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ABSTRACT

Development of online courses requires the use of appropriate educational philosophies that discourage rote learning and passive transfer of information from teacher to learner. This paper reports on the development, use and evaluation of two second year Biology online software packages used by students in constructivist environments. The courses on carbohydrate and lipid metabolism were developed in conjunction with subject experts but were designed from different perspectives. The carbohydrate metabolism course provided diverse views of a single knowledge domain and included the ability to find information in different ways. The lipid metabolism course was designed as a "notes-on-the-Web" module. Evaluations were conducted via paper- and electronic-based software evaluation, students interviews, and analyses of student performance (pre- and post-testing, examination results). Results showed that students enjoyed using the software, found the constructivist learning environments challenging, valued the permanent availability of online information, found the user interface of the software products easy to use and navigate. Analyses of examination results showed that students performed better than in the previous year (traditional lectures). Results for the carbohydrate course were superior to those of the other course. It appears that interactive components that foster constructivist-based learning skills are more important in online learning environments than presentation of information. (Contains 21 references.) (Author)

Web-Based Notes is an Inadequate Learning Resource

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Abstract: Development of on-line courses requires the use of appropriate educational philosophies that discourage rote learning and passive transfer of information from teacher to learner. This paper reports on the development, use and evaluation of two, second year, Biology on-line software packages used by students in constructivist environments. The courses on carbohydrate and lipid metabolism were developed in conjunction with subject experts but were designed from different perspectives. The carbohydrate metabolism course provided diverse views of a single knowledge domain and included the ability to find information in different ways. The lipid metabolism course was designed as a 'notes-on-the-Web' module. Evaluations were conducted via paper- and electronic-based software evaluation; student interviews; and analyses of student performance (pre- and post-testing; examination results). Results showed that students enjoyed using the software, found the constructivist learning environments challenging, valued the permanent availability of on-line information, found the user interface of the software products easy to use and navigate. Analyses of examination results showed that students performed better than in the previous year (traditional lectures). Results for the carbohydrate course were superior to those of the other course. It appears that interactive components that foster constructivist-based learning skills are more important in on-line learning environments than presentation of information.

Introduction

Attempts in the 1980s to bring technology into the classroom involved the creation of computer literacy classes at secondary school levels (Moersch, 1995) where students learned about computer architecture, operating procedures, basic software applications and introductory programming. 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 educational institutions becoming, not only information centres for specific content, but also arenas for technology development and innovation (Kook, 1997). However, technology is not a process, mindset, or a global solution, but is merely a tool. With the onset of the 21st century, it is undeniable that the computer, as a tool, has made by far the biggest impact on human endeavour. "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). Moersch (1995) stated that computers are used as tools that support and extend student understanding of concepts, processes and themes. In addition to its inherent use as communication tools, technology can also play a direct role in educational activities. Richards *et al.* (1997) argued that the use of technology is two-fold: it accelerates skill and knowledge acquisition and enhances teacher and student abilities. McDonald and Ingvarson (1997) argued that computer applications free students from laborious tasks of rewriting and copying notes. Dorfler (1991), on the other hand, stated that cognitive software tools amplify human ability as "information re-organizational devices" that extend activity and reflection to a higher meta-level.

While the use of computer technology could provide an increasing student population with adequate resources, the focus should still lie with educational issues (Hämäläinen *et al.*, 1996) and user needs (Brown, 1995). Collis (1997) stressed that technology should be used as a tool to make concrete an educational philosophy and Greening (1998) argued that theory should drive the application of technology within educational contexts rather than technology itself. 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". Constructivism is context dependent rather than content dependent (Greening, 1998) and focuses not on the content or its objectives, but on the diverseness and richness of the learning environment and the skills and competencies in learning that may not be directly monitored via behaviouristic assessment methods (Reeves, 1992). Today, most commercial educational software takes little notice of educational models other than instruction. This presents educational developers with two possible options of technology use where either (a) technology is supplemental and rests on existing structures (enrichment) or and (b) it is mandatory and changes the course structure completely (re-engineering) (Collis, 1997).

This project was based on the concept that integration of software into learning environments will only improve learning when courses are re-engineered to support constructivist-learning models and include tools to find, explore and organise information. In other words, the power of technology lies not in the presentation of information, but rather in the ability of learners to navigate information in different ways to enable their own cognitive development.

Materials and Methods

Course Design and Development: Two second-year biochemical courses were converted into resource-based on-line educational material. The original instructivist courses included notes, diagrams and overhead slides developed by the subject experts, based in part on the prescribed textbooks. The re-engineering of these courses included the development of a workbook that posed a number of problems, or exercises, supported by on-line resources. The first course, carbohydrate metabolism, consisted 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. Software developed for this course was based on the idea that multiple representation of a single knowledge domain would enhance the learning process. Analysis of the lecture course identified a number of content building blocks (molecules, reactions, biochemical terminology, processes and actual pathways). These knowledge units were individually constructed using Macromedia Flash 2.0 (figures and charts) and were stored, with relationship information, in a Microsoft Access database. These building blocks, accessed in different ways (using hyperlinks or through a built-in search tool) provided the material for students to construct their own representation of the pathways according to problems presented in the workbooks. In addition a glossary of terms was provided. 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, pathways) could be immediately viewed in separate browser windows. The second course (describing lipid breakdown) was based on a number of essays broken into separate topics that included molecular data. Notes were pre-prepared by the subject expert and converted into HTML (FrontPage 98) and graphics and diagrams (Macromedia Flash 2.0). These resources were grouped into essays, structures, processes, and transport mechanisms on the introductory page. No search or glossary was provided.

Learning Environment: Students worked in groups of three or four at a single computer (Intel Pentium 233MHz, running Microsoft Windows NT, with Internet Explorer 4.0 browsers and Macromedia Flash plug-in installed) using the supplied on-line material and textbooks to answer questions posed in workbooks. Assistants and the subject expert encouraged group communication and collaboration, provided support and guided learners when asked for help.

Evaluation: A number of different instruments were used to evaluate the courses and included: paper- and electronic-based course evaluation; student interviews and analyses of student performance (pre- and post-testing; examination results). Paper based evaluations were conducted to measure student attitudes with respect to enjoyment of 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 courses and were analysed qualitatively using QSR NUDIST (Qualitative Solutions and Research). Students used the on-line Educational Software Evaluation Tool (ESET) to assess the design of the user interface, pedagogy and interactivity of the software. These results were further analysed using the Wilcoxin Signed Ranks tests (SPSS, SPSS Inc). Thirteen students, who volunteered and represented each group, were informally interviewed to probe more deeply student opinions related to the use of on-line courseware and their use of the learning resources. Students answered questions in the following categories: personal use, perspectives of higher education, the learning environment, and learning outcomes and understanding. Interviews were recorded using a tape recorder, transcribed and analysed using QSR NUDIST.

Anonymous pre- and post-tests were constructed by 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. The Mann Whitney tests (SPSS) were used to evaluate these results. Performance data (examination results) was analysed using Wilcoxin Signed Ranks (SPSS) tests to identify significant differences between computer based and non-computer for the current year. A combination of the Mann Whitney and Wilcoxin tests (SPSS) 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.

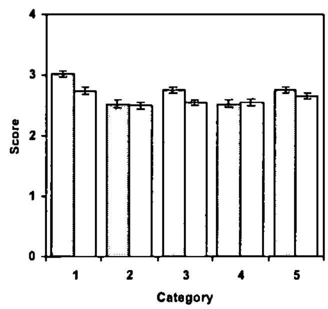

Figure 1. Paper-based student evaluation of the carbohydrate metabolism (n=44) and the lipid metabolism (n=33) courseware. (Bar = SE; Categories: 1. Content structure, 2. Course structure, 3. Software usage, 4. Environment and learning Activities, and 5. Skills and competencies; □ - carbohydrate metabolism, □ - lipid metabolism).

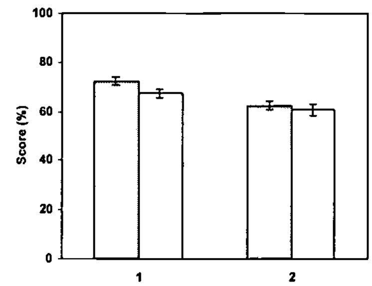

Figure 2. Student evaluation of (1) User Interface and Design and (2) Pedagogy and Interaction using the Education Software Evaluation Tool of the carbohydrate metabolism (□; n=42) and lipid metabolism (□; n=40) courseware (Bar = SE).

Results

Conventional paper based evaluations were conducted to determine student opinion with respect to the learning environment and use of the software. The questionnaire was divided into six categories (content structure; course structure; software usage; environment and learning activities; and skills and competencies) and included statements that students ranked (4-point scale) and short paragraphs answers. Students rated both courses in a similar manner; the content structure higher than any other category; the carbohydrate course content structure higher than that of the lipid metabolism course; and the course structure lower than any other category (Fig. 1). For the carbohydrate course the highest rated statements for each category were: content structure - "It was easy to find relevant information" (3.2); course structure - "I enjoyed working with Internet-based courseware" (3.2); software usage - "I found the glossary very useful" (3.0); environment and learning activities - comfortable working with the material presented" (2.8); and skills and competencies - "I enjoyed using the software" (3.1). Similarly, for the lipid metabolism course the statements ranked highest per category were: content structure – "Development of Internet-based courseware is a good idea" (2.9); course structure printed notes should have been provided" (3.1); software usage "I found the visuals very easy to understand" (2.8); environment and learning activities – "I felt comfortable" (2.8); and skills and competencies – "The course improved my computer skills" (3.1). Statements that scored the lowest included "I would prefer to work on my own" (2.2) for both courses, "I found the relevant information easily" (2.3) for the lipid metabolism course, "I found the time allocated for computer usage adequate" (2.2) both courses and "The course required a lot of problem solving exercises" (2.2) for the lipid metabolism course.

Using ESET students rated the user interface, design, pedagogy and interaction of the carbohydrate metabolism course software higher that the software used in the lipid metabolism course (Fig. 2). For the carbohydrate courseware students rated screen appearance (fonts -78.6%; choice of colours - 82.1%), layout (text flow - 76.2%; consistency - 76.2%), instructions (73.2%); presentation (72%); reading (80.4%); and the search facility (100%) highly. For the lipid metabolism courseware students rated screen fonts (71.9%) and colours (72.5%) high, and screen consistency (66.3%), picture layout (69.4%), intuitive interface (66.3%) and text flow (61.9%) low. Ease of reading was amongst the highest rating components (73.8%) but students found that there were insufficient links (59.4%). A Wilcoxin signed ranks test indicated that the User Interface section and Pedagogy and Interaction for carbohydrate metabolism software was rated significantly better than the lipid metabolism package (asymptote significance < 0.005, z = -3.845a and asymptote significance = 0.006, z = -2.726a respectively).

Students were interviewed to further probe their opinions regarding the two courses. Eight students (62%) said that they have used computers before (between one and two years) and five said that they had not previously used computers. Four of the students reported that they had access to computers at home. Those that had not used computers before stated that they soon became familiar with the software. When asked if they were aware that the computer-based courseware was part of a research project, nine (69.2%) responded positively and four said no (30.8%). Those who responded positively felt that the initiative was new and exciting, with them being the first to tryout this new form of learning. Students also felt that it was an improvement over conventional lecturing since it made learning easier. A few students thought that the approach was experimental and they had no reference to previous years and that the results of such initiatives are unpredictable since the use of technology is new. Students were asked if the change in learning environment was comfortable to work in. Seven students (53.8%) felt that they were comfortable, while three students (23.1%) maintained that they were not comfortable at first, but got used to the course after a while. Two students responded that they were initially lost and attributed this to their lack of computer knowledge as well as the wealth of information presented. However, they reported that they quickly adjusted to the new teaching method. Most of the student comments centred around interactions in the classroom and listed being able to work individually and at their own pace as an advantage. This was further probed by asking questions related to group work. Positive responses included division of labour (two responses), rich social experience (two responses) and ability to discuss problems with peers, tutors and the subject expert. Students did however maintain that group interactions often broke the flow of concentration, decreased the work rate and this caused them to work individually. Other problems identified were a lack of equal contribution, 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 development of shared understanding amongst participants (two responses). 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. Although the software was well received, the lipid metabolism software was found more difficult to use. 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. Working with software was more fun, challenging, much better than lectures, encouraged learning, was interactive, allowed one to find information quickly and easily, made one more responsible, built confidence, improved understanding and made visualization easier. Students were requested to identify the difference between understanding concepts and memorization of content. They clearly understood that there was a difference between understanding and memorization, and that understanding took place before memorization. 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). Students also felt that their initial experience with the software mentally prepared them to study for examinations.

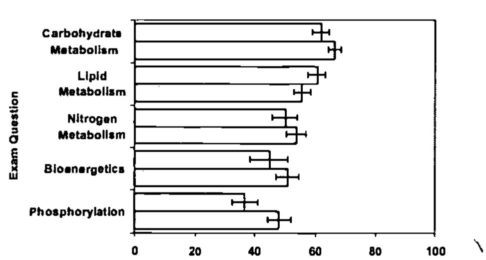

Figure 3. Comparative analysis of average student scores between two consecutive years (□ - 1998, n=39; □ - 1999, n=47; bar = SE).

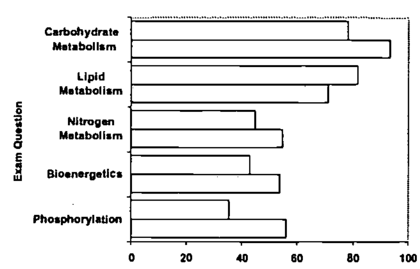

Figure 4. Comparative analysis of student pass rate between two consecutive years (□ - 1998, n=39; □ - 1999, n=47)

Pre- and post-tests were used to determine student understanding of the basic course content before and after using the developed materials. Students received no prior warning before sitting these test and had therefore not prepared themselves for testing. In the carbohydrate metabolism course, students (n=49) scored an average of 15.8 ±1.4% that increased to 34.7±1.4% in the post-test (n=44). Using a 95% confidence level, there was a significant difference between the pre- and post-test (asymptote significance < 0.005, z =-6.841, Mann-Whitney test) indicating that students had gained knowledge during the course. 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 (asymptote significance = 0.009, z=-2.596) indicating that students had gained knowledge during the course.

Examination results from the previous year (all lecture based) were compared (Fig. 3.). 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) while that for the other course on lipid decreased from 81.6% to 71.1% (Fig. 4). A comparison (Mann Whitney test) was made between 1998 examination performance and 1999 exam performance using the following sets of scores (1998 carbohydrate and lipid metabolism) - (1998 other courses) versus (1999 carbohydrate and lipid metabolism) - (1998 other courses). Although no significant difference was indicated (asymptote significance = 0.054, z = -19.925), the results can be seen as marginal. The 1999 examination performance results were further analysed using the Wilcoxin Signed Ranks test: the carbohydrate metabolism examination results were significantly better than either the lipid metabolism (asymptote significance = 0.003, z = -2.948) or the traditional lecture-based courses (asymptote significance < 0.005, z = -4.525). No significant difference was found between the lipid metabolism course and the traditional lecture course results (asymptote significance = 0.111, z = -1.594).

Discussion

In order to gain insight into the use of on-line material in constructivist classrooms two second-year biochemical courses were redesigned. The carbohydrate metabolism course on-line resources included multiple views of the knowledge domain, a search tool and glossary. The lipid metabolism course included only text and graphical resources on the Web. Both courses used a constructivist approach where students, working in groups, used the resources to answer problems posed in workbooks. A number of instruments were used to evaluate the courses and included paper and electronic evaluations, interviews and analyses of student performance.

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 colours" as basic but important components. 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. User interface design should also make full use of technology rather than "transferring paper or previous non-graphic interfaces onto the screen" (Starr, 1997). Results from the paper- and electronic-based evaluations, as well as student interviews, clearly indicated that students found the interfaces easy to use and adapted quickly to the use of the software in the classroom. The carbohydrate courseware was more highly rated than that used in the lipid metabolism course. While the user interface of both on-line resources was rated highly, the lack of search tools, glossary and self-testing components, which could be viewed as cognitive development tools, in the lipid metabolism software resulted in problems in the use of the resources and made it more difficult for students to find relevant information. These results support the arguments that the inclusion of different navigational tools supports different navigation styles (Jonassen and Grabinger, 1990) and learners who are allowed to make choices, answer questions and solve problems, are more motivation and productive (Jih and Reeves, 1992). The inclusion of a wider variety of navigational, visualization and self-assessment tools in the carbohydrate package supports the idea that software that actively engages students in constructive activities biases students towards knowledge transformation activities and away from simple knowledge replication (Ward and Tiessen, 1997).

Gustafson and Branch (1997) argued that the construction of knowledge and skills occur while learners interact with peers, media, content and teachers. Berge (1997) introduced the term "authentic learning activities" that includes inquiry, problem-based activities, case studies, projects, peer critique and support and self-reflection. While some students would have preferred lectures they argued that group work supported the development of understanding and felt that group work encouraged learning.

Reiser and Kegelmann (1994) stated that together with student "attitude data", the pre- and post-test method is a way of improving courseware evaluations. Use of such a method here found that students gained some insight into the concepts of both courses. Evaluation of examination results show that students performed better in the carbohydrate metabolism course compared to the lipid metabolism and traditionally taught courses. While both courses used constructivist principles, performance was only increased in the course that included software that provided learners with a richer set of tools to interrogate information and thereby build knowledge. It is interesting that students would have preferred written notes for the lipid metabolism course as they are familiar and have developed skills in using such media. The carbohydrate metabolism courseware consisted of discrete knowledge units (molecules, terms, pathways) and processes (reactions and control aspects) that fit more easily into a constructivist model. The lipids metabolism courseware was essay-based and textual in nature. The level of interactivity differed significantly between both packages and information was not rigidly structured in the carbohydrate on-line resource. Another important feature that distinguished the packages was the ease of navigation: the carbohydrate metabolism software was much easier to navigate and far more intuitive than the lipid metabolism software. Finally, the carbohydrate metabolism software proved to be more motivating in terms of fun, graphics and student interest. The results presented here clearly show that the use of on-line resources to provide information only provides no benefit to learners while those that are richly textured and include different navigational paths, are built of small interrelated knowledge blocks and include cognitive development tools improve learning. Therefore, computer-learning resources that are just electronic textbooks offer little value in knowledge development.

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