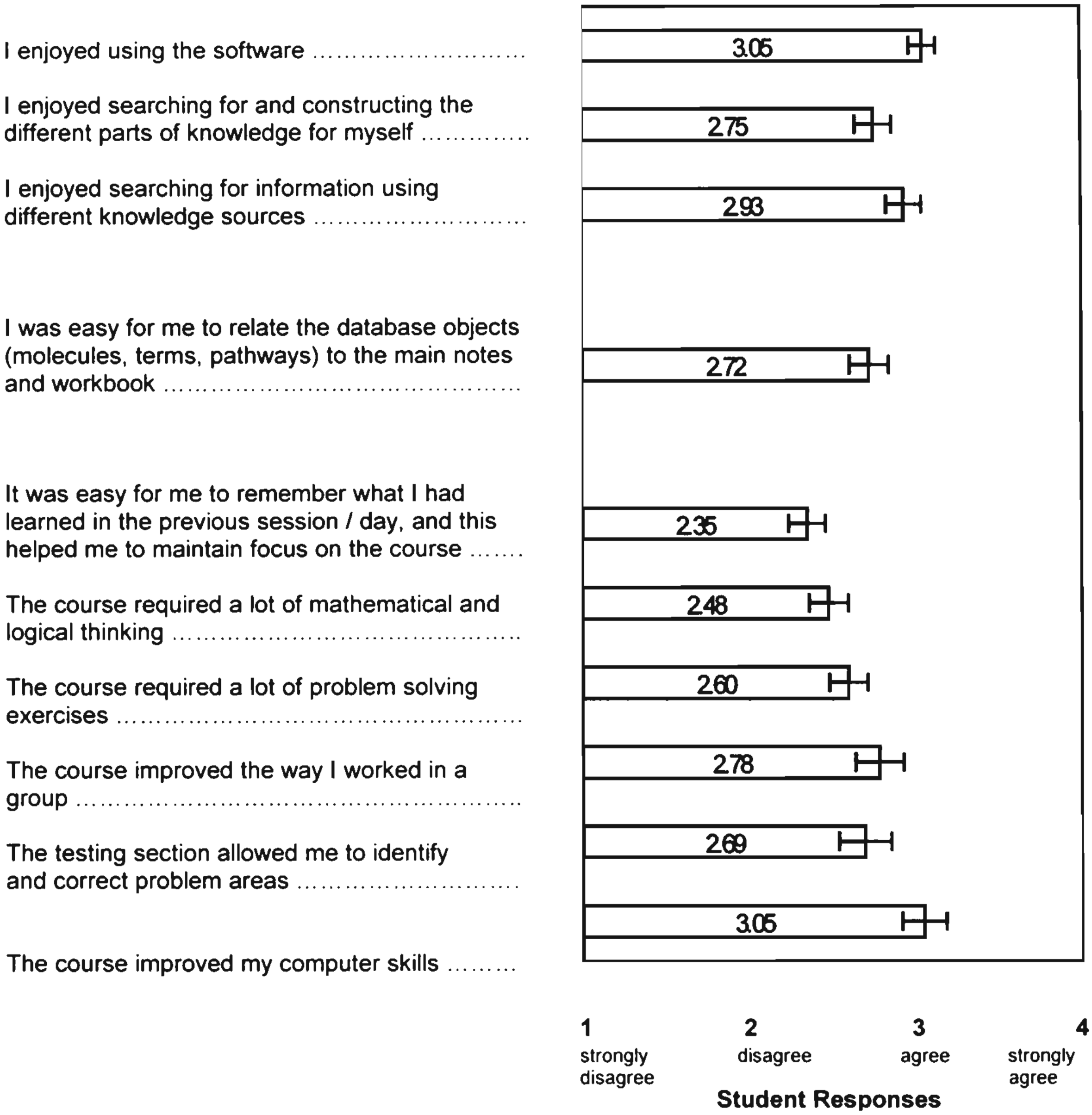

Figure 4.9: Paper-based student evaluation of Skills and Competencies for the Carbohydrate Metabolism courseware (n=44, bar = SE).

Students also provided open-ended views on what they didn't like about the course as well as ways in which it could be improved. Students identified two main problems: lack of computers (five responses) and insufficient time allocated to the course (five responses). Students would have also preferred more assistance from demonstrators, subject expert and/or course developer (four responses). Students also argued that a set of introductory lectures would have helped in guiding their learning (two responses). Two students stated that lack of computer literacy skills was a problem for them. Students also related positive aspects of the courseware such as it overall usefulness and creativity, as well as the enjoyment and facilitation of understanding.

When asked to provide feedback regarding course improvements, students, once again suggested the inclusion of introductory lectures (five responses), availability of computers (three responses), improvement of allocated time (four responses), and better support from demonstrators (four responses). Students also felt that conventional course components should have been added which include: tutorials (three responses), tests (two responses) and even essay questions (one response). Some of the user interface options that were recommended included sound and music and user friendliness.

Positive opinions included: " *..software was of a high standard and in my opinion, there is very little to be improved upon.*"; "*there is little need for improvement on software but I feel that there should have also been a few lectures during the course*"; "*fun and enjoyable to use*"; "*It was easy to understand*"; "*easy to relate to and find information*"; "*It was very easy to use and one could relate to what was in the course*", "*The way it was put one could easily remember after using the software*", "*Information given could be easily found in textbook and so it was made easy for us to get knowledge when computer was not available and it was explained quite well and it was well understood than the textbook.*"; "*Communication with other people*".

4.2.2. Lipid Metabolism Courseware

Students rated Content Structure and Skills and Competencies as the most favorable part of the course (Fig. 4.10.) followed by Software Usage and Environment and Learning Activities.

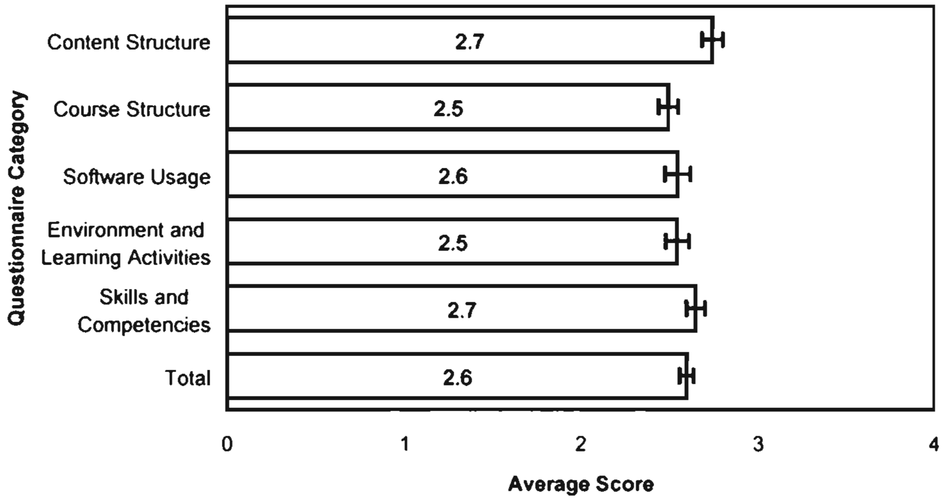

Figure 4.10: Paper-based student evaluation of the Lipid Metabolism courseware (n=33, bar = SE).

With respect to the Content Structure of the Lipid Metabolism course, students felt that sufficient content was provided but there is no clear indication that students find the information easily (Fig. 4.11.) These results indicate that students may have, to a small extent, found the content difficult to understand. They disagreed with the information being too simplistic and did not feel that additional content was required. For this course, students did, however, agree that it was a good idea to develop Internet-based courseware.

Students enjoyed working with the Internet-based courseware but did found that the problems presented in the workbook were not too difficult (Fig. 4.12.). Students once again felt they needed additional lectures and written and printed notes. They did, however prefer not to work alone, but rather in groups. Students agreed that the completed workbooks and courseware would make studying for the exam easier. They also agreed that working in groups facilitated understanding, and in some cases made use of additional resources such as textbooks or library books.

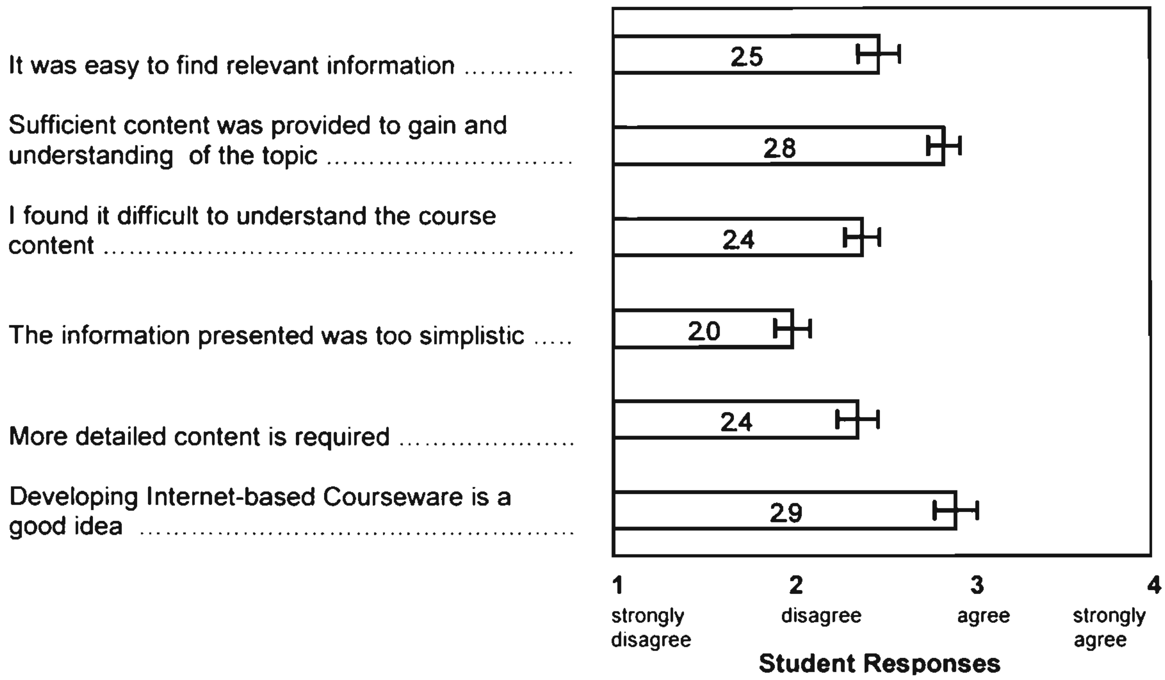

Figure 4.11: Paper-based student evaluation of Content Structure for the Lipid Metabolism courseware (n=33, bar = SE).

Students responded favorably towards the visual resources and ease of navigation system provided by the software (Fig. 4.13.). They did however, have difficulty in finding relevant content and strongly preferred having a search engine. Students found the tasks in the workbook easy to understand but did, when asked again, encountered difficulties in answering worksheet problems.

Students found demonstrator and lecturer assistance useful, but did not think that enough time was allocated for the web courseware (Fig 4.14.). Students did find working in the computer laboratory comfortable.

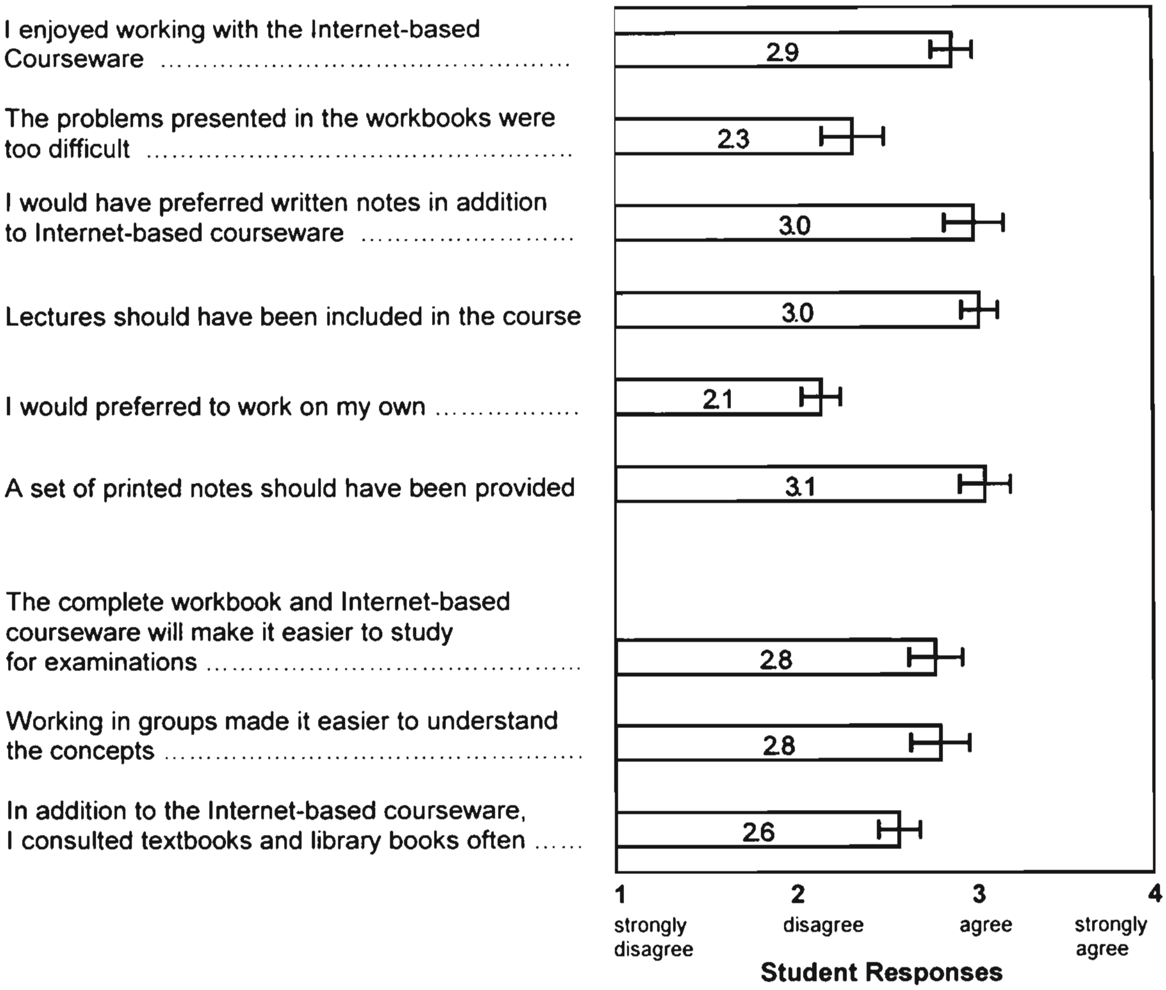

Figure 4.12: Paper-based student evaluation of Course Structure for the Lipid Metabolism courseware (n=33, bar = SE).

Students commented favorably on software use and enjoyed searching for and constructing information (Fig. 4.15.). Students did not however, agree that they remembered the previous session. They disagreed with the course requiring problem solving or mathematical skills. Students enjoyed working in groups and commented very highly on the courseware developing their computer skills.

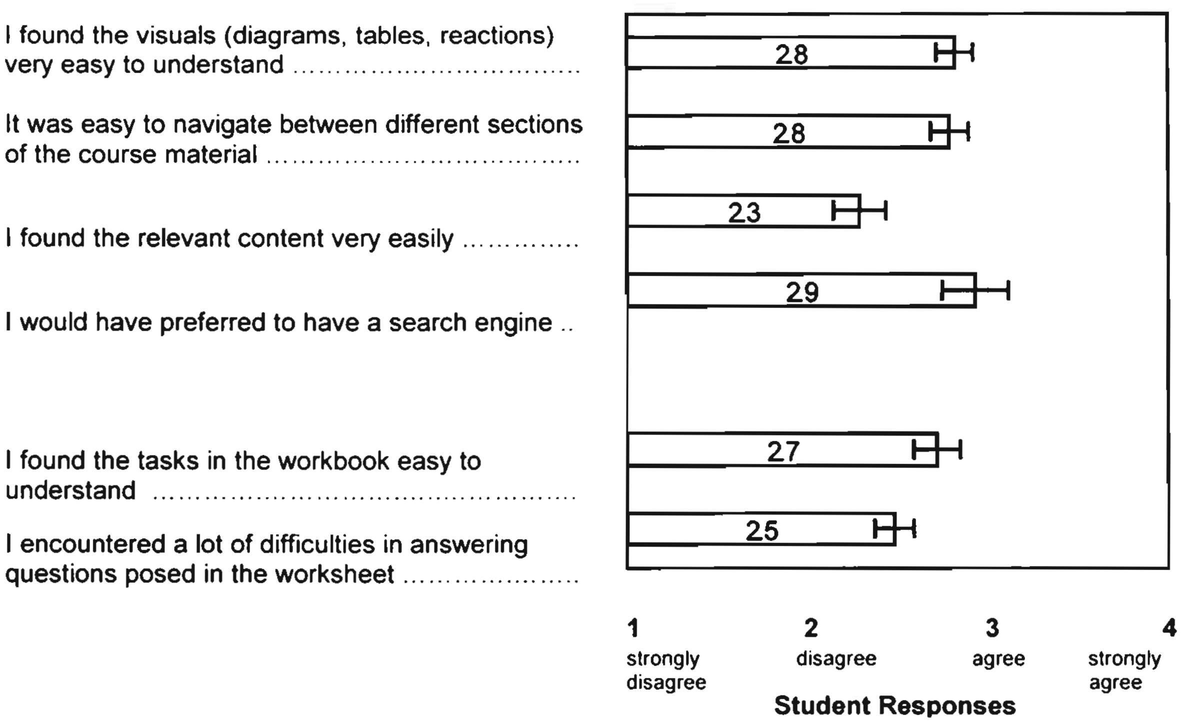

Figure 4.13: Paper-based student evaluation of Software Usage for the Lipid Metabolism courseware (n=33, bar = SE).

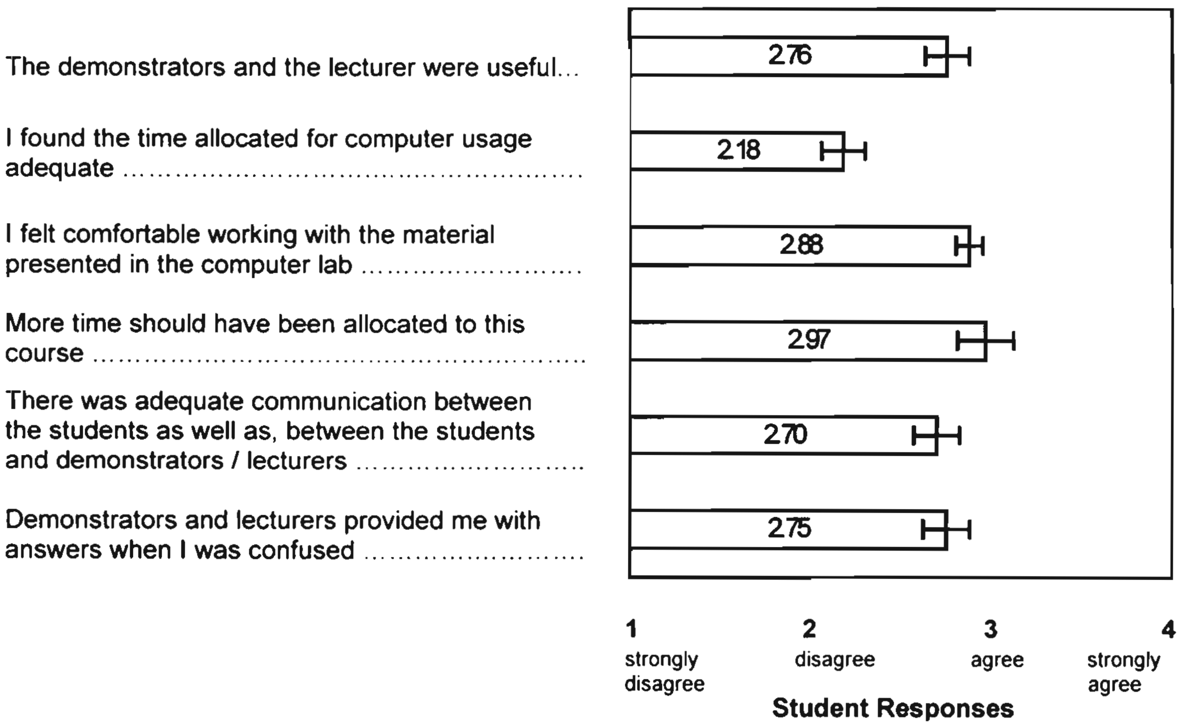

Figure 4.14: Paper-based student evaluation of Environment and Learning Activities for the Lipid Metabolism courseware (n=33, bar = SE).

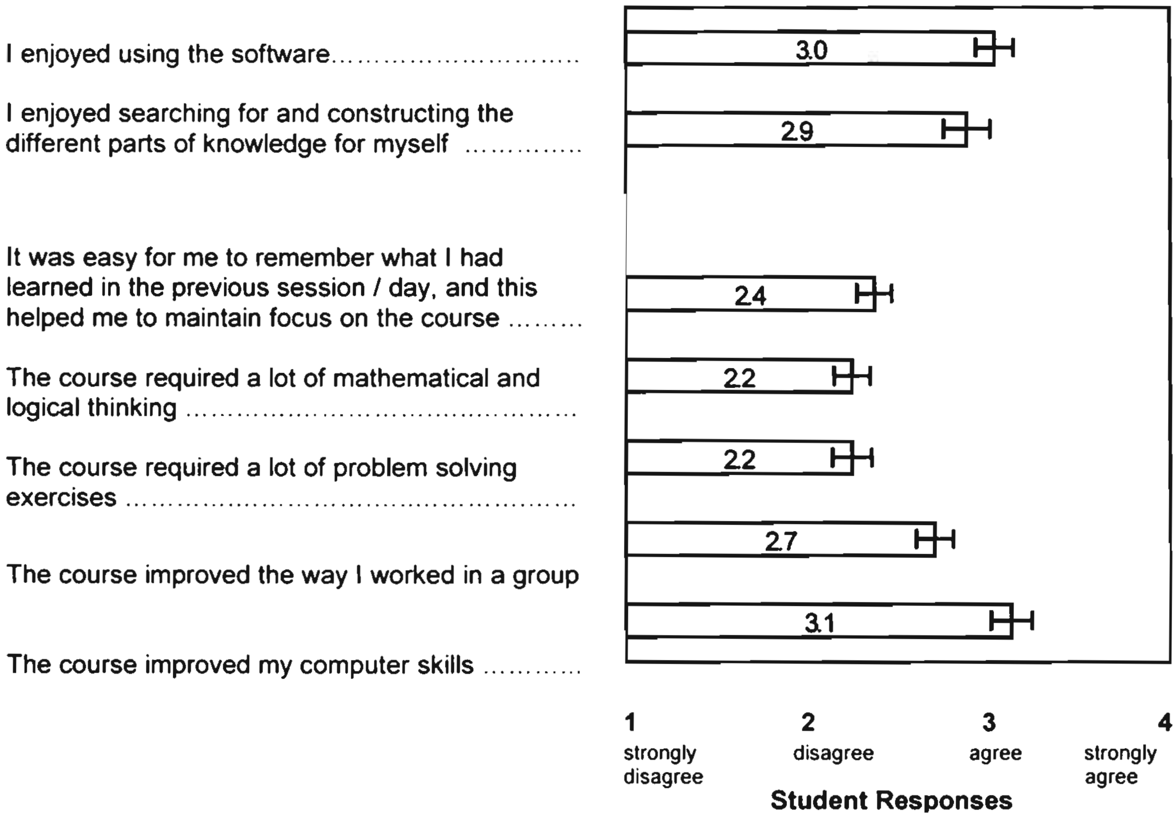

Figure 4.15: Paper-based student evaluation of Skills and Competencies for the Lipid Metabolism courseware (n=33, bar = SE).

Analysis of the open-ended questions identified three areas: user interface, environment conditions and content. Students found 'not being able to locate relevant information' as the biggest problem (six responses) and would have preferred a search engine or glossary. Environmental problems included: lack of computers (two responses); time limit (six responses) and insufficient assistance (one response). With respect to content, two students commented that it was difficult and two students thought there was too much information, although one student did feel additional information was necessary. Two students each felt that class notes and lectures should have been included. With respect to user interface, students suggested (one response each): "*a more simplistic design*", self tests, more links for continuity, and more visuals (diagrams and pictures).

4.3. ESET Evaluation Tool

The first part of this project involved the development of an education software evaluation tool (ESET). Although the tool was aimed for use by teachers, lecturers and instructional technologists, it was also used by students after each of the courses and provided a quantitative evaluation of the software itself. ESET evaluation was conducted for both courseware packages (Carbohydrate Metabolism and Lipid Metabolism)

4.3.1. Carbohydrate Metabolism Courseware

Student evaluation using ESET rated User Interface Design (72.5%) and Pedagogy and Interactivity highly (67.3%) (Fig. 4.16.). The average score for the software package, according to ESET was 69.9%.

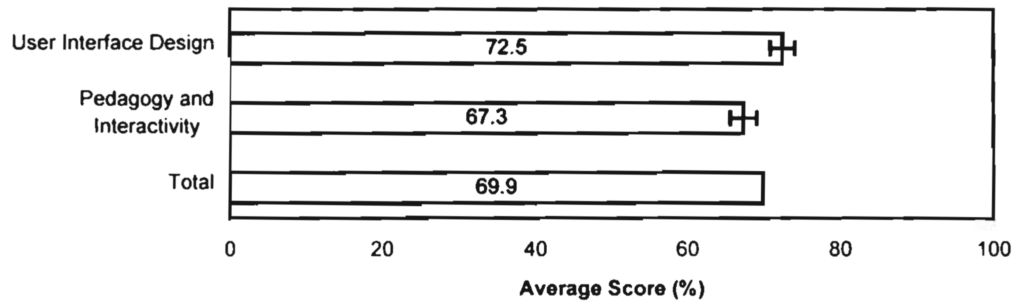

Figure 4.16: Student evaluation of the Carbohydrate Metabolism courseware using ESET (n=42, bar = SE).

Screen appearance (fonts,78.6%, choice of colors, 82.1%) and layout (text flow, 76.2%; consistency, 76.2%) scored highly in this courseware package (Fig. 4.16.). Students responded favorably to instruction availability (73.2%) and presentation (72%) as well as ease of reading (80.4%). A score of 100% was obtained for a search facility. The student evaluation of 'navigation links' (67.3%) and 'navigation ease' (78%) was high. As the software contained no features that allowed students to make references online, this aspect scored poorly (33.4%). Students found the software visually stimulating (76.2%), intuitive (72%) and improved with usage (83.3%). Quality control (78.6%) and

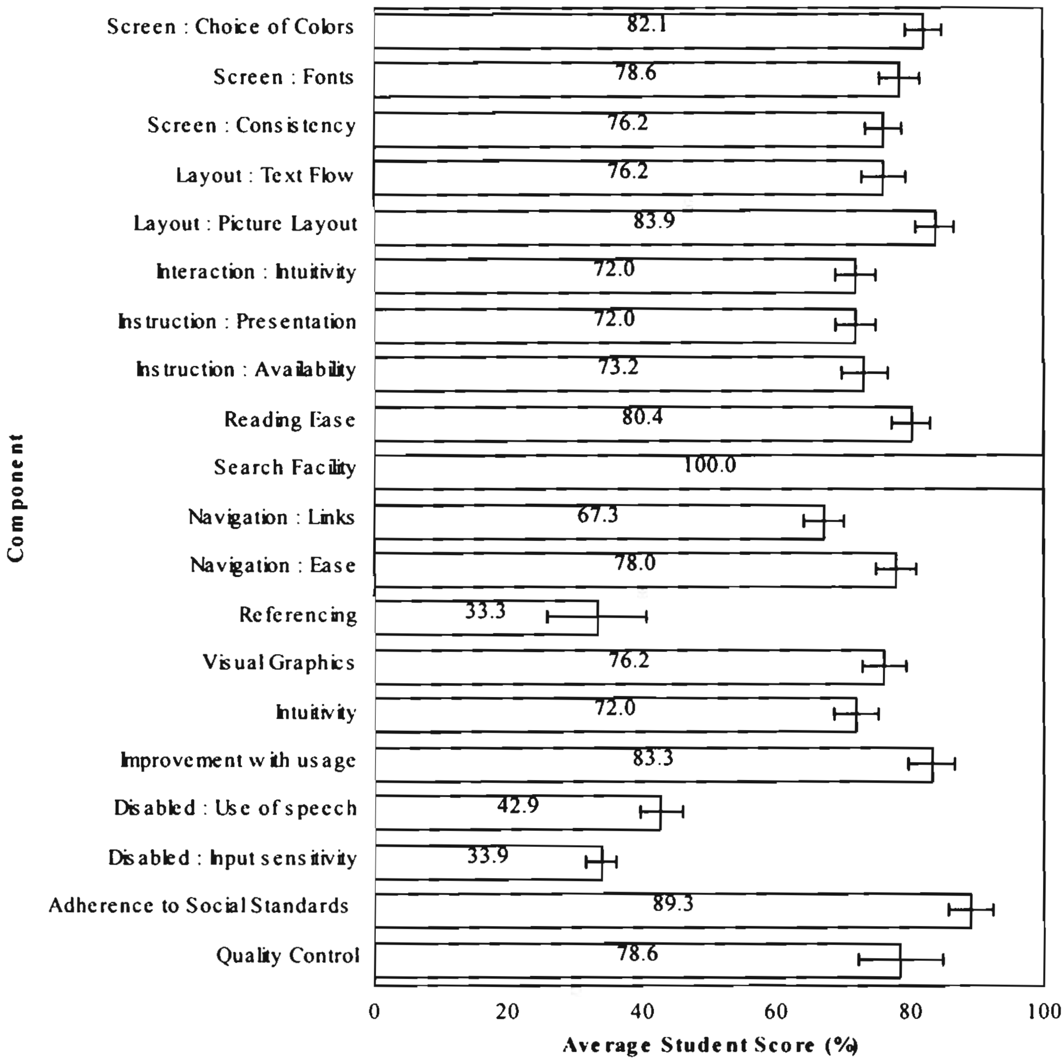

Figure 4.17: Student evaluation of User Interface Design components of Carbohydrate Metabolism courseware using ESET (n=42, bar = SE).

'Adherence to social standards' (89.3%) scored very highly, although attention to disabled students was not considered in this project. No disable student was present in the second year class.

Students found that there was sufficient content (78.6%) and rated self-paced learning 74.4%. Although students agreed that the software catered for different learning styles (71.4%), they scored 'customization' (62.6%), 'knowledge transfer' (60.7%) and simulation (61.9) lower. Students rated motivation as one the highest features of the software (fun, 74.4%, graphics, 74.4%, interest, 70%). Software feedback scored 62.5% and was not a prominent feature with immediate feedback (35.7%) only found in the testing section. Communication during the course received the highest rating by the students (81%) which included peer interaction and interaction with course assistants. Collaboration between students was rated as 65.3%.

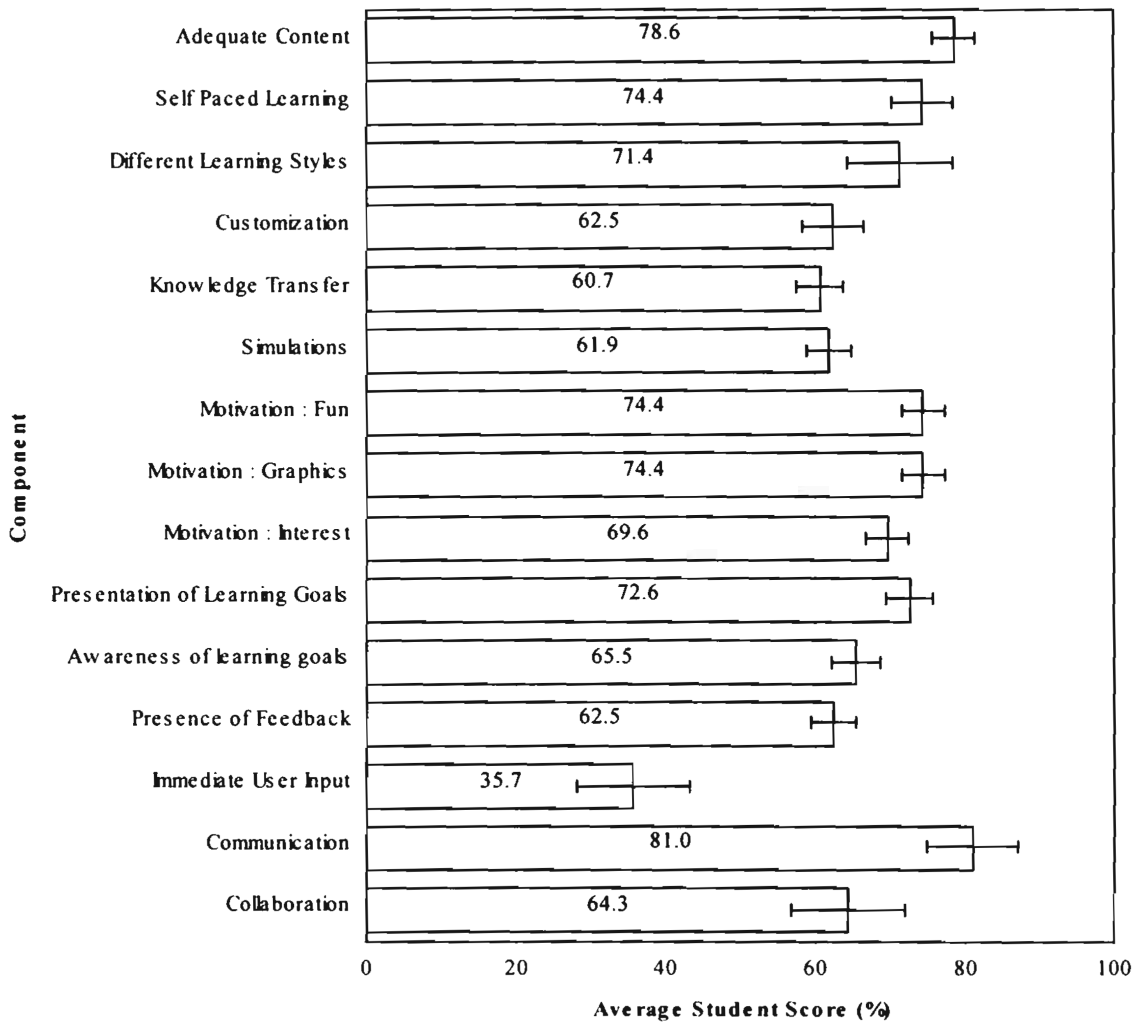

Figure 4.18: Student evaluation of Pedagogy and Interactivity components of Carbohydrate Metabolism courseware using ESET (n=42, bar=SE).

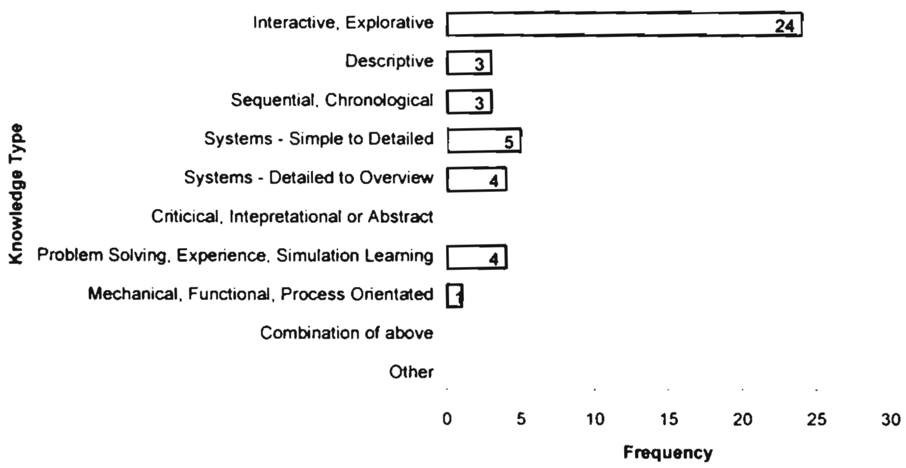

Figure 4.19: Student perception of knowledge structure in the Carbohydrate Metabolism courseware using ESET (n=42).

More than half the class(24/42) regarded the software as interactive and explorative with the remainder considering it systems based (9), descriptive (3), sequential and chronological (3) and problem solving, experience learning or simulation learning (4)(Fig. 4.19.) The predominant skill type required to use the courseware was identified as comprehension and reporting by 17 students (Fig. 4.20.). Nine students maintained that critical thinking was the major skill required. Other significant responses included 3D visualization (6) and communication (4).

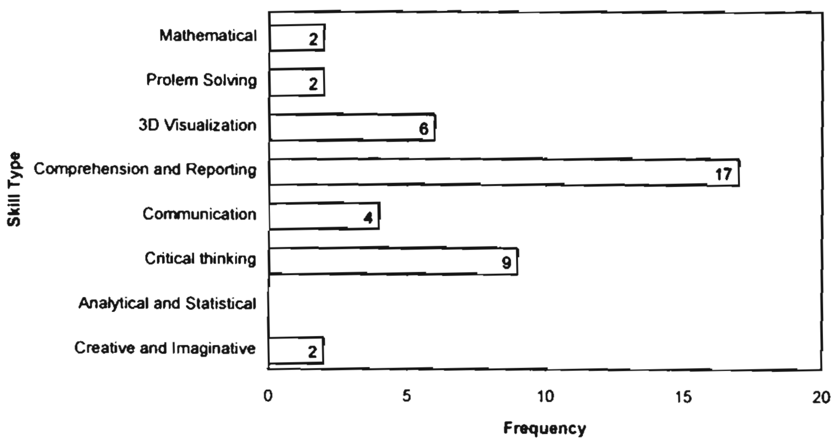

Figure 4.20: Student Perception of 'predominant skill type' in the "Carbohydrate Metabolism" courseware using the ESET tool (n=42).

Student also answered a number of ESET open-ended questions. When asked to report on the 'quality control' of the software, responses included: *" Well...the program is at the level of the student, there are no situations where a student can't follow so I'd say the software has been evaluated" and "The software needs to be more extensively tested so that the student knows what is expected of him. we need to have a "plan of attack". we were just given the software with the booklet and asked to find everything. Try to arrange the information in a sequence that is easier to understand. and check the spelling errors!!!"*

When asked whether adequate time was allowed for the content, 29 students (69% of the class) responded positively and 8 negatively (19%). The remainder of the students quoted 'computer shortages' (three responses), computer literacy problem (one response) and '*initially being lost*' (one responses). Positive responses included '*easy access*' and '*extensive content was provided*'.

Most of the students (76%) found the material manageable and understandable (cognitive load). "*Yes, the information is structured so that it is easy to find what one is looking for*" Some students found the material unmanageable (<10 %) "*I did not find the material manageable because there is a huge amount of unknown material and concepts to grasp. try, somehow to make the content a little easier to understand. it needs to be sequential and chronological*".

Students were also asked to provide feedback on the amount of time that was allocated to the course: 29 students (69%) agreed that the time allocated was adequate, while seven students (17%) disagreed. Students also felt that time should have been allocated to become familiar with the technology (five responses) before actually using it *"It can't be realistically determined, because some people will obviously have advantages over others at the speed at which they proceed i.e.: those who KNOW their way around the computer. If the biology department is so keen to introduce computers into the timetable, then they should perhaps consider a course first."*. Students also required time to integrate activities with their understanding (two responses). Three students argued that more computers would have optimized time allocation.

With respect to the knowledge structure of the course (Fig. 4.19.), students stated that the course was well structured (36 responses, 86%). Students indicated that they could work through the material using their own cognitive strategies (three responses) "*The structuring of the content is okay because everything should go according to a certain structural planning so that everybody works on the same thing. It is then up to the individual to choose which part of the subject to start with, which is exactly what is done in this section.*". Students also stated that it was clear, concise and simple to understand (five responses). They also listed the glossary, navigation, appearance and visuals of the software as being sufficient.

Students also expanded on the knowledge skills (Fig. 4.20.) utilized in the course. Popular responses included increased computer literacy (five responses), groupwork (three responses), decision making skills (two responses), time management (two responses) and comprehension and understanding (two responses). Students also listed (one response each) problem solving, self reliance, exploration, visualization and active involvement as skills needed to use the courseware.

Finally, students were ask to provide their views of the assessment modules in the course. Students said they enjoyed working with the quiz and short questions (nine responses) "*tutorials and problems were good. they focused on the important aspects and tested our overall knowledge of the subject at hand .the provision of the answers helped.*" and that it help improve awareness and reflection (seven responses). Three students felt the questions were a bit easy and suggested the inclusion of harder questions, while seven students noted that they did not use the assessment module at all.

4.3.2. Lipid Metabolism Courseware

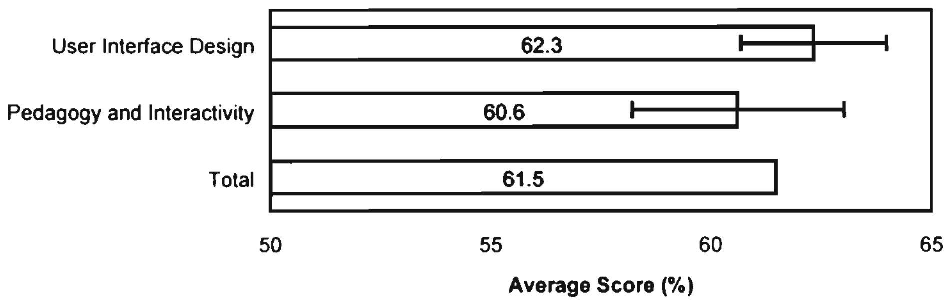

Figure 4.21: Student evaluation of the Lipid Metabolism courseware using ESET (n=40, bar = SE).

Students using ESET rated the User Interface Design and Pedagogy and Interactivity 62.3% and 60.6% respectively (Fig. 4.21.). Overall the package scored 61.5%.

For the User Interface section students rated screen fonts and colors 71.9% and 72.5% respectively, while screen consistency scored lower 66.3%, picture layout scored 69.4%, text flow 61.9% and intuitivity' at 66.3% (Fig. 4.22.). Although presentation of instructions scored 64.4%, the availability of instruction was rated 60%. Ease of reading was amongst the highest rating components (73.8%), whereas the lack of an actual search engine caused students to rate the search features poorly (55.0%). Students found it easy to navigate through the site (69.4%), but reported that there were insufficient links (59.4%). Online referencing capabilities (27.5%) was the lowest scoring component. Students found the visual component adequate (66.9%) and stated that with time it became easier to use the software (72.5%). Attention to disabled students was not catered for in this course and therefore use of speech (41.3%) or input sensitivity (36.3%) were rated poorly. Students rated adherence to social standards very highly (86.9%) and felt that quality control was reasonable (65%). A Wilcoxin signed ranks test indicated that the User Interface section for Carbohydrate Metabolism was rated significantly better by students than the Lipid Metabolism package (asymp. sig. < 0.005, z = -3.845[a]).

[a] based on positive ranks

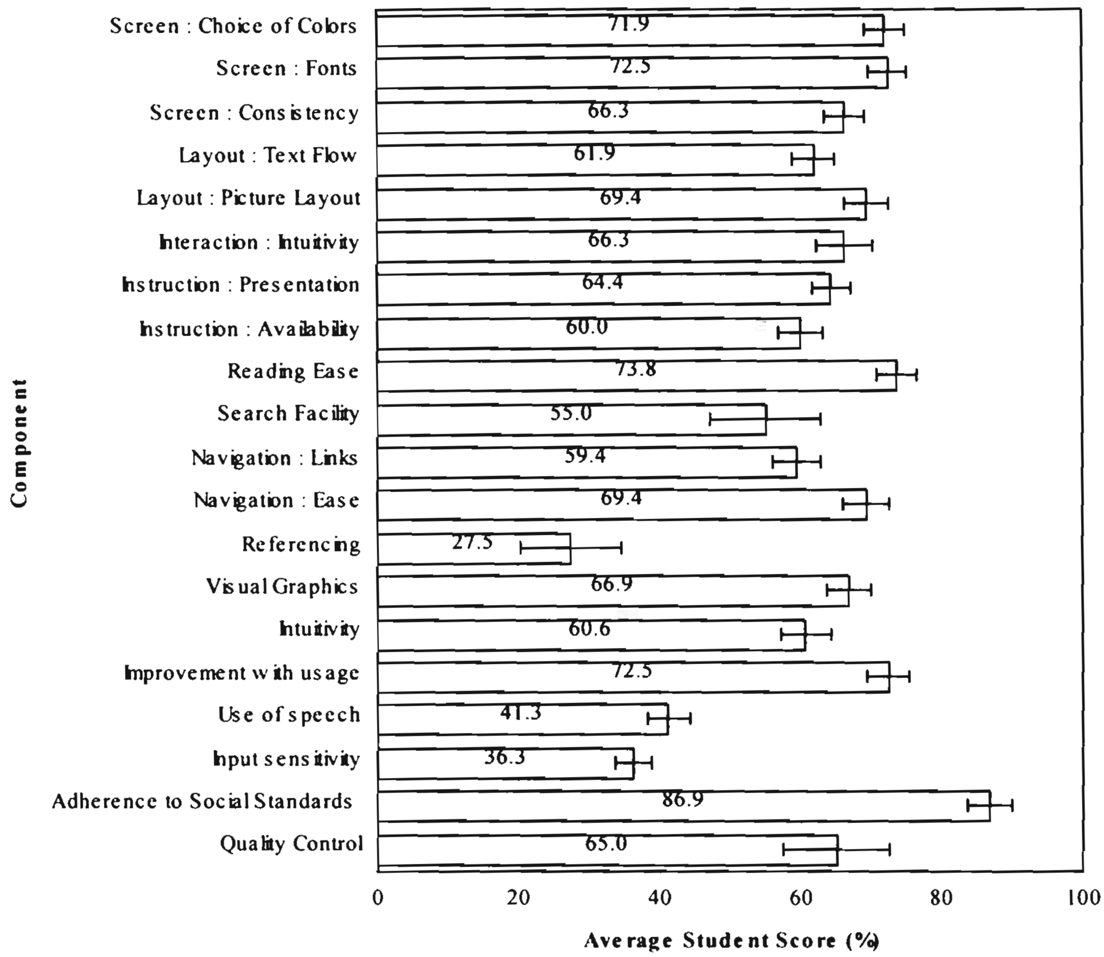

Figure 4.22: Student evaluation of User Interface Design components in the Lipid Metabolism using ESET (n=40, bar=SE).

The results related to Interactivity and Pedagogy indicated that the content was adequate (70.6%) and that self-paced learning activities were engaging (62.5%). Customization and allowance for different learning styles both scored 57.5%. Knowledge transfer scored 56.3% and use of simulations scored poorly (53.8%). Students found the software was fun to use (58.8%) and rating for graphics (65.6%) and interest (62.5%) were satisfactory. Learning goals were reasonably well presented (65.0%), but students may not have been fully aware of it at all times (58.8%). Feedback (50.6%) and immediate user input (47.5%) rated poorly. Communication between students however, seemed to be the highest rated component (75.0%) and collaboration between students was good (67.5%). A Wilcoxin signed ranks test indicated that the Pedagogy and Interactivity section for Carbohydrate Metabolism was rated significantly better by students than the Lipid Metabolism package (asymp. sig. = 0.006, z = -2.726[a]).

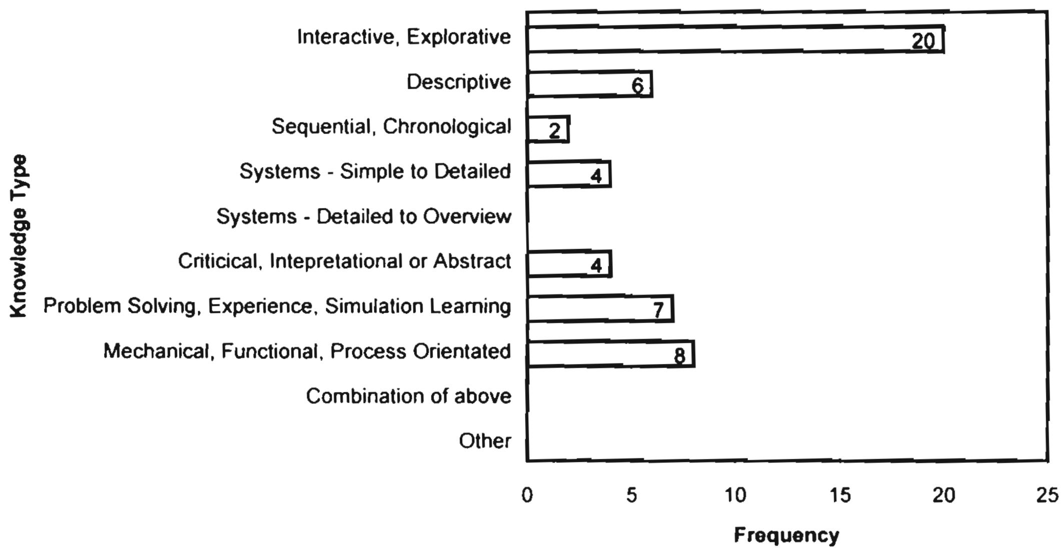

Figure 4.24: Student Perception of knowledge structure in the Carbohydrate Metabolism courseware using ESET (n=40).

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[a] based on positive ranks

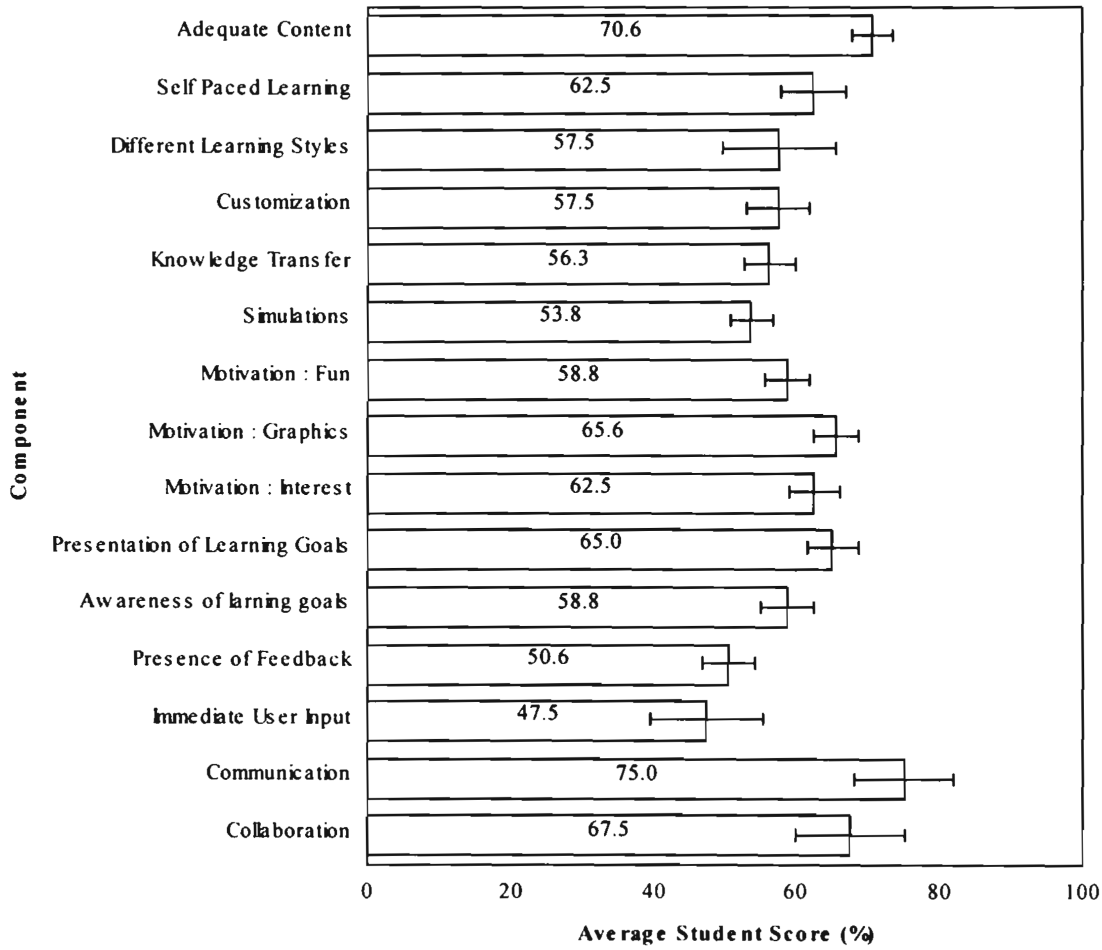


Figure 4.23: Student evaluation of Pedagogy and Interactivity components in the Lipid Metabolism courseware using ESET (n=40, bar = SE).

Student perception of the knowledge structure in the Lipid Metabolism Course are given in Fig. 4.24. These results indicate that 20 students (50%) of the class regarded the course as interactive and explorative. Eight students (20%) felt the course was mechanical, functional, or process in nature. Seven students (17.5%) thought it involved problem solving , experience, or simulation learning and six (15%) as descriptive. A further six students (15%) also regarded it as systems based. These results indicate the various ways in which students used and viewed the software.

Students (50%) regarded comprehension and reporting as the predominant activity when using the software, while eight students (20%) rated critical thinking as the main mode of operation (Fig. 4.24.). Four students utilized mathematical skills, and three, 3D visualization skills, while two students regarded communication as the most apparent feature of the course.

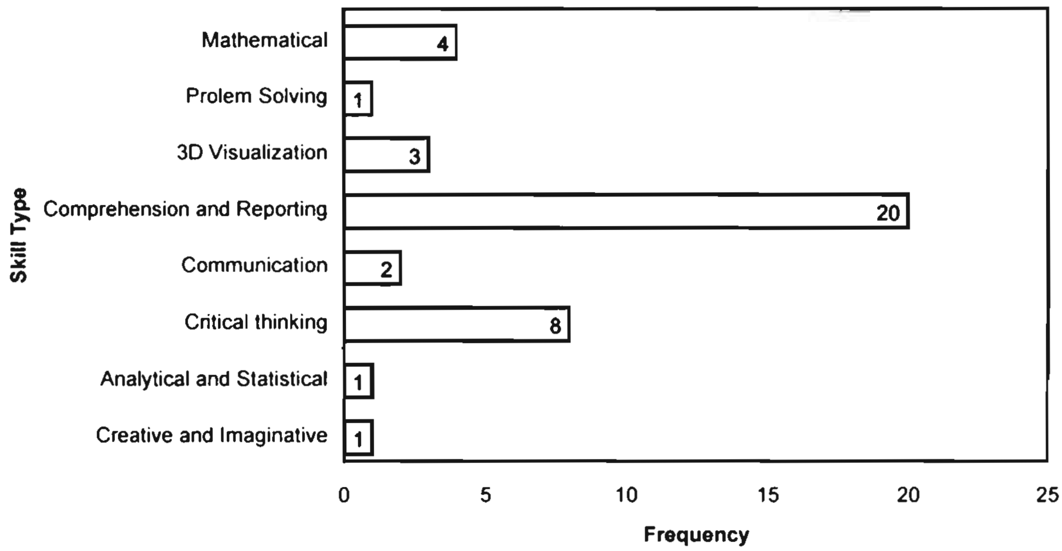


Figure 4.25: Student Perception of predominant skill type in the Carbohydrate Metabolism courseware using ESET (n=40)

Students did not respond the open ended questions of the quality control section, but did make a few comments: '*up to standard*', '*needs more visuals*', and '*difficult to find information*'.

Students did provide some feedback with respect to time allocation and content. 11 students said that time was adequate, whereas 11 disagreed. Five students noted that '*a bit more*' time should have been allocated. Students listed difficulty in finding information, readability, and computer shortages as affecting time usage.

When asked to comment on manageability of the material (cognitive load), 21 students (52.5%) agreed that it was manageable while four students disagreed (10%). Of the problems students listed, four students said information was difficult to find and six students commented that the information was vague and unclear. Students also indicated shortage of computers (two responses) and time (three responses) as constraints to accessing the courseware.

When asked to directly comment on the adequacy of time, students provided varying results. 14 (35%) students agreed that the time was adequate, while 16 students (40%) disagreed. Students regarded shortage of computers (five responses) as the major limiting factor.

Students did not provide much additional feedback with respect to knowledge structure but did mention the following comments: "*informative*", "*makes the user keen on using it again*", "*ease of use*", and "*well structured*".

Response towards knowledge transfer included increased computer literacy skills (three responses) and: working in groups, problem solving, information transfer, comprehension, self-directed learning and visualization (one response each).

4.4. Examination Performance Analysis

In addition to pre- and post test evaluations (formative and quantitative) examination performance was investigated (summative and quantitative) to determine how the two computer based modules faired against results from conventional teaching with the current year students.

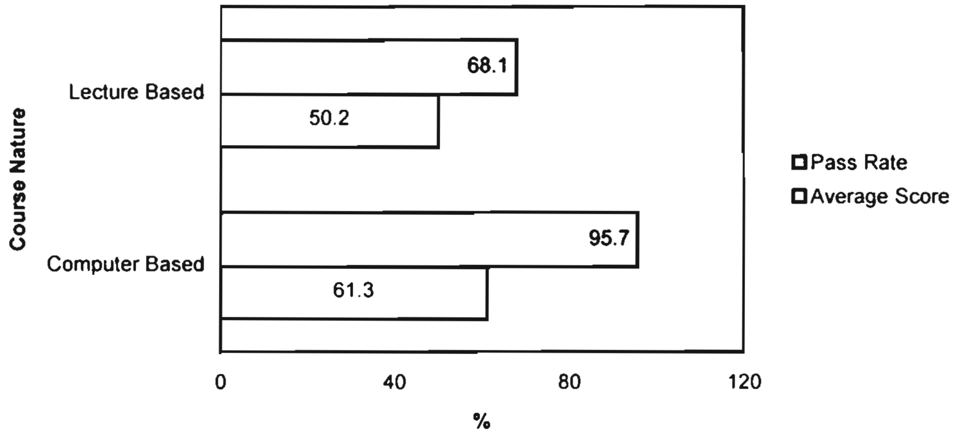


Figure 4.26: Exam performance comparison between computer based and non-computer based topics of second year Biology students (n=47).

Students performed, on average, 11.1% better examination questions for the Internet based courseware than in questions based on traditional lecture courses (Fig. 4.2.6.). Students also demonstrated a higher pass rate (27.7% higher) in the computer-based modules. Statistical analysis (Wilcoxin signed ranks test) indicated a significant difference between computer based exam performance and traditional lecture exam performance for 1999 (asymp. sig. < 0.005, z=-3.491).

Examination results from the previous year (all lecture based) were also compared (Fig. 4.27.). There was a 4.8% increase in the current year (66.5%) for the Carbohydrate Metabolism course, and a 5.04% decrease for the Lipid Metabolism courseware (55.5%). Students appeared to perform similarly in both examinations. However, the pass rate for the Carbohydrate Metabolism course increased from 78.4% to 93.6% (1999). The pass rate for the Lipid Metabolism course decreased from 81.6% to 71.1%.

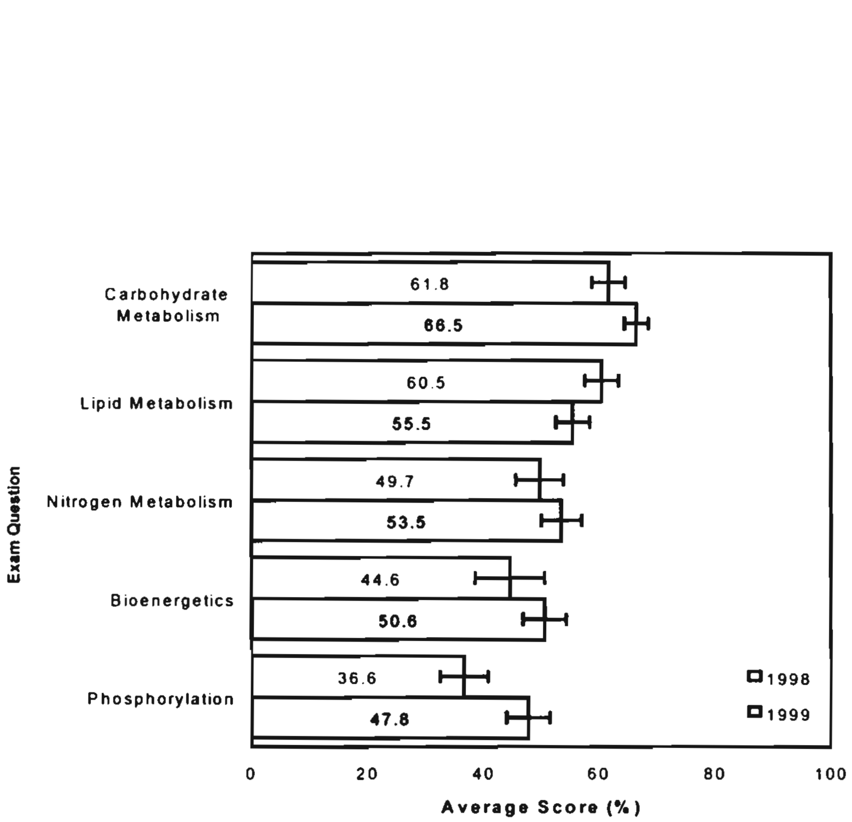


Figure 4.27: Comparative analysis of average student scores between two consecutive years (1998: n=39; 1999: n=47; bar = SE).

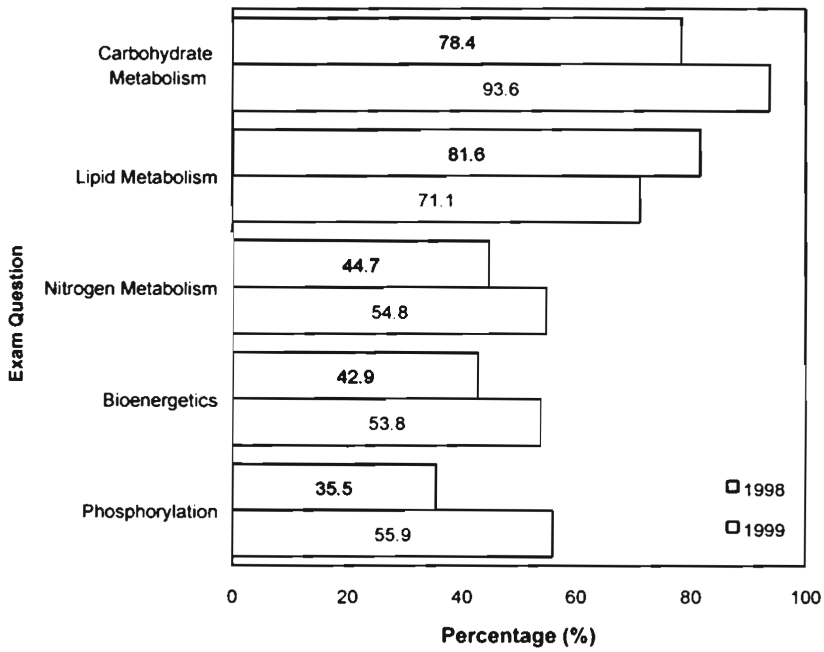


Fig. 4.28: Comparative analysis of student pass rate between two consecutive years (1998:n=39; 1999: n=47)

A comparison (Mann Whitney test) was made between 1998 exam performance and 1999 exam performance using the following sets of scores (1998 Carbohydrate and Lipid

Metabolism) - (1998 Other) vs. (1999 Carbohydrate and Lipid Metabolism) - (1998 Other). Although no significant difference was indicated (asymp. sig. = 0.054, z = -19.925), the results can be seen as marginal. The 1999 exam performance results were further analyzed (Wilcoxin Signed Ranks test) and indicated that the Carbohydrate Metabolism exam performance was significantly better than both the Lipids (asymp. sig. = 0.003, z = -2.948) and the lecture based scores (asymp. sig. < 0.005, z = -4.525). No significant difference was seen between the Lipid Metabolism performance and traditional lecture performances (asymp. sig. = 0.111, z = -1.594). These results indicated a distinct difference between the Carbohydrate and Lipid Metabolism packages.

4.5 Student Interviews

Students were informally interviewed, each for a period of 30-40 minutes. Five categories of questions were used during the interviews and included: learning environment; perspectives on higher education; learning objectives and outcomes; and personal value of the software.

4.5.1 Learning and Environment

Students were first asked to rate their computer usage. Eight students (62%) said that they have used computers before (between one and two years) and five of the students interviewed said that they had not previously used computers. Four of the students reported that they had access to computers at home. Although many students said they were confident using computers (seven responses), there appeared to be no strong dislike to the use of computers. Those that had not use computers before stated that they soon got used it because of facilities within the software.

"Ya... at the beginning of the course it was like "oh gosh! I don't know what to do" and I'm going to be a total fool, and something like that in the Biolan... but eventually you get used to it."

Students listed their main computer activities as: report writing (five responses); library searches (five responses); email (five responses); Internet (four responses); multimedia titles (four responses); and Internet Relay Chatting "IRC" (four responses). Student comments of computer features included: exploration,

"Ya... and the fact of spending so much time on the computer now, I started to um, explore stuff... which I never use to do last year",

and importance of computer literacy,

"me I think, computers are more important, I think students should do computers in their first year..".

When asked if students were aware that there computer-based courseware was part of a research project, nine students (69.2%) responded positively and four students said no

(30.8%). Response patterns included: positive responses (eight responses); neutral responses (three responses); and two students who termed it as experimental in nature. Amongst the positive responses, students felt that the initiative was new and exciting, with them being the first to tryout this new form of learning. Others felt that their input would help understand student learning and influence its future:

" I think its good.. because you guys are trying to make our learning easier.. much easier than before.. because some students have problems sitting in lectures... ",

" I thought it was good I mean like, um.. the research was good, because they'll understand how students are thinking and working.".

Students also felt that it was an improvement on conventional lecturing since it made learning easier. Those with a neutral attitude, felt that such technology initiatives are becoming a commonplace. A few students did however support the argument of it being experimental by saying that there was no reference to previous years, or that the results of such initiatives are unpredictable since such technology is new:

"Well... I must commend the people who are doing this....this research...but, um, personally, I'm not to happy with the part of the experiment , you know ......I'm not happy with that, because you don't know what the results are going to be like.".

Students were asked if the change in learning environment was comfortable to work in. Seven students (53.8%) felt that the course was adequately comfortable, while three students (23.1%) maintained that they were not comfortable at first, but got used to it after a while (three responses).

"first time.. no.. but once you get used to it, after a day.."

Two students responded that they were initially lost and attributed this to their lack of computer knowledge as well as the wealth of information.

"I'm not completely computer illiterate, it was just that there was so much information, you don't know where to start.. or."

Both these students reported that they quickly adjusted to the new teaching method. Another student commented that the physical setting of the environment was initially unorganized but became more structured as the course progressed.

".. at the beginning it was a problem... but...as the course progressed, we had less people sitting in the class ..so it was easier to use..."

Students were asked to suggest ideas in which the course and/or the environment could have improved. Students in general felt that the settings were quite adequate (nine responses, 69.2%). Students did however indicate problems such as lack of computers (four responses) and time management (two responses). With respect to the interface, two students felt that an introductory guide, or even lectures could have been incorporated into the course. One student also mentioned that basic computer literacy training could improve learning for first time computer users:

" about getting into computers, its not easy the first time.. and starting to learn it.. because we don't have any training.. so if we had time it would be better to get people to do basic things..".

Students however centered most of their responses around interactions in the classroom and listed advantageous experiences of the course including working individually,

"yes and no, because sometimes.. like you know, you prefer to work on your own.. like you get more work done on your own, but in groups and everything.. like.. you spend more time.. talking.. and there's only one screen .. ",

and self paced,

"no I though it was very good, because the environment was very relaxed.. you don't feel tense about anything, you feel you can take your time.. you can do things at your own pace.. so that's good..".

Students were asked to relate their experiences with respect to working in a group. The question sought to identify whether or not students enjoyed working in a group, as well as how this mode of learning improved their learning.

"It was better that we fell into groups and not, and we weren't forced to do it on an individual basis"

The interviews also highlighted three areas: student interaction, understanding, and peer responsibility. Positive aspects included: division of labor (two responses); rich social experience (two responses) and ability to consolidate with demonstrators. Students did however maintain that interaction often broke flow or concentration, amongst participants and in some cases, a slow rate of work, or lack of understanding may have led to students reverting to working by themselves due to difference in learning speeds (two responses) and wanting to "*figure out things for themselves*" (two responses).

Problems with responsibility within groups included lack of equal contribution (three responses), lack of self-discipline and "*discussion led by one person*".

Despite these problems, seven students indicated that their understanding within the group was greatly improved. The key supporting features included: group explanations and discussion of key concepts (five responses); helping one or more students with problems and misunderstandings (four responses),

".. and add our own thing to show this person what to do.. and by doing that, by being the teacher.. you basically acquiring a better understanding of it.. ";

argument on certain issues (two responses)

"yes I did.. I told you we fight a lot.. but....the conflict thing is that it's mentally stimulating.. ";

" ya.. because people can explain more.. they can elaborate more.. if something is unclear we can argue about it.. and then we can get to one understanding.. and we can get the demonstrator or anyone to help us and then I think its much more clearer.. "

and development of shared understand amongst participants (two responses).

" ya we discussed it and then we'd come to a conclusion.. and then move on.. "

A student also pointed out that they were able to view different perspectives of the same knowledge.

Students were asked to relate how they used their workbooks in conjunction with textbooks and/or other resources. Students maintained that the workbook was their primary source of information (nine responses, 69.2%) and argued that they were quite confident with these written notes. Students did, however, mention that they would, if the need arose, make use of their textbook to either catch up on notes (four responses) or gain a better understanding of the content (three responses).

Prior to the interviews four (30.8%) of the students interviewed were not aware that the web based resources were permanently available to them. All students reacted positively after this was reinforced at the interviews. They maintained that they would be using the web site again (seven responses, 53.9%) mainly for revision and consolidation (four responses), "catching up on notes" (three responses) and gaining a better understanding in problem areas,

" but say supposed you were getting an answer for a blank you had.. but you didn't quite understand the answer , which means you .. will you actually go back to the computer and try and sort of figure it out.. because everything is there.. "

Students were asked to list additional learning resources that they would use. Some (four responses) felt that there was no need to use additional resources and were quite confident that their workbooks and software were adequate resources. Other students mentioned library books (three responses), textbooks (three responses) and past year examination papers (five responses) as additional learning resources.

4.5.2 Perspectives of Higher Education

Students were asked to comment on the difficulty of the content. Eleven students (84.6%) regarded the content as simple and easy to understand, even though it may have been difficult to work with the software at first.

"... I think it was simplified enough...for, for... to understand...and still have some depth to it... to come to some sort of equilibrium, I think..."

" mmm.. it wasn't easy.. but once you get into it.. it kind of grows on you.. so.. I mean.. It takes a lot of work before you actually understand it.. so you got to work towards understanding it.."

Although the software was well received, the Lipid Metabolism software received a few comments: "required lots of reading", loss of focus and "required hard work". Students didn't have anything further to elaborate on with respect to course content and were quite satisfied with the content.

Students were asked to relate if any of the two topics were of any personal value or interest to them. Three students responded by saying that there was no personal interest, while four students said that they enjoyed the content and the process of learning and that it had raised their personal interest in the topic. A few students related the topics to either daily life (nutrition) or personal experiences. Two students, who maintained that they enjoyed the topics, did not necessarily see it as a field, or career, of interest. One of the students also noted that the use of specific examples (sport) raised their interest and appreciation of the topic.

Students were asked to relate computer usage in other subjects or topics. Five students (38.5%) could not recall using computers in any other subjects. Three students described computer usage in the other biology major (Environment Biology), two students did the Computer Literacy course offered by the University and one student was taking Computer Science as a third major. Students gave very brief descriptions of their computer use in other subjects and/or topics that included writing essays (three responses, as was predominant earlier in the results), use of Microsoft Excel and SPSS (statistics, three responses) to analyze data and voluntary use of Internet and multimedia to find information (two responses),

" Um...well I've used it... computers.. voluntarily....for other subjects...I found additional information ...I haven't been told to go an look at the information, I found it voluntarily... ".

Students were ask to relate there opinions on traditional assessment methods. In general students didn't seem to have given this aspect much thought (five students were not sure) while some felt that the current format was acceptable (four responses) but did make mention of time management being problematic for certain papers (two responses). Students remarked that they have become accustomed to the present system:

".. I'm so accustomed to it.. you know that transitional period, lets just say if that is going to happen.. there's going to be a lot of problems initially with people you know , to adjust to that sense.. "

and that they were not exposed other forms of alternatives (two responses). Students were further asked to provide alternatives which included ideas such as continuous assessment,

".. I don't like it.. I prefer continuous assessment.. I prefer that because you're working on it all the time.. there's no you got to sit answer study.. "

computer based testing ("to eliminate cheating"), more choices in examinations, assignments and projects, and even computer based testing exercises and modules (three responses). One student did however make the point that this new era of technology warranted a new approach in testing:

"Um, problem solving ..its definitely different requirements...and I think we're going to get this year...and old type of, old school type of examination... ", " Ya.. it must be.. because its almost against the grain... you're going a whole new direction.. ", " But... shouldn't.. you.. um, integrate this sort of thing more slowly...I know we're already in the nineties, the late nineties... "

4.5.3 Learning Objectives and Outcomes

Students were asked to comment on how they felt using technology compared with previous or conventional modes of learning. This question provided the most insightful and varied responses amongst students. Students described different ways in which the technology affected them and made many references to lectures, which they considered as the conventional mode. No negative comment, or problems, were provided by students. Students described their view with respect to lectures,

" it's difficult to say.. with um.. stuff like carbohydrates , maybe its better to go over the stuff on the internet.. because you are going through separate ways.. I supposed that if you could interact with it.. it would be far more fun.. than the lecturer that is going over it.. but then again.. It depends on the lecturer.. as well.. "

" um.. comparing to like.. say in a lecture.. some people get sleepy.. its not like they are lazy, its like the way you teach.. like some people don't know .. they can't really give you what you want.. and computers.. its easy to get in there.. you know the information you want.. if you don't understand it's there.. you can update.. its better to listen than trying to write all the notes down.", "... Um.. when I'm working on my own , I really like it more... because , like if you don't get it the first time, you can look at it again, in the lecture you can't , you know what I mean? ... here.. you have time to write your own notes... "

difficulty and challenge,

" .. those people are being thrown in the deep end, like its hard to adjust.. but you find that if this is the way that you're going to be working,

"I think its much better actually.. I know a lot of people don't and they would rather like lectures.. but I quite enjoyed it.. and a lot of people that haven't used it.. are scared.. "

active learning,

"I believe it is a better method.. because look at the different aspects that you're being exposed to other than.. just writing and listening.. and not comprehending.. you're going to actually have to put input.. in there yourself in order to get some sort of response.. "

" Well.. its obviously more interactive...than any other learning mode that I've come across, usually the lecturer speaks... and you just sit and write down notes... whereas this is much more three dimensional.." "... it's a ... you working on the computer...um... you conferring with your partner...you asking help from the demonstrators... its almost like you walk into another dimension"

getting information quickly and easily,

" its very fast.. you get the information just like that.. its not the textbook where you have to sift through it.. in the computer for example, if you're looking for a particular section, you just have to type in there what you want.. and it will give you relevant stuff...and you can just choose what you want.. "

" web software .. I admit is faster.. easier.. um.. its more informative.. the problem with it, is that you cannot necessarily get updated information , because you have to admit, some of it changes every day.. but.. its nice, its fun, its easy.. "

"but...the web-based technology...it was.... It was good in the sense that it asked specific questions, I'm talking about the carbohydrates, um, questions, it asked specific questions and you would look it up and there was the answer , staring at you, you didn't have to actually sift through any information, so it was good. The lipids , the one on lipids required more work "

" well.. first of all its more accessible.. you can get it anywhere.. any LAN .. "

responsibility,

" mmm.. I think like, I hated it during the beginning.. in another way, the web-site also taught me to be responsible to make me think.. ok, maybe I missed these steps.. there's no need for me to go and get the notes, I have to go find it for myself.. its still there.. I can just patch it.. it doesn't only help me educationally, but it also helps me to be responsible..

" She - ...um, I think it makes me a little bit more responsible as well, its now we don't go to the lecture and just take down notes, now we to make the effort yourself... "

confidence,

"Ok... it has benefited me...in like we said earlier on... as... I'm not so afraid...like... of using the computer... I'm more confident...definitely ... and this is like a big step for me...because now I'm going to get more...interactive with the computers...when it comes to other topics and other things... even if its...just for having fun... "...because its going to help me become more confident.......

stimulating,

"its more interesting and exciting for the eye and the brain.. when you're trying to learn something.. to be able to move around.. it stimulates you more than having to stare at black and white.. it stimulates more of an interest.. "

adaptation,

"... initially I think the only problem with that is.. this is a natural problem because its going to occur anywhere you have change.. if people adapt.. ".

Students were asked if the software was suitable with respect to the nature of the content, and whether it improved their speed and quality of learning. All the students interviewed, agreed that the course software was appropriate. Students said that the software improved understanding,

"Instead of it being spoon fed to you in the lecture, where you understand it just for that second, here your going through it to understand it , so when it comes to learning for the exams, you're a lot more comfortable, and familiar with it... "

made relating and visualizing information easier (six responses),

"like you see an enzyme and you put it there.. you understand the steps easier.. than when you are reading your notes.. sometimes you can't understand these things , how did it happen that way.. but when you're looking in the computer , you see that put this, and this is how it works.. you have a clear understand of it.. when you're studying you just go and look through.. see.. what is happening and you understand it.. "

"to an extent.. its when you see it in front of you , you happen to retain more.. because it's a proven fact that you retain pictures more.. um, its easier to read through, because there's a lot of unwanted jargon and stuff there.. um.. easier .. "

facilitated ease of use (three responses),

" um.. as I said.. the nature of the material is the same as that you would find in the textbook .. but the fact that you don't have to go to the index or something like that in the middle of it.. and just disturb the whole procedure, you could find information as you wanted it.. "

"lets just say, that for someone who has not been using the computer very often, over a long period of time, um, I found that they way, it was actually very smartly done to put it like that, you know you're looking for something and then hey presto , it pops up onto the screen and its like a sense of achievement.. its like, hey I know.. this is there and I can.. like always come back to it..

and promoted self pace and controlled learning (three responses)

"to a certain extent.. I can't say it dramatically made me into a good student and I understand everything the first time.. um, but um, I think it lets you go at your own pace... for me it was a very good thing..." .

Students were requested to identify and relate, if they could, any difference between understanding concepts and memorization thereof. The results indicated a strong pattern in student minds that there was a different between understanding and memory, and that understanding took place before memory. Students maintained that they did not remember much of what they learned (five responses), but could understand nearly all of what they covered (eight responses). Reasons for poor memory retention included "too much detail" and conflict with other subjects.

" I don't want that interfering with my learning at the moment.. for Cell ..."
" right now.. I got other problems , I got other subjects.. you can't spend one time.. on one subject.."

Students however, felt that initially understanding was more important than remembering content, which would come later with revision. Students also made distinctions between learning and studying which they regarded as separate activities.

" well, I would think so because , if you had to ask me this after I studied it, then I can tell you , honestly how much I understood and remembered?"

"Um... well...at this stage I'm not really.... um...I understand what I'm doing .... but I'm not really learning it yet... I'm going through it...from the beginning to the end...in my studying it at the moment.. " " So I don't think I remember a lot at this moment but I think I understand it..."

Students felt that their initial experience with the software (learning) mentally prepared them to study for examinations (two responses). They further added that the software aided in compartmentalization of knowledge, confidence in learning and visualization.

"no, no, understanding it.. because I have like , how do I put it, its like more compartmentalized in my mind ... and its only like a key to opening.."

"I think I'm more comfortable...with understanding something...because , um, I'm more confident, If I understand.... I can remember something that I understand..."

Students were asked if they could think of any specific problems or difficulties they had during the course. Only one student commented on initial difficulties.

"Obviously, initially, we all had difficulties just adjusting, I suppose...um, after that, I think it got better.. I don't have a problems now at the moment ...Its just the adjustment I suppose...ya...".

All of the students interviewed commented that feedback was good, and identified demonstrators and course facilitator as the major source of feedback. They indicated that no feedback was necessary from the subject expert (lecturer), although they did approach the lecturer when it was absolutely necessary. Students didn't seem to think that software feedback was necessary, since demonstrators and the course developer helped them with problems when required (three responses). Students remarked that demonstrators, although were busy at time (three responses), were very helpful (four responses) and improved students' confidence and comfort (two responses),

" Ya... and so.. by you established this repore with them, it's making them more comfortable , and as I said in a comfortable situation, your knowledge is going to gleam out through your ears and things like that, so.. .so that's how we learn.....".

With respect to the software, students felt that it was "well designed with sufficient theory" (one response) and "self explanatory" (one response).

Students were asked to describe their usage of the online testing section (Carbohydrate Metabolism course). Five students reported using the testing section, while the remaining eight remarked that they would use it if time allowed (three responses) or to recap and revise (five responses). Students had the following comments to make about the testing section relating to: immediate feedback, *"yes.. only if you get the questions right then you know you are on the right part.. it's a very good idea, because sometimes you might have misconceptions.. you get that sorted out by making mistakes.. in the questions "*

" ya.. we did them in a group.. and then we answered the question.. and if you answer it will tell you.. so you know you're wrong and it will tell you the right answer .. we knew when we were wrong.. and why.. "

" ya.. in a way the onus.. especially since it led you to you know , go back if you didn't know something.. "

and improved understanding

" Um... a broader understanding...of the topic.... And the finer points as well...", " Because like, certain things like, specific enzymes, important stuff , like little things...enzymes for certain pathways...you wouldn't like pay much attention to it...you'd pay attention to the entire process that is going on...but the testing means you link certain enzymes to certain pathways...and remember it... ".

4.5.4 Personal Value

Students were asked to explain how the software personally benefited their learning. Students explained their own experiences and provided a wide variety of responses. Some of the trends identified included comparison to traditional modes of learning (four responses), useful activities and outcomes (six responses) and improvement of both the content (three responses) and their understanding of it (four responses). Student responses described and/or related to: comparison with lectures,

"Ultimately, well It was an interesting experience.. with something different to do .. than lectures.. ya.. that probably benefited me, some of it.. but um.. maybe not personally, because I'm used to using the Internet.. but I think other members of the group probably did.. "

"Yes I did... and I guarantee that if I had just taken down notes, there's certain aspects of note-taking , that's.. that's limited because you're not going to get certain things down, then you gonna say... like oh (censored)... what was that middle thing...by that time the lecturer has already gotten to the 5th or 6th point, and you're stuck at the first...that's beneficial because you have a better in dept structure of your notes.... "

"in that, um, well it was better than the lectures...because now I understand ..some stuff a whole lot more...because I've been through it so many times...because I have to understand it...its not being spoon fed to you basically.. I'm looking into it...but I'm not understanding it..."

confidence,

"It is... because when I'm going to be learning, I'm going to know that ..... I can't be stupid and not know what's happening because , I've done this before, and sometimes you like, need to basically talk to yourself , and realized that this is familiar, or I'm familiar with this , and therefore its easier , and if you think of something as being easier, well, you know if you like a certain subject , you find you do better in it... and... that's the whole point...of it..."

multiple learning environment

"yes.. well.. I am learning more than one subject at a time.. I'm learning more than just biology.. I'm learning to navigate my way around the software.. and learning how to find information in different ways.. constructing my own knowledge from reading from different sections.. and then.. answering questions..

perspective,

" um... I think so...it gives me a... I dunno, a new outlook on what learning is all about...you always pushed into one way...of learning...and you don't really know ... that there are other alternative methods of learning , um.. so just opening up your mind to new things...new horizons...and I'm quite happy to accept new things..."

detailed content,

"yes.. because .. you come up from school and it was a very narrow kind of thing.. and you come to university second year and you see the really detailed thing.. that actually go into the process.. so it is very beneficial.. in school you though it was simple.. but now there's so much of detail.."

Students were asked if the course increased their motivation or presented them with sufficient challenge. Strong patterns emerged towards self responsibility (four responses),

"Ya... I suppose if this section had been on ... in the lectures... I wouldn't have gone out of my way to lookup more information...but... um.... I was busy using the computer... outside of lecture time ...you know...to read up .. more, so I was actually spending more time...than I would be in lectures I supposed.."

time management (eight responses) and self awareness of learning and progress (three responses)

"um, I have to admit it did make things much better, because you got here early.. did your work, got it over and done with.. um, you know you were going somewhere with it.. with the lecture, unfortunately, you do not know where they are going to go next.. ".

Students also made specific comments on the software being fun and enjoyable as well as technology being a new learning resource. In terms of the content, students felt that the nature of the material was straightforward and warranted a lot of work on their part (two responses).

" its not always presented to you straightforward... "

"to an extent.... Yes.. the fact that ... I had no idea...how to ... you know...to start off with... no-one knew how to use it because, it was like a new thing , so in that sense, maybe, its challenging... "

Two students felt is was straightforward and didn't think it challenged them much.

Students were ask to relate how actively working with information compared to traditional lectures. Students compared the software to working with lectures (two responses)

"lecturers.. well sometimes you don't get what they're saying.. like so.. reading of the notes.. the information, it was like. Ok.. "

"in lectures, um.. practically, you don't really pay attention, you just right.. for Africa.. for Lipids.. you were, um, awake.. I would say.. um, and you had to keep on moving back and forth.. judging which answer is accurate.. "

and commented on the interaction with both the software and the group (two responses)

"I would actually, you know, be so involved in getting this down.. and this accurate involvement .. and the actual involvement of the people with the, um, information that you're basically going to be finding, this

active involvement leads to a better understanding of the work.. I'm sure that's what you'll basically had in mind.. when you'll created this program..".

One student said that information was "*organized and well presented*", although two other students argued that more exposure

"As compared to lectures.... um, I think I'm on the fence actually...ya... not on the fence... ya.. I prefer working with the computer... I would imagine you would need a bit more exposure...to this sort of thing...and actually have a look at your performance..."

and balance was requires to make an accurate judgements

" um, I dunno... you have to ...you can't be given everything on a silver plate...you have... go look for the answer.... On the other hand... you don't want it to be too difficult so it inhibits you... some... ya.. some sort of balance between ....".

When asked if the software was fun and enjoyable, all students agreed and listed briefly aspects such as: color (two responses) and (one response each): input from testing; opening multiple links simultaneously; author's personal efforts; zooming in and out of diagrams; working in a group and navigating through information.

When asked if students enjoyed working at their own pace, seven of the students remarked that they did, while six students commented that their progress was a bit slow,

" um.. the thing at varsity you find that your own pace is never really fast enough.."

but reported no serious problems. Students maintained that self paced learning drove them to finish earlier, allowed them to relax

"yes.. definitely.. well .. when you came in there you felt like you had your own.. schedule to keep up to.. and there are no pressures or nothing else .. you're respond more to it.. you more relaxed.. and I think you gain more when you're relaxed than when you're tensed..",

and engaged them in active learning. Although students had to work in their spare time (four responses) and felt constricted by the deadline

" Um.. I don't think you could work at it with your own pace...you had to sort of...um, monitor your pace according to the deadline....you know......but.. just looking at the deadline...and adjusting to that...it was fine...."

Some students commented that working in a group slowed them down a bit and encouraged laziness from time to time.

Students described how being able to search and construct information aided their learning. The few responses included:

"yes.. I would think so....because usually in lectures we are given a series of reactions, and we don't quite have the time to look at it and try and figure out what is happening...where.. wereas with this.. we would actually have to write it down ourselves and in, in, in ...the order that it was given, and then when we were looking at it, we could actually see, you know with the different colors and stuff, what is actually being removed, and what is added and things like that ...."

"yes.. because you build up your own knowledge.. and its sticks.. whereas in a lecturer, you're just taking down notes.. and the material is new to you, whereas when you build it on your own you have to experience building up your own knowledge and by the time the exams come you basically know the general idea.. it makes it much easier.."

Students were finally asked if there was other comments, or problems, they could think of. Some responses reinforced the need for more computers in the laboratory, literacy skills at the beginning of the course, larger physical space and more time. Students also thought it would be a good idea if books could be marked, or marks allocated to each question and in terms of the software (Lipids), more pictures and links were required.

5. Discussion

This project comprised of three major phases, i.e. development, implementation and evaluation of educational software. Development of the software began with converting material originally used (lecture notes and textbook), into a databased based format. For the carbohydrate metabolism course, the graphical material (molecules and pathways) was converted into searchable database knowledge units, whereas the textual information was used to narrate to students the sequence of biochemical pathways. Content from the Lipid Metabolism course was more essay based but was categorized according to different types of knowledge i.e. structures, processes, transport, and essays relating to the human body.

Both courses were implemented in the same learning environment with the same socio-constructivist settings and resources (demonstrators, courseware developer and subject expert) as well as the time range. The only difference however, was that the level of interactivity in the Carbohydrate Metabolism offered more features (searchable database, online testing, and greater dept and navigability options than the Lipid Metabolism course which, although was well presented and structured, contained only static information. Therefore, this project aimed, in part, to investigate the effectiveness between interactive software and static content.

The final phase of this project involved evaluation which was mainly summative in nature (exam performance, interviews), i.e. "designed to produce comprehensive assessment of the object" (Persico, 1997), but also included enough specific formative information (ESET, paper based evaluation) to improve nature the design of the courseware.

Evaluation of software is crucial since it informs the decision of purchase and/or use of software and forms part of an "ongoing, formative evaluation of the process of implementing large scale computer use" (de Lisle, 1997). Broad questions involved in general evaluation of software include: matching curriculum objectives, instructional soundness, and most importantly, "do students learn the skills that the program is designed to teach" (Zahner *et al.*, 1992). Evaluation may occur at different levels, i.e. evaluation of the developmental procedure (curriculum, content and software development), evaluation of implementation (usage) , or even formal evaluation of the evaluation process itself. In terms of research design, Richey and Nelson (1996) outlined two development research methodologies in instructional technology (Table 5.1.):

Table 5.1: Summary of the two types of developmental research, Richey and Nelson (1996)

	Developmental Research	
	Type I	**Type II**
Emphasis	Study of specific product or program design, development and /or evaluation project.	Study of design, development, or evaluation processes, tools or models.
Product	Lessons learned from developing specific products and analyzing the conditions, which facilitate their use.	New design, development, and evaluation procedures and/or models, and conditions, which facilitate their use.

The development of the evaluation tool (ESET) followed the type II format, whereas the courseware development project for undergraduates (Carbohydrate and Lipid metabolism) was type I in nature.

Discussions of project results are based on evaluation of the following aspects: The software (user interface, pedagogy and interactivity components), the learning environment (physical space, learning resources, interaction and guidance, and assessment and feedback), and finally student evaluation (student activities and skills, learning and understanding, student attitude and student performance). These different aspects were obtained from the various quantitative and qualitative techniques outlined in the results section (Table 4.1) in order to provide sufficient support for usage of computer based learning resources in education. The underlying theme that is evident throughout the discussion is traditional versus technology-based learning. Focus is based on how technology can be integrated into higher education, either in part or as an entire experience. Finally, a schematic of the software development and evaluation process will be presented to illustrated all components and resources involved in developing and evaluation software.

5.1. Software Evaluation

Evaluation of the software (Carbohydrate Metabolism and Lipid Metabolism) was accomplished mainly via the ESET (quantitative) as well as paper based evaluations (qualitative) in order to assess the use of User Interface as well as Pedagogy and Interactivity components. Highlights of the software functionality in this regard may provide a better understanding of how such software could be used in a learning environment.

5.1.1. User Interface

The software developed for this project used highly intuitive graphics that were simple, clear and easy to understand both to display content (Figure 5.1) and to aid in navigation. User Interface analysis of both packages using the ESET tool showed that the presentation and aesthetic aspects were well received by students. This was further supported by students in interviews. Jarz *et al.* (1997) stated that a user interface has a significant influence on the 'look and feel' of the system and its success and includes "symbols and colors" as basic but important components. This highlights the need for good design (fonts, colors and layout) in which students scored highly using ESET for both packages. With the impact of multimedia technology, education has become visually appealing and enhanced. Results from the paper-based evaluation saw students rating visuals provided in the course highly and also commented in interviews that it improved their relating and understanding of information. Barker (1990) stated that one of the functions of user interfaces is to enable the learner to visualize what is happening within the learning domain with which they are interacting. In a four-year study with primary and secondary students, MacDonald and Ingvarson (1997) highlighted how simple concepts could be illustrated in powerful way "Such visual demonstrations where the child can manipulate the tool and experiment with outcomes can contribute towards strong constructivist learning".

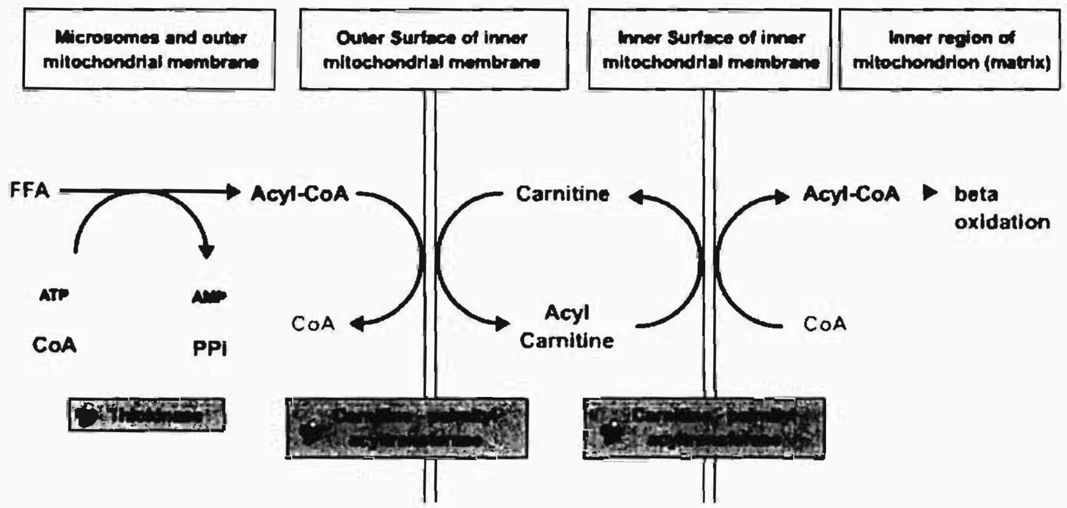


Figure 5.1: Fast loading vector graphics (Macromedia Flash) used to illustrate molecules and reactions in the Lipid Metabolism software.

The evolution of graphic and authoring technologies has made multimedia and Internet applications quite a powerful medium for interface development. It is important that user interface design make full use of technology rather than "transferring paper or previous non-graphic interfaces onto the screen" (Starr, 1997). This author further adds that interfaces should be visually appealing and should be written in user terminology rather than programmer terminology.

5.1.2. Pedagogy and Interactivity

Specific interactivity and pedagogical components are discussed later with respect to the learning environment and activities or student learning, however one of the main themes prevalent here, is that of navigation and interactivity. Paper based evaluation revealed that students found it easy to navigate through the different sections of the material, however, ESET analysis showed that student rated navigation (ease of use and links) more highly for the Carbohydrate Metabolism, than for the Lipid Metabolism courseware. There was also a difference in intuitivity of use (understanding of interface).

Being able to maneuver or navigate through software easily and logically provides one of the biggest challenges for developers. Some important questions (Jonassen and Grabinger, 1990) raised with respect to navigation include: navigation through the system without help, different navigation styles amongst users and availability and suitability of navigation aids. Although not directly evaluated or presented in the results, the courseware allowed users to navigate to different knowledge units (terms, molecules, pathways, essays) in separate browser windows (Figure 5.2., Figure. 5.3.). Such a mechanism allowed the user to quickly find additional information while maintaining focus on the original content.

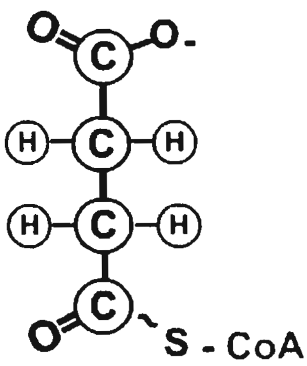
lactic acid fermentation | Close biochemical

Fermentation process that occurs as an alternative pathway to the Citric acid cycle (in animals, lactic acid bacteria) under anaerobic conditions. Pyruvate exiting Glycolysis cannot undergo oxidation and is thus converted to lactate, producing NAD+, producing a smaller, but significant amount of energy (than aerobic Glycolysis).

See Also

anaerobic
aerobic
Glycolysis
NAD+

Figure 5.2: Terminology window opened in separate browser window with "see also" links in the Carbohydrate Metabolism software



Name
Succinyl-CoA

Class: organic compound

Number of carbons: 4

Description
Produced in the 4th reaction of the Citric acid cycle, this compound is synthesized from 5C alpha-ketoglutarate. This compound is the first 4C compound to be

Figure 5.3: Molecular window opened in separate browser window with "see also" links in the Carbohydrate Metabolism software

However, the software did not allow students to bookmark areas of interest or problematic areas, and such a feature in software would greatly benefit users. Taylor (1996) summarized navigation as: how to run software, how to find one's way about, how to respond when asked questions, keep track of places visited, retrace steps and how to jump from one place to another.

Giving student freedom of movement allowed viewing of material at their own discretion thus providing a personal experience. This level of user control, or non-linearity, (Kumar *et al.*, 1994) is basic to interactivity since the designer can create links independent of a rigid structure and allow the user to seek elaboration of hyperlinks, choose which topic to view, or follow different pathways through the program. It is also conceivable that ease of navigation allows students to move through material quicker as well as make it more comfortable, enjoyable, timesaving and non-distracting (according to student interviews) to work with.

There are, however dangers associated with too much freedom of movement. Jih and Reeves (1992) pointed out that students using hypertext materials could become confused and lose track of what is going on, and where they are located in the program. This could result in frustration and prohibit learners taking full advantage of opportunities presented by technology-based resources. Many students mentioned initially being lost or confused when working with the software (interviews). One way of overcoming this problem in a classroom setting is to provide students with suitable guidance, both in the software as well as personal assistance (discussed later). Jarz *et al.* (1997) maintained that a compromise between guided learning and free navigation presents the best conditions for optimal learning.

One of the biggest buzzwords in software today is that of "interactivity". Unfortunately, interactivity cannot be directly measured as a single product or phenomenon, since a combination of activities and learning processes may contribute towards interactivity, both with the software and amongst users and facilitators. Although much of this interaction is discussed later, its useful to expand on some ideas regarding software interactivity at this point.

Starr (1997) argues that true interactivity goes beyond simple hypertext and linking but involves information exchange between the user and the server, quoting components such as feedback, searches, scoring of test answers and simulations based on user inputs. With the exception of simulations, students rated all these components highly in Carbohydrate Metabolism (Lipid Metabolism did not contain on-line testing or search engines).

The term "interactivity" has become ubiquitous. Aldrich *et al.* (1998) listed examples such as interactive TV, interactivity multimedia, interactivity video etc. The author offered a simple definition "interactivity is directed at the level of the interface where the user takes some action and the computer responds to the action" but argues that greater depth of research of cognitive activities and problem solving is involved. Jih and Reeves (1992) placed emphasis on mental processes and internal motivations of the learning rather than the software. These authors argued that interactive learning systems are designed to engage behaviors such as making choices, answering questions and solving problems and added that the basic assumption here is increasing learner motivation and to enhance performance and productivity.

Although Ward and Tiessen (1997) regard web based technologies to be limited to "point and click", technology has vastly been improved (examples used in courseware: vector Flash graphics, the intelligent use of databases with dynamically generated content) to afford a more interactive experience engaging users in the above-mentioned learning behaviors. "It is not obvious to use these resources and this software in ways which actively engage students in constructive activities which bias students towards knowledge transforming activities (as opposed to simple knowledge replication)" (Ward and Tiessen, 1997).

In summary, evaluation of the software identified sufficient interactivity although additional functionality such as manipulation, annotations, creativity, experimentation and simulation testing (Aldrich, et al., 1998) would greatly enrich the learning process.

5.2. Learning Environment and Activities

To fully appreciate the benefits of educational software, it is necessary to understand its use within the context of the learning environment, to describe and relate physical factors, resources, activities and interactions that occur directly with the software and/or as a result of software use. Development of learning environments involves collaboration of various parties including commerce; teaching faculty, students, and information specialists who need to work together in order to realize the potential of Internet-based education (Graziadei and McCombs, 1995). Greening (1998) stated that attention to the learning environment is important in terms of education goals and emphasizes problem-based learning and constructivist approaches. Results discussed here emphasize physical space, learning resources, interaction and guidance, and assessment and feedback.

5.2.1. Physical Space Considerations

Although many authors describe virtual universities or virtual communities (Richards *et al.*, 1997; Collis, 1997), formal education remains physically based. Therefore, one needs to account for how physical spaces and environments need to be modified, or improved, in order to maximize technology based learning initiatives with respect to socio-constructivist environments.

Results from this study identified time management and physical space considerations as problematic. Results from four sources (paper based evaluations, ESET evaluation, ESET open ended questions and interviews) identified time limit, physical constraints, and resource shortages (computers) as factors that inhibited learning to some extent. Examination of these problems usually lead to budgetary or curricular issues and since technology based courseware is relatively new, such structures need to be readdressed in this regard.

Examples of environment settings range from simple and practical described how existing classrooms were renovated to provide a large, shared work area, separated from the actual classroom where students did not have to work on their own (McDonald and Ingvarson, 1997) to complex and robust technology centers "Different rooms can be configured for either computer labs, video conferencing, or simulations. The learning lab, separate from the computer lab, can be either a regular classroom or a lab with a capacity of 70 students, 400 network ports, 95 computers and four video conferencing site, with computing support services located adjacent to both of these rooms" (Horgan, 1998). The range between these two examples is mainly subject to budgetary constraints and importance placed on technology integration.

Time is also a crucial factor in environment settings analysis. Just as students may be time restricted in lecture-based or teacher-centered models, so to do short blocks of time affect learning (McDonald and Ingvarson, 1997). These authors support longer periods of time without interruptions. In addition to physically lengthening physical time, results of this study (from ESET, interviews) indicate that students work faster with software that foster ease of use and navigation. Students also argued (in interviews) that computer literacy training (as a separate program) would have optimized their speed and efficiency.

In general, courseware developers should strongly be encouraged to conduct "needs assessments" (Reeves and Hedberg, 1998) in order to better understand and optimize physical space and time allocation with respect to technology integration. One also needs to take into account the nature of computer hardware and software, which continuously needs to be upgraded and maintained which further adds to logistical considerations.

5.2.2. Learning Resources

The next aspect of the learning environment, and probably the most important, is the learning resources being provided for students. Although physical space, time and hardware are considered to be resources, focus here, is placed on resources developed for students (software, workbooks and additional material) and describe the nature and use of the content provided.

In the overall paper based evaluation, students rated course and content structure highly. Although some students would have preferred conventional resources such as printed notes, lectures and tutorials, they listed the completed workbooks and Internet-based courseware as their main resources (from paper based evaluation and interviews). The use of technology in many cases can provide adequate coverage of resources since it presents tremendous potential and can be constantly updated, corrected and distributed globally from a single server. Benefits of such technology include automation of content production, which will be years ahead of textbooks (Starr, 1997).

In an example given by Anderson (1997), "the main advantage to students was that all the material was continuously available and while the bulk of course slides and practical exercises were print based, the visual quality of the on-screen display exceeded the printed version offering high-quality images". All students that were interviewed commented favorably on the courseware being permanently available to them. Anderson also argues that the potential of "ubiquitous" information also eliminates the need for information to be repeated (i.e. in a lecture for example), and steers more responsibility towards the student and away from the teacher (discussed later). Resources should be "self-instructing and self-managing" (McDonald and Ingvarson, 1997), thus lessening the burden on the teacher as information provider.

Also, there is a strong trend from "getting enough information" to "getting the right type of information" (Lake, 1995). Learners need to build information based upon a specific structure. This is where one needs to place in context the types of knowledge that is best suited for technology-based distribution. With respect to suitability, students (interviews) stated that the topics presented required visual elements and warranted the use of technology. Barker (1990) stated that the ease of which a subject can lend itself to technology is referred to as the "openness" of the software and included factors such as: prior experience of learners, intellectual complexity of subject matter, availability of development handles within the source material as well as the level of automation that the learning domain will support.

In Carbohydrate metabolism the content took the form of a databased knowledge system. Here the focus was to exam the types of knowledge (within the software itself) students made use of and how they combined and integrated such information into their learning. The use of the search facility and glossary proved to be the most useful feature as rated by students in the paper based evaluation and interviews. There was no strong inclination towards any one type of search strategy and students showed that they used all software resources (molecules, glossary and pathways) equally. The results support the idea that students enjoyed searching for and constructing their own information (paper based evaluation) and that databased knowledge "blocks" provided an ideal environment for such learning activities involving different knowledge types. Jarz *et al.* (1997) stated that splitting up information into chunks resembles situations in the real world, where information needed, is seldom found in one place. The author further added that building information resembles piecing together a puzzle "... the user is confronted with a realistic situation: He or she must look in several different places of the case study to find the puzzle pieces (or chunks of information) needed for the solution". This type of activity fosters valuable problem solving skills (discussed later).

The power of the computer to search for and retrieve information can be used to interlink and annotate related topics creating a web of information, or a personal trail of information, thus becoming and interactivity part of the learning process (Graziadei and McCombs, 1995). Shneiderman and Kearsley (1989) describes hypertext as a database which has active cross references that allows the user to jump from section to section. In addition to it being a presentation format, databases also present students with a medium for constructing their own knowledge in the form of pictures and written notes (Choi and Hannafin, 1995). Students stated in interviews that the absence of database and/or search features in the Lipid Metabolism courseware inhibited their learning considerably.

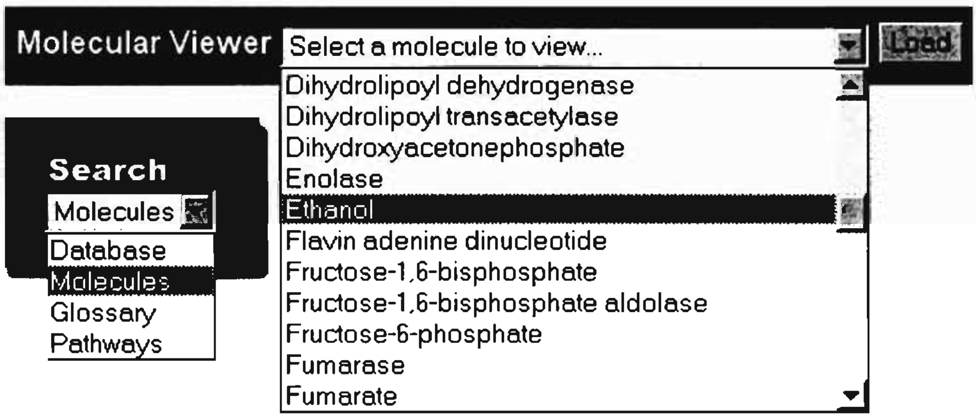


Figure 5.4: Searchable database in the form of a molecular viewer, term viewer, or pathway viewer in the Carbohydrate Metabolism software

Finally, it is necessary to consider the content, or cognitive load, being presented to students. Students felt that the amount of knowledge being presented was adequate for both courses (paper based evaluations and ESET) and interviews showed that students were quite confident with the amount, since they stated that the courseware and notes were sufficient for exam preparation. Although they experienced initial difficulty, they regarded the content as easy to follow but was also challenging. Students argued that a lot of effort was required in order to process and understand the information.

Jih and Reeves (1992) argued that users are normally presented with three types of cognitive loads: content of the information, structure of the program, and response strategies available. In other words, students have to know what they are looking at, how to work with it and what to do with it. These authors stated that learners needed to perceive options, conceptualize a choice, and take some physical action all of which are provided by human-computer interfaces. It is appropriate at this point; to emphasize how much better such systems are in comparison to traditional learning models. Although content plays an important role in software development, some educators think that generalizable, domain-free, cognitive processes can be developed regardless of the subject matter being studied (White and Purdom, 1996): "They value intellectual process over content and believe that practically any content can be used to facilitate problem solving, critical thinking and higher order thinking processes". In this study, two different content types were encountered (Carbohydrate metabolism and Lipid metabolism) and results showed that the difference in content type might affect developmental and learning processes (discussed later).

5.2.3. Guidance and Interaction

The following discussion deals with the amount of guidance and assistance provided to students, as well as interactions between the different parties in the learning environment. It is also important to note the equilibrium between providing assistance and allowing students to navigate and learn on their own.

Results of the ESET evaluation showed that students rated instruction and goals presentation availability and presentation much higher in the Carbohydrate Metabolism course than the Lipid course. Castellan (1993) stated that students needed to know what the goals of the course are in order to develop a useful schema for the knowledge or skills to be acquired. The author added that students who are familiar with the goals of the course could monitor their own progress towards these goals thus establishing confidence and satisfaction.

In addition to being presented with a set of goals and objectives, albeit specific or loosely defined, students need to be guided during the period of contact with the course material. In this study, students were provided with demonstrator assistance as well as feedback from both the courseware developer and subject expert. Students regarded demonstrators as crucial to their learning and more specifically to their problem solving. Students mentioned (in interviews) that feedback and immediate responses minimized confusion and misconceptions and optimized their speed of courseware usage. Students rated demonstrator helpfulness highly in the paper-based evaluations. Students mainly called upon demonstrators and the courseware developer and consulted the subject expert only when really necessary. Structuring of learning settings in this way highlights two important aspects, (a) importance of guidance and support to students and (b) decentralization of the lecturer or teacher as the provider of information.

Previously it was discussed how guidance can prevent students from becoming disorientated and confused. Wilson (1995) argued that students given generous access to resources are likely to learn something if they are given guidance and proper support. The author added that interaction should be supported and nurtured rather than controlled or dictated in any fashion, i.e. transforming instructional environments into learning environments. Brandt et al. (1993) pointed out the importance of guiding students "Coaching involves observing and helping individuals while they attempt to learn or perform a task". It includes directing learner attention, reminding of overlooked steps as well as providing feedback, challenging and structuring ways to do things, and providing additional tasks and problem solving situations (Choi and Hannafin, 1995). These authors add that advice and guidance (in situated learning environments) helps students maximize use of their own cognitive resources and knowledge.

Kook (1997) proposed four new roles for educators i.e. teachers as information consultants, teachers as team collaborators, teachers as facilitators and teachers as course developers. These examples support the way in which the Carbohydrate and Lipid metabolism projects were designed. Subject experts became part of the team, rather than a central figure. This stimulated students to work in groups and interact with each other.

Studies have shown that in certain cases, teachers may interfere in discussion groups causing participants to become less spontaneous and less likely to contribute their own ideas (Needham and Hill, 1987). These authors also regarded the teacher as managers rather than controllers whose tasks should include: ensuring students understand tasks, negotiating rules for classroom operations, setting time limits and providing non-threathening environments that encourage ideas rather than judging ideas. Such structures can be seen to nurture creative thinking skills. As teachers become academic advisors (Kook, 1997) in this new environment, their understanding and familiarity of technology must improve. With experience, teachers should regard technology as an opportunity and less as a threat (McDonald and Ingvarson, 1997).

In order for such a learning environment to be successful, there must be sufficient allowance for communication between all parties involved. Paper based evaluation showed that students rate the level of communication highly for both courseware packages. The use of the ESET tool and interviews confirmed this same rating. Communication is a crucial part of the learning cycle. "...by hearing themselves and their peers discuss and communicate information helps the learner correct any misconceptions, and provides other ways of perceiving the information to form powerful memories" (Dwyer, 1995). Although the Internet is regarded as "a place to talk", where learners can communicate globally (Lake, 1995), this project illustrated the effectiveness of communication in the classroom, as opposed to students working on their own. In their case study with primary and secondary learners, McDonald and Ingvarson (1997) argued that effective communication with students was a vital pre-requisite. With regards to "collaborative project-based learning", Ward and Tiessen (1997) stated that the main activity involved students (and teachers) working together to collect resources and add intellectual value to them. Mayes (1995) introduces the concept of dialogue, which he argued is fundamental to education. The author states "...although it is possible to learn without discussion, the need to support deep learning through tutorial and peer-group dialogue is paramount".

In this project, collaborative learning activities were not technology based, but supported the courseware packages. It is important to note that neither effective communication nor collaboration was achieved via technological means, highlighting that pedagogical activities need to take preference over technology itself. In other words, conventional classroom practices such as communication and collaboration form the foundations for technology use and facilitation which follows a very basic principle i.e. "...people of any age develop and strengthen their own understanding when attempting to teach someone else" (McDonald and Ingvarson, 1997). Many students mentioned that by helping others in their group improved their understanding of concepts and often allowed them to perceive information from different angles. Choi and Hannafin (1995) stated that collaboration is inherent in every day action and that individuals attempt to solve problems by interacting with other people using socially provided schemata and contextual cues. These authors also add that students learn to negotiate meaning with others and experience shared responsibility (discussed later) for learning.

5.2.4. Assessment and Feedback

Assessment usually involves some form of testing, either by oneself, or administered by the teacher at the end of the course. A testing section of the Carbohydrate Metabolism course, which included multiple choice and short questions (with model answers) (Fig. 5.5), was rated highly by students. Students enjoyed using a system that gave them immediate feedback and linked them to relevant content (paper-based evaluation and interview).

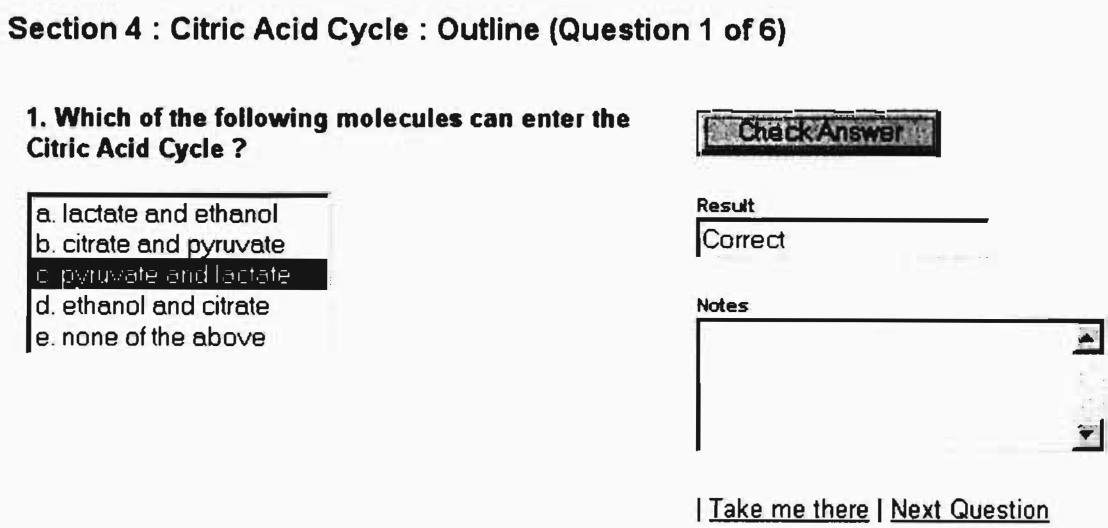


Figure 5.5: Online testing section with multiple choice questions and immediate feedback and links to corresponding content in the Carbohydrate Metabolism courseware

Students were also asked (in interviews) to provide their views on current assessment methods. Most students accepted current methods and listed possibilities including continuous assessment or making use of computer technology to facilitate the assessment process (i.e. computer based testing). Besides the formal examination at the end of the semester, no other assessments were used in either course.

Assessment plays an important role in the classroom. Richards *et al.* (1997) stated that assessment mechanisms improve motivation, assist in the organization and assimilation of information and help remediate inadequacies in knowledge transfer. According to Nightingale *et al.* (1995), "Good assessment practices allows teachers to demonstrate the quality of their students' learning to others" and provides students with the chance to learn in depth and test the limits of their understanding. However, as the learning environment becomes more loosely defined due to technology use, assessment needs to be restructured. Barker (1990) for example, argued that appropriate "handles" (measure or observational strategy that can be used to assess learning) are necessary to gauge how well students are progressing and list problem solving environments (similar to this project) as an example. Although, in the project, assessment was direct and offered simple feedback, Kumar *et al.* (1994) proposed that the use of computer technology warrants more indirect forms of assessment based on cognitive rather than behaviorist psychology. Assessment conducted as part of this study, was based on the provision of resources as well as skills and activities exhibited by students (discussed later).

Students were also allowed to assess themselves via the software. Dwyer (1995) argued that self-questioning and self-reflection allows the learner to internalize information making it personally relevant. Nightingale *et al.* (1995) stated that giving students opportunity for self-assessment makes them a participant in the learning process where they become more aware, or conscious of their progress, i.e. giving students responsibility for their own learning and outcomes.

Assessment practices are changing in response to changes in modern learning environments. "If a change is made to the teaching / learning philosophy, the way tests are designed and used must also be reconsidered"(Dwyer, 1995). This author argued that traditional testing focuses on memorization rather than high-level skills required for the future. Assessment is a multi-dimensional process involving diverse measures and standards related to student thought, behavior and performance (Choi and Hannafin, 1995).

The results of this study provide substantial evidence for successful ways in which learning environment can be constructed. Also, computer-based learning resources need to be embedded within restructured classrooms that allow students to make use of dynamic resources that promotes sound pedagogical principles of communication and collaboration between learners. In addition to providing the software and environment, student activities need to be guided and assessed accordingly.

5.3. Student Evaluation

The final part of this study involved the evaluation of student learning, attitude and performance with respect to courseware developed. Evaluating how students rate and perform in the course represents one of the most important criteria when implementing new teaching technologies. Most of the results were obtained from student response data via questionnaires, ESET, interviews and exam performance.

5.3.1. Student Learning

Student learning can be categorized into two main components, i.e. practical activities (activities and skills exhibited) and mental cognition (learning and understanding). Being able to identify useful learning activities and behaviors enables researchers to correlate the level of learning and understanding achievable which is usually hard to quantify on its own. Although learning is ultimately gauged by traditional assessment methods, the aim of this study was to provide resources, learning environments, and activities for students that foster appropriate skills that ultimately lead to students learning. Specific activities, skills and associated learning modes are discussed here in order to provide a setting for learning and knowledge building.

Three major themes emanated from observation of skills and activities in this study: the challenge of activity based learning, self-paced learning and searching for and constructing information. Also included, is a discussion of other specific learning skills displayed by students as well as the learning process involved.

Gustafson and Branch (1997) described ideal learning activities as "...constructing knowledge and skills while at the same time interacting with peers, media, content and teachers...". Ward and Tiessen (1997) stated that together with the use of powerful tools, activities must foster student's purposeful engagement with information resources and meaningful interaction with other students, both in the classroom and beyond. Berge (1997) introduces the term "authentic learning activities" in the author includes: inquiry, problem-based activities, case studies, projects, peer critique and support and self-reflection.

The use of technology in this study completely revolutionized the actual process involved in learning. Students were more involved with the material when compared to traditional methods. The main activity involved students logging into the Web site, searching through different resource types, conferring with team members and answering problems posed in their workbooks. When asked to rate the use of workbook and software (paper based evaluation), students regarded the process as difficult and challenging but found it easy to understand and use (both in Carbohydrate and Lipid Metabolism). Reaching equilibrium between difficulty and challenge is important since too little challenge will prove boring, while too much could cause frustration (Brandt et al., 1993).

Using computer technology, student activities were paced according to each individual or group. In some cases students resorted to working on their own at times and regarded self-paced learning as highly beneficial to them. When questioned in interviews, students confirmed that they greatly benefited from working at their own pace. The nature of the courseware allowed different students to follow unique paths of learning at different paces, each based on their own individual skills, interests and group interaction. Students also said that they obtained help from their team members or demonstrators if they were behind. The flexibility of such interactive systems allowed learners to pursue experiences in a self-directed, non-linear manner consistent with constructivist models of learning (Kumar *et al.*, 1994). Taylor (1996) argues that benefits of independent learning allows students to develop at a pace set by themselves which encourages a mature and scholarly approach to learning. Also, control becomes less of a classroom issue for teachers, since students become more involved in directing their own learning and teachers become 'trouble shooters' (McDonald and Ingvarson, 1997), which relates well to the theme of "guided learning" as previously discussed.

The predominant activity underlying both courses included searching for and constructing knowledge from various searchable data sources. Students in both courses enjoyed searching for and constructing their knowledge (paper based evaluations). Results from the interviews indicate that students found personally constructed information much easier to build and understand. The functionality of a search engine (in the Carbohydrate Metabolism course) allowed students to search for information in different formats and construct pathways based on problems in their workbooks. Although information was accessible as single units in a database (i.e. as a molecule, term, or pathway), a detailed definition or description of the unit accompanied it. Students said in interviews that this eliminated the laborious task of having to look up the definition or description of the unit in an index. Once they were familiar with a knowledge unit (example: glucose, which had a definition, molecular image, class description and links to other similar units), students needed to incorporate the unit into the "larger picture" in their workbooks. The presence of links or "see also", which is commonly used in computer software help files, enabled students to make connections to related information thus forming bridges or networks of information.

Jean Piaget (1970), whose central concern was the process by which humans construct their knowledge of the world, postulated the existence of cognitive schemes that are formed and developed through the co-ordination and internalization of a person's actions and objects in the world. According to Driver *et al.* (1994) knowledge is not transmitted directly from one person to another but is actively built up by the learner. Kumar *et al.* (1994) stated that non-linear capabilities of hypermedia could provide students with a range of options to build patterns or concepts. These authors maintain that once patterns have been established, terminology can be introduced to further develop concepts using examples. Once learners have in mind the general nature of the phenomena they are dealing with, fundamental or basic ideas are applied to new problems (Bruner, 1996). In the Carbohydrate Metabolism course students were introduced to the overall process and given the initial reactions. Using these pieces of information students had to build reactions for a reaction pathway linking to other relevant content in the database.

Students build information based on what they already knew. Learning comes about when current knowledge schemes change through the resolution of disequilibration (Driver *et al.*, 1994). This resolution requires internal mental activity and results in previous knowledge schemes being modified, i.e. a process of conceptual change. According to these authors, providing student with cognitive conflicts, i.e. problem solving environments encourages learners to continuously develop new knowledge schemes. Once the "big picture has been established, new information is integrated into present understanding and students reflect on how their present perceptions and understanding differs from their new understanding. Students then constantly restructure and re-organize information (Kumar, 1994) in order for it to become usable knowledge (Bruner, 1996). Giving students resources and tools to build information presents them with an environment and opportunity for effective knowledge construction and highly effective learning. If students can work quicker, they can think quicker. From observation and results of the interviews, working with resources that are easy to find and build, together with peer assistance and guidance provides a coherent flow of mental thought.

In addition to the main activity of searching for and constructing knowledge students also identified problem solving, 3D visualization, comprehension and reporting, communication, decision making and critical thinking as important skills required to navigate both the courseware packages. Students also stated in the paper-based evaluations and interviews that the course greatly improved their computer skills. Taylor (1996) emphasizes that inquiry-based learning involves understanding and knowing how to ask questions. The author stated that learning is highly dependent on students' information handling skills. Computers offer tremendous potential for students to view and "handle" information and thus learners need training in the use of multimedia. Taylor lists skills such as operation, navigation, investigation and reflection as important in effecting information-handling skills. In a feedback study using university teachers, Nightingale *et al.* (1995) identified the following core skills sought of students: critical thinking, making decisions, problem solving, developing plans, performing procedures and demonstrating techniques, managing and developing oneself, accessing and managing information, demonstrating knowledge and understanding, designing, creating, performing and communicating. These authors believe that these are areas that most academics identify as key descriptors of student learning.

The skills and activities displayed by students in this study conform to the constructivist model of learning. Fosnot (1996) defined constructivism as a theory about knowledge and learning which describes what "knowing" is and how one "comes to know". Knowledge is temporary, developmental, non-objective, internally constructed and socially and culturally mediated. The constructivist view of learning involves teachers giving students the opportunity to search for patterns, raise their own questions, and construct their own models, concepts, and strategies. The constructivist classroom is seen as a community of learners engaged in activity, discourse, and reflection where the teacher is the facilitator. Dick (1997) stated that constructivism suggests ways in which the learning environment may be arranged and managed in order to provide students with the best possible context in which to learn. It is difficult, however, to fully support constructivism since no empirical feedback mechanism that identifies what is not working well (Dick 1997).

Here, intuition and creativity on the part of the developer play a major role in implementing constructivist learning environments.

Having set the stage for constructivist learning, there is also a need to evaluate overall understanding achieved as a result of technology usage. Interview results indicated that students regarded understanding and memory as two separate processes in learning. Many of the students interviewed, understood the concepts in both courses but were not ready for the examinations until they went over it again to memorize content. Although traditional assessment relies on memorization of content (Dwyer, 1995), this study focussed on understanding of content, conceptualization and specific skills fostered using technology. Students provided two reasons that improved their understanding and memory retention (deep learning) during courseware usage itself. The software gave them confidence and the nature of the resources helped to compartmentalize and structure information mentally. Students stated that the visual nature of the content and real life context and examples (in Lipid Metabolism) helped them to better understand and prepare for the examinations.

Richards *et al.* (1997) described two types of knowledge: working knowledge (to address current task problems) and deep knowledge (providing understand in the long term). Information presentation is normally followed by conceptualization where concepts are iteratively refined, understood, and internalized by action, applying the knowledge in performing practical tasks (Anderson, 1995). The process whereby students visualize or compartmentalize information mentally, as described in this project, can be akin to the term "concept mapping" which can be either a physical or mental process. According to Andersson (1994), concept mapping is structured according to inherent structures found in the knowledge domain. Concept mapping has a profound role to play in analyzing the processes of learning, and they provide a means for understanding human knowledge with the aid of computer technology (Bower and Hilgard, 1981, de Mey, 1992).

Deep learning is a by-product of understanding, where understanding occurs best by performing tasks, and reflecting on them by oneself and with members of the group

(Anderson, 1997). Dwyer (1995) presented the "optimum learning cycle" based on recent brain research, in which he listed steps involved in the way students naturally learn. These steps are depicted together with the activities and skills (depicted as symbols) evident in the results of this study (Fig. 5.6).

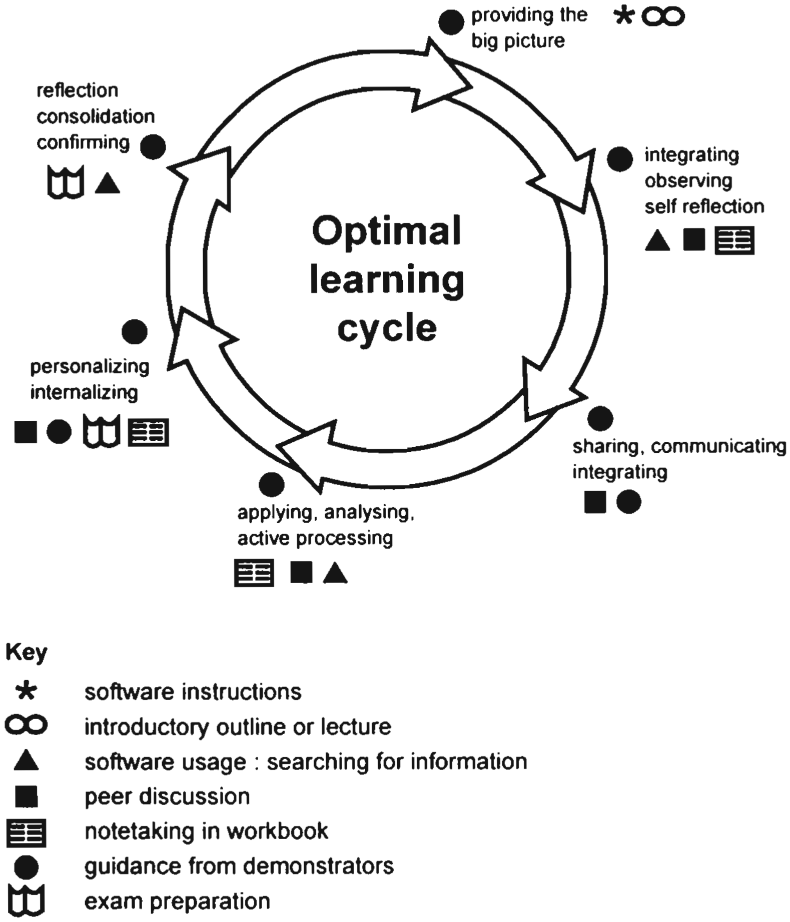


Figure . 5.6: Optimal Learning Cycle (Dwyer, 1995) with symbolic additions from study.

The results of this study show that activities during the course not only strengthen working knowledge but may also contribute towards deep knowledge transfer via pattern formation, organization of information, concept mapping, communication, and reflection. For deep learning, a student applies analysis, attempts synthesis of concepts, and evaluates what has been done where knowledge is built through experience and dialogue. (Anderson, 1997). In other words, the active nature of the courseware enables students to engage in deep learning and understanding, which is not always possible in didactic teaching methods.

5.3.2. Student Attitude and Enjoyment

Student attitude and enjoyment was also evaluated in this study via interviews and paper-based evaluations. This was conducted in order to build a profile of students that used the courseware and to get feedback from their usage of it. In order support the use of technology, this study aimed to better understand student experience and familiarity with technology and their views with respect to technology.

Students felt that the development of such courseware was a good idea and supported it by rating the course comfort (physical, social, and education settings) highly. Interviews revealed that the average computer experience amongst students was between none and two years with little to no usage in other subjects. Students showed great eagerness towards technology and listed many applications that they used, including word processing and Internet (Web, IRC, and e-mail). The assumption of this project was that students had little or no computer experience and this determined the way in which the interface was designed as well as the level and type of guidance presented to students. Most of the students found it easy to use the software and whilst those with minimal computer experience reported initial difficulties, these were overcome within a few days with help provided by peers and demonstrators. Students were quite confident about the research behind the courseware and regarded it as innovative and beneficial. They also maintained that the course had improved their speed and quality of learning and were personally beneficial to their ultimate learning.

Maus (1997) reported on the dangers of technology use by rote, without pedagogical guiding or pressure to diversify teaching portfolios. The author argued that practical technological knowledge is no different than any other academic skill that is required of students. The author made a proposal for "...standardized required courses, that provide a basic training in general technological skills deemed necessary for the completion of an undergraduate degree in any major". White and Purdom (1996) stressed that schools must teach computer literacy to begin instilling computer skills for the workforce of the next generation. In addition to computer literacy courses, these authors stated that the adaptive view of social relevance welcomed modern technology as a way of teaching any of the information and skills used by students in any subject. In other words computers will no longer be a subject or discipline on its own, but a "tool" or skill similar to reading or writing.

The study also evaluated student enjoyment and motivation during the course. Results from paper based evaluation and interviews indicate that students rated software enjoyment very highly for both courses. Motivational aspects of the software such fun, graphics and interest were highly rated by students using ESET who scored Lipid Metabolism considerably lower. Gunn (1997) listed motivational factors as awareness of learning goals, attractive appearance of programs, and providing challenge and feedback. Motivational aspects were resolved in the interviews where students stated that being responsible for their own learning highly motivated them. Being given responsibility to manage their own time and being aware of their own progress also motivated them. "A further aspect of teaching approaches adopted is to give learners awareness of the learning process itself, to develop confidence and motivation for further learning to occur (Needham and Hill, 1987).

5.3.3. Student Performance

Student performance analysis involved analyzing pre- and post tests as well as the current year and previous year examination results. The pre and posttests showed that students had gained information in both courses. Pre- and post tests were used by McDonald and Ingvarson (1997) in order to identify existing knowledge and to assess, using post tests, the understanding of students when the work was complete. Reiser and Kegelmann (1994) state that together with student "attitude data", the pre- and post test method is a way of improving courseware evaluations.

In addition to the qualitative data supporting the development of courseware products, evaluation of examination results show that students performed better in the computer-based questions than the traditionally taught topics for 1999. Comparison with previous years showed no significant difference but further analysis showed that improvement in Carbohydrate Metabolism results was significantly higher than Lipid Metabolism results. Student performance was lower than previous years for the Lipid Metabolism topic.

5.4. Evaluation Summary of Carbohydrate Metabolism versus Lipid Metabolism

The developmental procedures and type of interactivity possible for each of these courses were different due to the nature of content and openness of the content i.e. level of which content can be suitable presented by technology. As mentioned earlier, the Carbohydrate Metabolism course consisted of discrete knowledge units (molecules, terms, pathways) and processes (reactions and control aspects). These units could easily fit the constructivist model, whereas the Lipids Metabolism course was more essay based and textual in nature. The degree to which the content pieces could be broken down was smaller that that achieved in the Carbohydrate course. The nature of material as such had considerable effects on the way in which software could be developed to fit the constructivism model of learning.

Secondly, the level of interactivity differed significantly between both packages. In terms of interactive components, the carbohydrate software contained more components that the Lipid Metabolism course. The evaluation results obtained in this study showed that the use of a searchable database was highly rated by students and was shown to be highly essential to the level of student learning in terms of being able to find information quickly and easily. Furthermore, this information was not rigidly structured and students formed their own pathways of information use. The results conversely showed that the lack of a search engine, and information that was inherently structured (rather than being structured by the students) caused students great difficulty in finding information. Another important feature that distinguished the packages apart was the ease of navigation. Evaluation by students showed the carbohydrate metabolism software was much easier to navigate and far more intuitive than the lipid metabolism software. Finally, even though students found the real-life examples in the lipid metabolism courseware helpful, the carbohydrate metabolism software proved to be more motivating in terms of fun, graphics and student interest.

In terms of similarities between the packages, this study revealed that the visual based learning was highly effective in both packages and that students found it highly explorative and interactive with adequate content for learning. The environment fostered a communicative environment that presented students with challenging problems which they enjoyed working at in their own group, each, according to their own strengths, interests and pace.

5.5. Developmental and Evaluation Models

A model proposed for software development and evaluation (Fig. 5.7.) is presented in order to provide developers with an outline of the type of research and developmental procedures that was involved during this study. The model used consisted of four phases: material development, assessment of existing course, developing software, and finally implementation and evaluation of software.

Material development involved input from both the subject expert and the courseware developer. The content was characterized according to the knowledge type and structure. A breakdown of possible knowledge structures is presented in the ESET evaluation tool (Appendix I). Once the core knowledge has been characterized, course objectives and goals are drawn up. The next step in the process is to determine the extent to which the prior (existing) course fulfils these goals and aims. This includes analyzing the structure, environmental settings and learning activities of the existing course. This is where many of the weaknesses of traditional teaching can be documented and brought to focus. This type of information is usually the result of a "needs analysis" where developers target student, environment and time needs. Once the needs analysis has been accomplished, technological solutions are developed to address both the practical and learning needs of the students. In many cases, technology may be used not only to address weakness but to enhance learning and skill development only possible by computer-based technology.

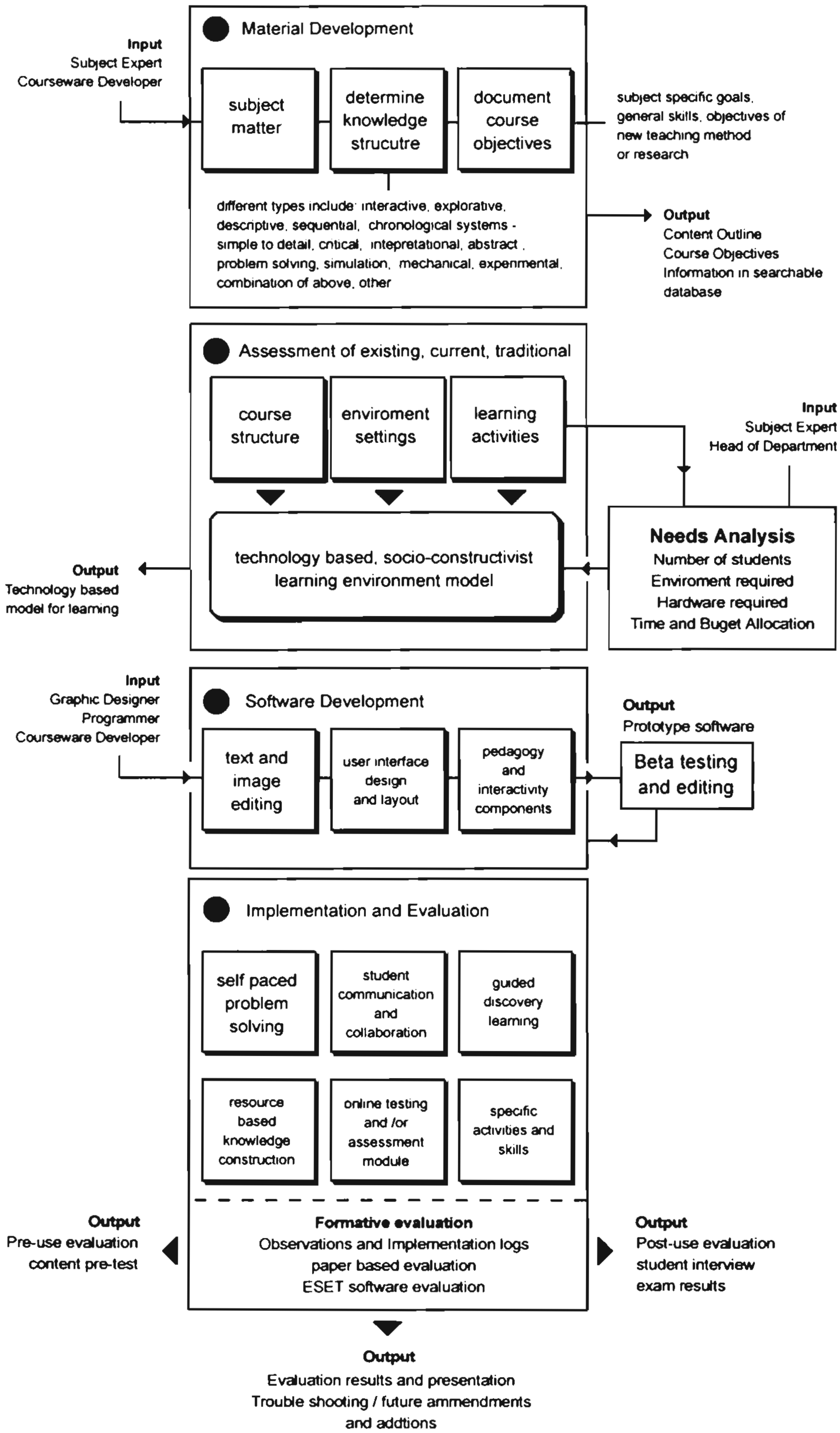


Figure 5.7: Developmental and evaluation model for technology-based courseware

The final methodology for technology enhancement will take the form of a model, or guideline, or set of procedures and objectives.

Thereafter, software is developed (according to the model outlined) that addresses the aims and objectives set out in the material development phases. This is where most of the labour is spent. Graphic designers, programmers and courseware developers construct text, graphics, images, user interface, navigation and the pedagogical and interactive components. Software is then tested and edited for final release.

In this model implementation and evaluation are presented together because these two processes occur together. In fact, evaluation such as pre-tests begins before students engage with software. Furthermore, evaluation such as observations and feedback occur during use of the software. At the end of the course, further evaluation such as paper-based evaluation, formal evaluation tools and interviews will add to the bulk of the evaluation data. Evaluation results are then used to present progress of both the software and students as well as provide specific information for product improvement.

5.6. General Discussion and Conclusion

The main aim of the project was to develop courseware based on sound pedagogical principles and practices, and included technology to enhance the speed, quality, and depth of learning. The project also showed how dynamic, interactive, learner controlled, and learner constructed content performs better than static, non-interactive content. In the carbohydrate course, information was actively built by students from searchable databased "knowledge units". Furthermore, the software contained intuitive navigation that allowed students to find information easily and logically from the database. The design of the software placed user's in control of building and shaping information according to their own pace and cognition. It also contained a testing section that gave students immediate feedback on questions. The Lipid Metabolism software however, contained static content, with no search engine. Students found the information tedious to work with and difficult to find. Although it was well designed and presented, it did not afford students many of the functionalities found in the Carbohydrate Metabolism software.

This project successfully established a viable constructivist learning environments that students enjoyed. The qualitative and quantitative results presented here serve as case study of successful technology use. This study provides a model for developing software as well as the components that distinguish truly interactive software from static content. Furthermore, the evaluation tool, offers developers a method for evaluating and improving their own software, or as a guide for new developers to build software that is pedagogically based and fosters problem solving and information building skills.

A most common theme that pervaded this research was the comparison between traditional and technology based models. The software development model presented in this study (Figure 5.7) illustrated how technology based models can be developed from analyzing and characterizing traditional teaching methods. In this study technology was used to address weaknesses associated with conventional teaching and to enhance and promote constructivist based learning via interactive software.

This study also illustrated how lecture-based traditional classrooms can be converted into socio-constructivist learning environments, which foster groupwork and communication between students and teachers, and how the use of rich Internet-based resources can change the role of teachers from information providers to facilitators. Learning becomes student-centered and places much more responsibility on the student.

Students are more motivated to learn as a result of being in charge, of and managing, their own learning. The results also show that the resources and environment provided fostered various important learning activities and skills that promoted deep learning during actual use. The development of interactive software however, goes beyond just simply putting notes on the web. This project identified several key concepts that promote successful learning as well as components (or lack thereof) that can inhibit learning. The nature and type of content being presented must involve in depth analysis in knowledge structure and type in order to determine the way in which the material is to be modified or re-presented, using technology. The inclusion of powerful software functionality (feedback and assessment modules) and/or guidance in the form of course assistants and facilitator optimizes technology-based learning environments. However, developers need to bear in mind that technology should support sound pedagogical principles of teaching and not attempt to replace it

Integrating technology into tertiary education has rapidly become commonplace with many barriers (budget, ideology, policy) being re-addressed. Technology is becoming one of *the* biggest investments made by learning institutions. The development of resources that utilize the power of computer technology as a tool, provide students with dynamic, interactive, self contain learning materials, are not yet fully realized. Also, students view computer technology as an integral part of their learning environments. This study also suggest that much more infrastructural and policy changes need to occur in order to provide students with mandatory computer literacy skills.

Although not directly evaluated in this study, the role of the teacher is rapidly changing from information provider to resource developer. Teachers are constantly developing new methodologies for teaching and computer technology offers tremendous potential not only for improving administrative, practical and assessment functions, but also as a authoring medium. Authoring systems and multimedia graphics are becoming more accessible, and with training and guidelines, teachers can provide a host of rich interactive applications for students.

The future of computer technology has only just begun. Much research has gone into providing resources that are completely self-driven and sustainable. Visions of future technology include systems that possess artificial intelligence models that are currently available in many games and simulations, as well as systems that track user progress and are able to provide highly technical and accurate feedback. Research in this field will continue to set trends and provide standards for the future of interactive education.

Research in this field has considerable potential for expansion with future visions of high bandwidth Internet technologies. Specific areas for software development could include artificial intelligence to assess student answers in tests for example. Also, technology could be used to create, monitor and manage user profiles and behaviours. Profiles and usage statistics for example could be used to provide students with immediate feedback as well as dictate interaction pathways between the student and the software.

Future technology should provide systems that are based on fundamental human-cognitive behavior that best model the way in which the mind thinks and learns. This should include research on mental visualization and manipulation of information and the way in which concepts are understood by the mind. In other words, students should develop skills to manipulate and integrate new information rather than memorize content. It is envisaged that computer technology can free up the human mind of laborious tasks such as simply memorizing content, and instead build minds that are designed to think and solve problems making use of all available tools at their disposal.

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7. Appendix

Appendix I: Educational Software Evaluation Tool (Paper-based version of the tool).

Evaluating Internet Courseware

The following tool can be used electronically at http://www.nu.ac.za/bioped/edutech

Contents

A. How to use this tool

The following tool asks technical and pedagogical questions of software in order to evaluate their usefulness in educational settings. It consists of (a) multiple choice questions which scores can be given as well as (b) open ended questions which report or provide information on a particular aspects

1. Select questions that pertain to either the multimedia or internet-based product you wish to evaluate for each of the categories :
(1) Overview, Implementation, Planning, (2) User Interface Design, (3) Pedagogy and Interactivity, (4) Curriculum Incorporation,

Mark these in the Checklist column (x) NB : Internet based questions have already been identified and checked (x), while those for Multimedia only, are checked as M

2. It would also be useful to select additional components that you feel may be useful or pertinent to your specific course goals. Please review the questionnaire carefully before marking these in the Checklist column (x)

3. Score each MCQ question as follows :
1 - Very bad / Absent, 2 - Poor, 3 - Good, 4 - Present / Very Good

4. For each of the information / Report type questions, comments may be added on a separate sheet.

5. Now you have a score and a summary report sheet for each category that can be presented in support of the package.

6. For prospecting multiple packages, the MCQ scores can be compared, provided the same set of criteria are used.

B. Overview and Planning

Place score(1-4) in the box marked ☐ or fill out a report sheet

Please provide a short description of the course content.

Please provide a summary of the course goals (global and subject specific).

Please comment on the demographic makeup of the class including student background.

Please comment on the amount of assistance required during the course (e.g. Demonstrators and technical assistants).

Can you comment on the type of environment required for the course (e.g. room size, classroom layout, power-points, chairs, tables etc.)?

Can you comment on the Equipment / Software required (e.g. computers, audio-visual equipment, sound equipment, projects etc.)?

Implementation Log : Can you provide a description of planning and details of how the course was carried out ?

Problem Areas: Can you comment on Technical difficulties, Equipment Availability, Time Constraints?

Operation of software in classroom environment - Where there any technical difficulties that you encountered during planning and/or implementation ?

Data collection and processing : Please provide a summary of how evaluation data (if any) was collected and processed.

Programming: Can you comment on the choice of software (Type of software used, requirements) and short developmental summary (optional)?

How long did it take to develop the software with respect to planning, development, beta-testing and how long would it take (estimate) to upgrade the software for the following year?

Can the software be easily tampered with (i.e. deleted, modified)?....................................... ☐

C. User Interface Design

Place score(1-4) in the box marked or fill out a report sheet

Screen Design	Subtotal Score ☐

Choice of colors (good contrast): Are the color uniform and pleasing to the eye? ....

Fonts: Are they easy to recognize and read? ....

Is there uniformity in design when moving / navigating from one page to another? ....

Layout	Subtotal Score ☐

Text flow: Is it simple, readable and easy to follow? ....

Are the pictures and text well laid/spaced out and non-distracting? ....

Interaction	Subtotal Score ☐

Interaction: Does the student easily understand what is required of him/her when using the software? ....

Instructions	Subtotal Score ☐

Are the instructions clearly and effectively explained and presented? ....

Are they always available /easily accessible (e.g. Help of Tutorial Section)? ....

Customization	Subtotal Score ☐

Does the software allow for features to be turned on/off or be adjusted? ....

Information Presentation	Subtotal Score ☐

Reading Ease (Size and clarity of text, icons and interactive objects): How well are these designed? ....

Are there any Search Features/Engines or Topic Index? ....

Ease of use and navigation	Subtotal Score ☐

Links: Are they easy and logical to follow? ....

User progress monitoring and status: Does the software provide up-to-date information on the users progress? ....

Is it easy to move from one destination to another? ....

Are the choices or navigation menus always accessible? ....

Referencing	Subtotal Score ☐

Is the user allowed to bookmark areas, sections for later reference ? ....

Multimedia options	Subtotal Score ☐

Effective Use of Visual graphics (pictures, diagrams, animation): Are these sufficiently provided in the software? ....

Attention to Size considerations: If the software is Internet-based, does it load quickly? ....

Intelligent User Interface	Subtotal Score ☐

Is the interface intuitive? Does it make sense where to start and what to do thereafter? ....

Does the student improve with usage? ....

Can repetitive displays be bypassed? ....

Attention to disabled users	Subtotal Score ☐

Does the software make use of speech recognition or speech delivery? ....

Is the interface sensitive to physically disabled students? ....

Social standards	Subtotal Score ☐

Is the software free of gender, ethnic, or other social bias? ....

Quality control	Subtotal Score ☐

Quality Control: Has the software been evaluated or tested by the developers (or anybody else) and are these results available? ....

D. Pedagogy and Interactivity

Place score(1-4) in the box marked or fill out a report sheet

Course content	Subtotal Score ☐

Does the software offer an adequate presentation of the content ? ....

Is the content appropriate for the time being allocated for the exercise, both per session and in total? ....

Cognitive load Subtotal Score ☐

Does the student find the material manageable and understandable? ....

Self-paced learning Subtotal Score ☐

Are learner's allowed to process material at a pace comfortable to them and independent to the teacher or their peers? ....

Time management Subtotal Score ☐

Is the time allocated for the exercise adequate and realistic, and was the course completed in the allocated time? ....

Adaptive Interactivity Subtotal Score ☐

Does the program alter its approach based on feedback received from the user? ....

Learning styles Subtotal Score ☐

Does the program cater for different or individual learning styles. (e.g. of learning styles, abstract, visual, problem solving, chronological)? ....

Customization Subtotal Score ☐

Does the student have the option of choosing different styles, formats, order of viewing the material? ....

Knowledge structure

How is the content structured ? (tick)

☐ Interactive and explorative

☐ Descriptive and narrative

☐ Sequential and chronological

☐ Systems - Simple to Detailed

☐ Systems - Detailed to overview

☐ Critical, Interpretational or Abstract

☐ Problem solving, experience, simulation

☐ Mechanical, Functional, Process Orientated

☐ Combination of above

☐ Other (Please Specify)

Are there any identifiable learning skills or abilities students learn while using the software?

Do students easily remember and understand what they learned?

Is there provision for experience learning, simulations, testing-and-learning, modeling? .... ☐

Is the software fun, enjoyable to use? ☐

Are the graphics stimulating and interactive? ☐

Is the software based on interesting themes? ☐

Are the goals of the exercise clearly indicated and explained? ☐

Are students made aware of general and subject specific learning goals? ☐

Are there any assessment sections in the software? ☐

Please provide comments on the type of assessment procedures present in the software (e.g. test, tutorials, or any form of active and immediate assessment).

Does the assessment possess difficulty levels, can these be manually set/chosen? ☐

Does the software contain randomization / artificial intelligence procedures? ☐

Please comment on the accuracy of the assessment i.e. report of student usage patterns and behaviours.

Are the students actions, paths, choices etc. monitored and used for remediation? .... ☐

Please list the global and 'subject specific' skills and competencies that the software intends to teach.

Does the software provide students with adequate feedback when undertaking tasks? .... ☐

Does the software recognize areas in which users are having difficulty and make the students aware of this? .... ☐

Does the software generate a usage report (common success / difficulty areas) for both students and teachers? .... ☐

Does the software make provision for users to comment immediately on the usage of the software (as opposed to 'after-usage' questionnaires)?.. ☐

Is there provision for peer-peer or peer-teacher knowledge sharing? .... ☐

Are students allowed to collaborate on joint projects (distance learning)? .... ☐

E. Curriculum Incorporation

Place score(1-4) in the box marked ☐ or fill out a report sheet

What is the main purpose of the software?

☐ Teacher's Guide ☐ Supplementary Course Resource

☐ Practical Exercise ☐ Full hands-on Interactive Course

Is the software an improvement on conventional teaching fundamentals, or does it merely provide technical improvements.

Does the software (and the evaluation process) improve in the management and implementation, of the course as a whole.

Does implementation of the course improve student attitudes, opinions and results?

Is the software re-usable and easily upgraded?

Is the development of the software (if applicable) feasible in terms of budgetary availability, if not, can it be justified by number of students served, duration of usage, or quality, effectiveness of courseware.

What are the views, opinions of subject experts, professional experts, external examiners etc.

Are there any comments the evaluator would like to add concerning the criteria of this evaluation?

Are there any comments the evaluator would like to add concerning ease of use of this tool

Section B (Overview and Planning) .... n/a

Section C (User Interface Design) .... ☐

Section D (Pedagogy and Interactivity) .... ☐

Section E (Curriculum Incorporation) .... n/a

Total Score .... ☐

Appendix II: Paper Based Evaluations for Carbohydrate Metabolism and Lipid Metabolism

Carbohydrate Metabolism Paper Based Evaluation

Place a tick in the appropriate boxes

The following Question relates to the Content Structure

It was easy to find relevant information	strongly agree	agree	disagree	strongly disagree
Sufficient content was provided to gain an understanding of the topic	strongly agree	agree	disagree	strongly disagree
I found it difficult to understand the course content	strongly agree	agree	disagree	Strongly disagree
The information presented was too simplistic	strongly agree	agree	disagree	Strongly disagree
More detailed content is required	strongly agree	agree	disagree	Strongly disagree
Developing Internet-Based Courseware is a good idea	strongly agree	agree	disagree	Strongly disagree

The following Question relates to the Course Structure

I enjoyed working with the Internet-based courseware	strongly agree	agree	disagree	strongly disagree
The problems presented in the worksheets were too difficult	strongly agree	agree	disagree	strongly disagree
I would have preferred written notes in addition to the Internet-based courseware	strongly agree	agree	disagree	Strongly disagree
Lectures should have been included in the course	strongly agree	agree	disagree	Strongly disagree
I would preferred to work on my own	strongly agree	agree	disagree	Strongly disagree
A set of printed notes should have been provided	strongly agree	agree	disagree	Strongly disagree
The completed workbooks and Internet-based courseware will make it easier to study for examinations	strongly agree	agree	disagree	Strongly disagree
Working in groups made it easier to understand the concepts	strongly agree	agree	disagree	Strongly disagree
In addition to the Internet-based courseware, I consulted textbooks and library books often	strongly agree	agree	disagree	Strongly disagree

The following Question relates to Software Usage

I found the visuals (molecules, reactions, pathways) very easy to understand	strongly agree	agree	disagree	strongly disagree
It was easy to navigate between the different sections of the course material	strongly agree	agree	disagree	strongly disagree
I used the database mainly to answer problems in the workbook..............	strongly agree	agree	disagree	Strongly disagree
I used the course notes mainly to find answers......................................	strongly agree	agree	disagree	Strongly Disagre
I used the Molecular Viewer mainly to find answers................................	strongly agree	agree	disagree	Strongly Disagre
I used the pathways and slides mostly to find answers............................	strongly agree	agree	disagree	Strongly disagree
I used all the resources (Molecules, Glossary, Pathways) equally to find answers	strongly agree	agree	disagree	Strongly disagree
I found the Glossary very useful to search for important terms	strongly agree	agree	disagree	Strongly disagree
I found the database search engine useful in finding information quickly and easily	strongly agree	agree	disagree	Strongly disagree
I found the tasks in the workbook easy to understand	strongly agree	agree	disagree	Strongly disagree
I encountered a lot of difficulties in answering questions posed in the worksheet	strongly agree	agree	disagree	Strongly disagree

The following Question relates to Environment and Learning Activities

The demonstrators and the lecturer were useful	strongly agree	Agree	disagree	Strongly disagree
I found the time allocated for computer usage adequate	strongly agree	Agree	disagree	Strongly disagree
I felt it comfortable working with the material presented in the computer lab	strongly agree	Agree	disagree	Strongly disagree
More time should have been allocated to this course	strongly agree	Agree	disagree	Strongly disagree
There was adequate communication between the students as well as the between students and demonstrators/lecturers	strongly agree	Agree	disagree	Strongly disagree
Demonstrators and lecturers provided me with answers when I was confused	strongly agree	Agree	disagree	Strongly disagree

The following Question relates to Online Testing

I preferred not having to be marked when working with tests	strongly agree	agree	disagree	Strongly disagree
I found the immediate response of the testing very useful	strongly agree	agree	disagree	Strongly disagree
Links to prevalent content in the testing section allowed me to clarify misunderstandings	strongly agree	agree	disagree	Strongly disagree
The short question section was very useful in reinforcing what I had learned during the coureswork	strongly agree	agree	disagree	Strongly disagree
I found the test section very boring	strongly agree	agree	disagree	Strongly disagree
I did not use the on-line testing section at all	strongly agree	agree	disagree	Strongly disagree

The following Question relates to Skills and Competencies

I enjoyed using the software	strongly agree	agree	disagree	Strongly disagree
I enjoyed searching for and constructing the different parts of knowledge for myself	strongly agree	agree	disagree	Strongly disagree
I enjoyed searching for information using different knowledge sources	strongly agree	agree	disagree	Strongly disagree
It was easy for me to relate the database objects (molecules, terms, pathways) to the main notes and workbooks	strongly agree	agree	disagree	Strongly disagree
It was easy for me to remember what I had learned in the previous session / day, and this helped me to maintain focus on the course	strongly agree	agree	disagree	Strongly disagree
The course required a lot of Mathematical and Logical thinking	strongly agree	agree	disagree	Strongly disagree
The course required a lot of problem solving exercises	strongly agree	agree	disagree	Strongly disagree
The course improved the way I work in a group	strongly agree	agree	disagree	Strongly disagree
The testing section allowed me to identify and correct problem areas	strongly agree	agree	disagree	Strongly disagree
The course improved my computer skills	Strongly Agree	agree	disagree	Strongly disagree

Recommendations

What did you not like about the course and software ?

How could the software and course be improved?

Lipid Metabolism Paper Based Evaluation

Place a tick in the appropriate boxes

The following Question relates to the Content Structure

It was easy to find relevant information	strongly agree	agree	disagree	strongly disagree
Sufficient content was provided to gain an understanding of the topic	strongly agree	agree	disagree	strongly disagree
I found it difficult to understand the course content	strongly agree	agree	disagree	Strongly disagree
The information presented was too simplistic	strongly agree	agree	disagree	Strongly disagree
More detailed content is required	strongly agree	agree	disagree	Strongly disagree
Developing Internet-Based Courseware is a good idea	strongly agree	agree	disagree	Strongly disagree

The following Question relates to the Course Structure

I enjoyed working with the Internet-based courseware	strongly agree	agree	disagree	strongly disagree
The problems presented in the worksheets were too difficult	strongly agree	agree	disagree	strongly disagree
I would have preferred written notes in addition to the Internet-based courseware	strongly agree	agree	disagree	Strongly disagree
Lectures should have been included in the course	strongly agree	agree	disagree	Strongly disagree
I would preferred to work on my own	strongly agree	agree	disagree	Strongly disagree
A set of printed notes should have been provided	strongly agree	agree	disagree	Strongly disagree
The completed workbooks and Internet-based courseware will make it easier to study for examinations	strongly agree	agree	disagree	Strongly disagree
Working in groups made it easier to understand the concepts	strongly agree	agree	disagree	Strongly disagree
In addition to the Internet-based courseware, I consulted textbooks and library books often	strongly agree	agree	disagree	Strongly disagree

The following Question relates to Software Usage

I found the visuals (diagrams, tables, reactions) very easy to understand	strongly agree	agree	disagree	strongly disagree
It was easy to navigate between the different sections of the course material	strongly agree	agree	disagree	strongly disagree
I found the relevant content very easily	strongly agree	agree	disagree	Strongly disagree
I would have preferred to have a search engine	strongly agree	agree	disagree	Strongly disagree
I found the questions in the workbook easy to understand	strongly agree	agree	disagree	Strongly disagree
I encountered a lot of difficulties in answering questions posed in the worksheet	strongly agree	agree	disagree	Strongly disagree

The following Question relates to Environment and Learning Activities

The demonstrators and the lecturer were useful	strongly agree	Agree	disagree	Strongly disagree
I found the time allocated for computer usage adequate	strongly agree	Agree	disagree	Strongly disagree
I felt it comfortable working with the material presented in the computer lab	strongly agree	Agree	disagree	Strongly disagree
More time should have been allocated to this course	strongly agree	Agree	disagree	Strongly disagree

	strongly agree	Agree	disagree	Strongly disagree
There was adequate communication between the students as well as the between students and demonstrators/lecturers	strongly agree	Agree	disagree	Strongly disagree
Demonstrators and lecturers provided me with answers when I was confused	strongly agree	Agree	disagree	Strongly disagree

The following Question relates to Skills and Competencies

I enjoyed using the software	strongly agree	agree	disagree	Strongly disagree
I enjoyed searching for and constructing the different parts of knowledge for myself	strongly agree	agree	disagree	Strongly disagree
It was easy for me to remember what I had learned in the previous session / day, and this helped me to maintain focus on the course	strongly agree	agree	disagree	Strongly disagree
The course required a lot of Mathematical and Logical thinking	strongly agree	agree	disagree	Strongly disagree
The course required a lot of problem solving exercises	strongly agree	agree	disagree	Strongly disagree
The course improved the way I work in a group	strongly agree	agree	disagree	Strongly disagree
The course improved my computer skills	Strongly Agree	agree	disagree	Strongly disagree

Recommendations

What did you not like about the course and software ?

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How could the software and course be improved?

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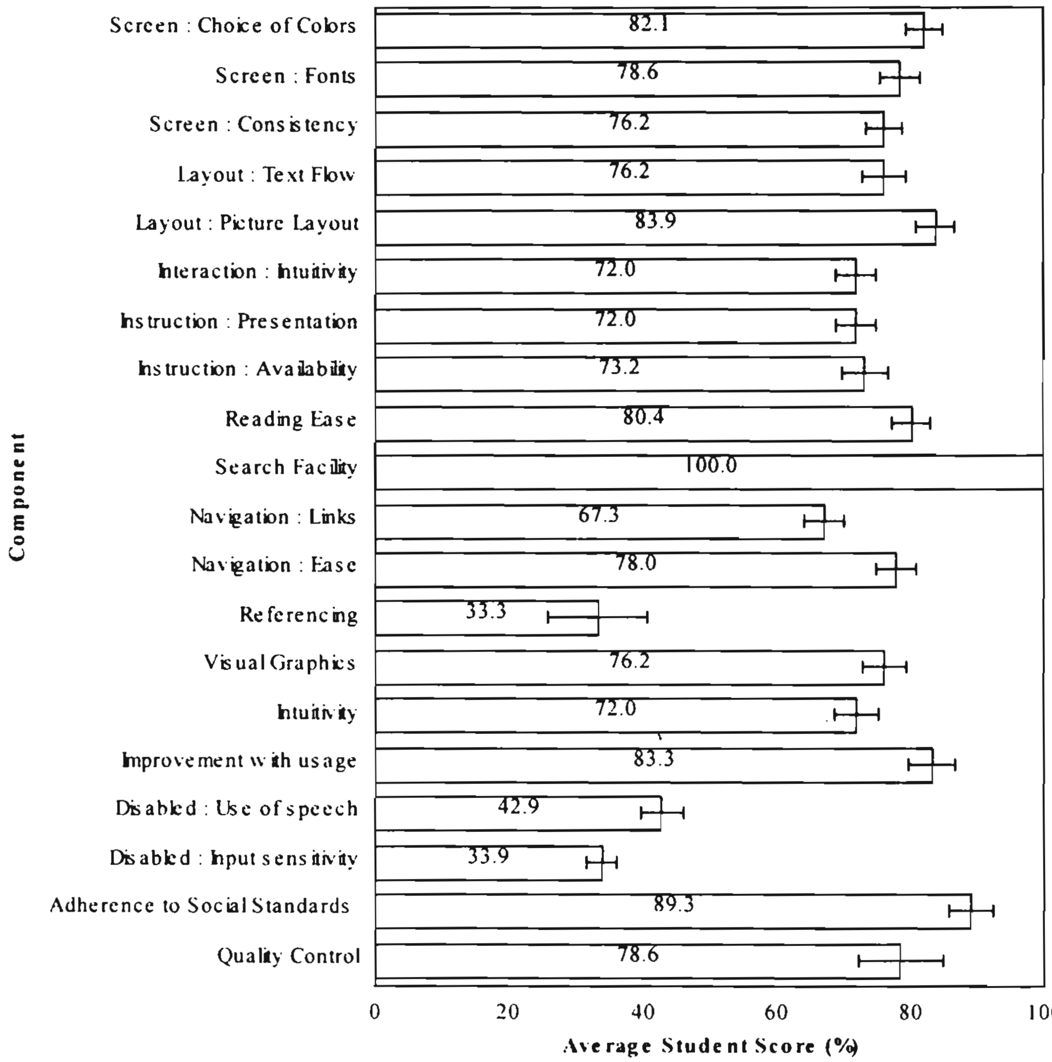

Figure 4.17: Student evaluation of User Interface Design components of Carbohydrate Metabolism courseware using ESET (n=42, bar = SE).

Appendix III: Outline of Interviews

The following outline was used to interview students. Students were reminded that they were each chosen as a representative of the group and their input was anonymous. Students where asked to answer yes, or no for questions and to elaborate if they felt it necessary. Students were also asked to elaborate on specific questions. This enable the interview process to be as informal and as comfortable as possible. Students were also asked to regard the interview process as pertaining to both the Carbohydrate and Lipid metabolism pathway. The introductory and personal character sections were used to acclimatize students to the informal interview process, but was not used for evaluation purposes. The remaining sections (personal computer use, learning environment, higher education, learning outcomes and objectives, personal value) were used for qualitative evaluative purposes.

Introduction

- Where do you live?
- How long have you been at this campus?
- Do you like studying here. Why?

Personal Character

- Have you thought about your future study plans / career perspectives?
- Do you engage in creative activities, building ?
- Do you keep a journal, diary, organizer
- Name some of the things that you consider yourself responsible for?
- Do you consider yourself to be a very disciplined worker?

Personal Computer Use

- Do you use computer technology. For what purposes (prior) ?
- How confident are you in using computers?
- For what purposes do you use computers? (General, Internet, Library, Email, Encyclopedias, Graphics, music..

Learning Environment

- Were you aware that this course was part of a research project? How did this make you feel?
- Did you find the course comfortable to work with?
- Do you think there was anyway in which the settings could have been improved?
- Did you enjoy working in groups?
- Did you find that a greater understanding was achieved while working in a group?
- To what extent do you think you will use the workbook for studying?
- To what extent do you think you will use the textbook for studying?
- Do you think you will be making use of the web-site again?
- Are you aware that the web-site is permanently available to you as a resource?
- Have you, or do you plan on making use of any additional learning resources?

Higher Education

- Did you find the course content easy to understand?
- Would you say that you have developed a personal interest, or personal value in the topic?
- Are you familiar with careers in the field of Biochemistry?
- Have you made use of computer technology in other subjects?
- Do you think the format for tests, examinations should be changed. If yes, how?

Learning Outcomes and Objectives

- How does the use of web-based courseware compare to other learning modes?
- Do you think the type of material you learning was suited to the use of computer technology (speed, quality)?
- How much of the content do you think you have (a) understood and (b) remember?
- Do you think you had considerable difficulties?

- Do you think you got sufficient feedback from the lecturer, demonstrators and software?
- Did you make use of the on-line testing?
- Did it help you in any way?

Personal Value

Did you find the web courseware beneficial to your learning?
Would you say you were more or lesser motivated and challenged than conventional learning modes?
Did you prefer to be actively involved in working with the information?
Would you say you found the software fun and enjoyable to use?
Did you enjoy working at your own pace?
Did you enjoy searching for, and constructing information on your own, rather than being presented with the information?

Problems

Can you list any problems you encountered?
Are there any other comments or recommendations you would like to make?