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ABSTRACT

New technologies such as Magnetic Resonance Imaging (MRI) and Positron Emission Tomography (PET) have led to recent discoveries about how the brain works and how people learn. The interactive capabilities of World Wide Web-based instructional strategies can be employed to better match how we teach with how we know students learn. This paper summarizes the following assumptions on the nature of learning, based on the argument that learning occurs through building and traversing neuronal pathways: learning occurs through making connections; the best predictor of what students will learn is what they already know; nothing is learned until it is internalized into long term memory, ready for later retrieval along well-worn pathways; and students learn in different ways. The paper also provides an overview of instructional strategies that promote learning (reflection, reconstruction, and rehearsal) and an argument for taking advantage of the interactive capabilities of the WWW to create an optimal setting for learning. It concludes with a description of PROJECT LEARN, a staff and media development project at Lincoln University (New Zealand) that successfully integrates these ideas to enhance undergraduate education. A figure presents the continuum of interactivity available via the WWW. Contains 11 references. (Author/DLS)

Designing Instruction for the Web: Incorporating New Conceptions of the Learning Process

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Abstract: New technologies such as Magnetic Resonance Imaging (MRI) and Positron Emission Tomography (PET) have led to recent discoveries about how the brain works, indeed how we learn. The interactive capabilities of WWW-based instructional strategies can be employed to better match how we teach with how we know students learn. This paper provides a summary of new conceptions of how learning occurs, an overview of instructional strategies which are known to promote learning, and an argument for taking advantage of the interactive capabilities of the WWW to create an optimal setting for learning. It concludes with a description of a staff and media development project which successfully integrates these ideas to enhance undergraduate education.

Learning is the process by which we acquire new information. Memory is the process by which that knowledge is stored and recalled when required.

The typical tertiary education classroom, can better be described as a theatre of transcription than an optimal setting for learning. To walk into most undergraduate classes, one would likely see students frantically taking notes while their professor stands at the front engaging in a 50-minute monologue of factual information, stopping only to scribble a few words or a diagram on the chalkboard. There is often little interaction among the learners or between the teacher and learner.

How congruent is this description with what is known about how students learn? Not very.

The Learning Process

Previous conceptions of learning envisaged filling empty spaces with information, which became "bins" or neatly organised "filing cabinets" of knowledge from which the mind retrieved what it required. Today we know that learning is not a process of filling an empty bin with knowledge for later retrieval. There are no bins of knowledge that we look for when we learn or remember. A memory does not exist in a specific location in the brain. As early as 1949, it was known that long term memory is developed through the establishment of repeated connections, or pathways, among masses of neurones [Hebb, 1949]. It is the activation of the mental pathways, rather than the arrival at a specific destination, which enables us to learn and remember.

The brain works through "an electrochemical process, which distributes both chemicals and electric charges through an incredible network of tubes extending throughout the brain and body. It appears that *learning consists of the growth of additional neural connections* stimulated by the passage of electrical current along nerve cells (neurones) and enhanced by chemicals (neurotransmitters) discharged into the gaps (synapses) between neighboring cells" [Valiant, 1996]. Mental effort actually changes the physical structure of the brain, as additional neural connections are created, the density of the brain's mass is increased. (Note: To be called "dense" or "think-headed" is a compliment!)

People learn differently and know things differently because they take different pathways on different occasions; dependent on the context, their previous experiences, and their current physical and emotional state. Not all pathways are accessed in the same way. The nature of the learning or memory task will prompt different access routes.

However, as a particular pathway is re-used, additional connections are built which strengthen the linkages. Undoubtedly some of these mental pathways, like tracks in a forest, become so worn that the mind seeks to use these easy routes to arrive at an understanding -- the path of least resistance. Other paths are more difficult, are never discovered, or are overgrown for a variety of reasons. As pathways are lost with non-use, we "forget." In many cases learning means adjusting existing pathways or removing pathways among memories that become "known" as incorrect.

Assumptions on the Nature of Learning

From the argument that learning occurs through building and traversing neuronal pathways, we can assume that:

- Learning occurs through making connections.

  It is doubtful that any idea is ever truly new; for a new idea would have to be constructed by the mind without any links to anything already known. Even a new word in a different language will be processed by the mind through links to existing words in the vocabulary. Those links may be words with similar meanings or simply similar sounds.

  For example, one person seeing the word "togafiti" for the first time may associate it with the word "graffiti" or a Roman toga. Another person, who recognised the word as Samoan and knew that that the "g" is pronounced "ng" would follow entirely different pathways that lead to a connection with something to do with "Tonga."

- The best predictor of what students learn is what they already know.

  New learning is more easily achieved if there is an existing pathway or framework waiting for it. These existing pathways can facilitate or hinder new learning. Sometimes existing pathways divert new ideas into what the learner wants to believe and thus affirms existing beliefs, even when the incoming idea is contrary. If what is "coming in" happens to be diverted into an existing pathway, the learner may feel more comfortable than if the new information challenges an existing concept. Any biology teacher can tell of students who achieve pass examinations on the principles of biological evolution, but not believe the basic tenets of the theory. The new pathways were not embedded or placed in contradiction with deeper held beliefs.

- Nothing is learned until it is internalised into long term memory, ready for later retrieval along well-worn pathways.

  Learners can create a new pathway easily, but that path will not be available in a month's time unless it is very strongly connected with a specific context, something already known, or frequently rehearsed. Memory consists of all the bits and pieces of an experience -- the sights, sounds, smells, and emotions. Each fragment is stored in areas of the brain responsible for handling that particular sensation. Sounds are stored in the auditory cortex, sights in the visual cortex, etc. Keeping track of what's where is a region of the brain called the "hippocampus," which functions as a sort of memory index. Recalling an event requires re-assembling all those fragments, it is literally a process of re-membering.

- Students learn in different ways.

Students have different preferences for the way in which they learn and these preferences vary within individuals, across time and contexts. Each student's mental pathways are idiosyncratic. The specific bits of knowledge and links among them will differ because of life experience and preferred methods of receiving and processing information.

Instructional Strategies which Promote Learning

Perkins proposes that there are three dimensions of intelligence: neural, experiential, and reflective. He posits that in-born, neural intelligence can be influenced through nutrition and maturation, though very little can be changed through instruction or practice. Educators do, however, have great opportunity to influence the other two. New neural connections are developed as students experience their environment; and additional connections are created as they reflect on their experiences and seek alternate pathways to understanding. [Perkins, 1997].

Assisting students learn involves creating opportunities which facilitate the building and activation of these mental pathways. This is best done by gaining an understanding of what students already know; followed by designing activities which require them to reflect upon the new information, affirm correct conceptions, and alter any previous misconceptions.

The Three R's -- Information is not knowledge. Information is not connected; it is "out there" waiting for students to bring it into their knowing. To do that, they need to do more than say it, print it, hear it, read it, sing it, dance it or spell it. Teachers have to encourage connecting information to something already known and that process is best achieved with *Reflection.* Reflection is thinking about something, examining any linkages or any connections anew; indeed thinking about one's thinking. Reflection is encouraged through asking questions which require analysing similarities and differences, applying the information to new situations, and assimilating, or synthesising, the new information with what was previously known. Lev Vygotsky discovered that the brain learns and remembers more information during socially interactive vs. isolated learning situations; the physical characteristics of the brain change as we engage with others [Caine & Caine, 1997]. Therefore, students may most benefit from presenting these questions as items for discussion in small groups or in the larger classroom setting.

Sometimes this reflective process will reveal misconceptions in previous understandings and prompt the *Reconstruction* of old pathways. Jean Piaget, a noted Swiss educational psychologist, developed a theory of intellectual development which recognised that increasingly complex levels of thinking and understandings of the world are developed in a number of stages brought on by life experience and maturation. For example, infants understand the world through their senses. If they can see Mommy, they know Mommy exists. However, if Mommy disappears from their sight, then Mommy no longer exists for them. This is why infants will become frightened when Mommy leaves the room. It also explains the fascination with "peek-a-boo" type games, in which the adult disappears and instantly re-appears. It is through these experiences, and natural maturation of the brain, that infants come to understand object permanence -- "Mommy still exists even if I can't see her." Infants reconstruct their mental pathways to accomodate this new understanding.

To prevent the loss of a useful pathway or script, teachers need to encourage *Rehearsal* through repetition and revisitation. Running the script again and again, along varied routes strengthens the pathway. Storytellers remember stories by telling them. Comedians remember jokes better than others because they tell them. Some teachers remember faces or names better than others because they repeat them or recall them more often. Teachers lose the names of last year's class through non-use, though they remember the complex taxonomies in their own disciplines through frequent recall.

This repetition should come from presenting the information in a variety of ways; for rote rehearsing is not as effective as rehearsing with a variety of stimuli and in a variety of contexts. For example, to assist students understand the concept of "virus," the term could be presented in computing,

biological, and medical contexts. Similarly, increasing the number of senses involved in the learning experience contributes to the amount of information received and retained.

Students enjoy variety and will learn more when the instructional methods change than when they are boringly similar. Some will prefer information to come to them on a screen or in a book or from a friend or from a teacher. Much is known about the benefits of varying the approach to meet the different needs and preferences of students. Researchers have identified eighteen factors (elements of the emotional, sociological, and physical environments) which affect learning styles [Dunn, Dunn, & Price, 1987]. Effective teaching methods recognise and allow for this variety in the learning style preferences of students.

Supporting Learning with Modern Technologies

Interactive multimedia (known as "hypermedia") learning materials offer many pedagogical advantages which address the needs identified above. First, the combination of text, graphics, video, and sound enable the creation of multi-sensory experiences which are more likely to be remembered. Their interactivity precludes the necessity for presenting the information in a linear form. Indeed, Bill Atkinson, the creator of HyperCard, the first widely available hypermedia authoring tool, refers to it as an electronic construction set which creates new possibilities for teaching and learning. Each learner can experience a different presentation based upon the paths they choose.

Learners do not have to sit passively watching a presentation someone else has prepared. They are allowed to interact with the media themselves. They can access the presentation in the order of their choice and they can use many resources to create their own study materials, thus guiding their own learning. Marchionini [cited in Azarmsa, 1991] refers to this as a "fluid environment (which) requires learners to constantly make decisions and evaluate progress, thus forcing students to apply higher order thinking skills" [p. 170].

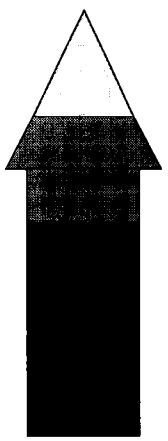
For example, an author might create a hypermedia resource on Napoleon Bonaparte and, at key points, link passages of text, graphics, video, and sound. These links to additional information would be signalled to the learner by means of a font change or graphic icon. Learners might have the option to see a picture of Napoleon, review a map of Napoleon's campaigns, skip to a passage about his exile on Elba, get biographical data on Josephine, or obtain a definition of an unfamiliar word. In other words, each time the material is read it could be accessed in any sequence and to any degree of detail. Students could explore these links to construct their own pathways regarding Napoleon's decision making skills, his driving personal characteristics, etc.

Teachers and students learn from each other [Angelo, 1993]. Hypermedia offers a tremendous potential for enhancing these teacher-student and learner-learner relationships. Students can develop their own tours through the knowledge base and share their experiences with their teachers and other learners. Further, the creation of multimedia and hypermedia materials fosters cooperative relationships among learners as they work together to share the creativity and responsibility needed to produce such a project.

The rapid advancement of the Internet, particularly the development and prolific expansion of the World Wide Web, enable educators to create multimedia teaching resources and interactive instructional strategies which can be delivered to any student without regard to time, place, or computing platform. Educators must recognise, however, that the medium of delivery is not the most important condition for learning. It is no better to distribute large amounts of static information via the WWW than it is to engage in a 50-minute monologue. Nothing happens until the learner is actively engaged; and at a level beyond passively responding by copying a lecturer's words or pressing an <ENTER> key.

WWW-based instructional strategies vary in terms of the degree of interactivity between the learner and the teacher, the learner and the learners, and the learner and the material. Figure 1 illustrates the range between passive to active instructional strategies.

Educators must adopt teaching strategies which marry the new conceptions of learning with the benefits of WWW interactivity. However, academic staff tend to teach as they have been taught. For teachers to adopt new instructional strategies (technology based or not) involves raising the teachers' awareness of how they and their students learn and supporting their moves to teach differently. It involves an awareness of new methods, developing new skills with the methods and knowing when to apply those methods to optimise student learning [Joyce and Showers, 1998]. The process is further complicated when staff are expected to use technologies, such as WWW, with which they are unfamiliar.



5 The materials require that students work collaboratively to respond to assignments or create new learning resources to be shared with other peers.

4 The materials require that students seek additional information and write their own materials which link to the existing ones.

3 The materials contain questions that students are asked to reflect on or respond to, either off-line or online. Answers are provided through successive screens or through teacher marks or comments.

2 The posted materials have "hot point" links to other related or supportive information.

1 The teacher's written lecture notes, tests, diagrams, questions, exams, etc. are placed on the web without alteration.

Figure 1: Continuum of Interactivity Available via the WWW

Linking New Conceptions of Learning with Teaching via the WWW

Personnel within the Education Centre at Lincoln University (New Zealand) have designed a new staff development project, PROJECT LEARN, which recognises the new conceptions of learning, the interactive potential of the World Wide Web, and the challenge of assisting academic staff adopt these new technologies into their instructional repertoire.

Many tertiary institutions are moving into distance delivery of their educational programmes by adopting Internet-based methods. At Lincoln, we are encouraging academic staff to use these same technologies to first support and enhance our on-campus learning. Beginning by supplementing on-campus instruction gives us more control over the pace and assessment of our innovations and gives us face-to-face connection with students. We believe that combining teaching methodologies which focus on how learners learn with WWW-based delivery methods will give us a model that works equally well for on-campus and off-campus students; for the WWW allows for the best of both worlds: independent pathways through the material and interaction with teacher and peers.

PROJECT LEARN, initiated in June, 1997, is primarily an in-depth media and staff development activity. It is structured to respond to earlier feedback from academic staff (survey data obtained in April, 1997) on what resources they needed to incorporate more technology-based instructional methods in their classrooms: knowledge of how to re-design their subjects and the technical support necessary for developing new curriculum resources. Paramount features of the project are the incorporation of two principles found to be important when supporting teachers: providing different

strategies for different stages in the change process, and offering continued monitoring and support as the new strategies are implemented [Scott, 1996 and Joyce & Showers, 1988].

PROJECT LEARN is currently focused on first-year compulsory subjects taught within the University. In subsequent years, second and third year compulsory subjects will be brought into the project. By concentrating on compulsory subjects, we are able to direct our efforts toward creating materials which will be used by the greatest number of students--thereby increasing the impact of our efforts for change.

Project personnel recognise that developing a deeper understanding of content requires more than passively absorbing a body of facts and regurgitating it in an examination. Students learn best by being engaged with the content, actively processing the new information in new ways [Bonwell & Eison, 1991]. A key premise to PROJECT LEARN is that the instructional resources developed will engage students in exercises which promote an active learning experience, where active learning is defined as "instructional activities involving students in doing things and thinking about what they are doing" [Bonwell & Eison, 1991]. It takes advantage of the WWW's interactive capabilities to design learning experiences which allow students to interact with (not just read) subject-specific material, interact with related resources which peak their personal interests, and interact with other students and teachers to enrich and embed their learning.

The PROJECT LEARN team is made up of content specialists (the academics teaching the subjects), instructional design specialists, graphic artists, HTML programmers, and some managerial and clerical support. Currently, no attempt is made to fully convert an on-campus course to distance delivery. Rather, the team begins by having an instructional designer meet individually with each academic to gain an overview of his or her instructional goals. These two then identify one element of the subject -- perhaps a teaching strategy, assessment activity, or content module -- which can be better accomplished by taking advantage of WWW capabilities. The nstructional designer then discusses the issues with the technical support staff for the creation of the materials. The academic is brought in periodically to review the work in progress.

During the development process the academic's involvement is two-fold: providing the content and the instructional objectives. When the subject is taught the following semester, the academic is given additional assistance with implementing the Web-based resources. The academic will later be expected to maintain and further enhance the resource.

Features of the project which have thus far indicated success include: the acceptance of the client academic staff (12 of the 15 academics approached eagerly agreed to participate); the creation of a template to facilitate efficient web development; and the diverse, yet complimentary, skills of the project staff involved. February, 1998 saw the first PROJECT LEARN materials being used by approximately 2500 students. An evaluation of the materials--in terms of their content validity, instructional design, and impact on student learning-- will be conducted. Those results should be ready for presentation and discussion during the Ed-Media/Ed-Telecom '98 conference.

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