Curriculum design innovation in flexible science teaching

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Abstract: In this paper you will be introduced to a number of guidelines, which can be used to inform good teaching practice and rigorous curriculum design.

Guidelines relate to:
1. *application of a common sequence of events for how learners learn;*
2. *accommodating different learning styles;*
3. *adopting a purposeful approach to teaching and learning;*
4. *using assessment as a central driving force in the curriculum and as an organising structure leading to coherence of teaching and learning approach; and*
5. *the increasing emphasis that is being placed on the development of generic graduate competencies over and above discipline content knowledge.*

The guidelines are particularly significant in relation to adult learning and together they form the basis of a practical approach for learning module development. Three specific learning modules are used to illustrate the application of the guidelines. They are taken from a second year subject in introductory supercomputing that uses scientific case studies.

Introduction

Over the last three decades a number of papers have been published in the area of adult learning (andragogy) in higher degree institutions (Knowles, 1980, 1984, 1995; Perry, 1975, 1981; Westrup and Jack, 1998; Panasud and Lebaron, 1999; Pascual-Leone and Irwin, 1998; Schroth, Pankake and Gates, 1999; Healy, 2001). Andragogy has close links with pedagogy (children's learning), and some concepts in these fields are closely coupled (Healy, 2001). Through research it has been shown that adults learn best when they can see how what is being taught has relevance and applicability to their own lives (Knowles, 1980, 1984). For example, a science student that has a keen interest in aquarium fish can better appreciate scientific concepts and content related to pH, than a student who has a guinea pig as a pet.

Lecturers designing and developing educational materials to aid adult learning in the form of curriculum construction should consider a number of key factors related to the learners' background. For example:
- what the student does;
- where they do it;
- whether they like their work;
- what significant impact does that have on the student; and
- whether there is a sociological implication to it.

In any given semester we may observe different learners within the classroom. These different learners can be classified according to Perry (1975, 1981). The classifications take into account that the learners absorb information differently, depending (in part) on the relevance of the materials and the connection they can make with it. For this reason, we aim to develop educational materials that have high impact factors (for example, solving scientific problems that influence the ecological status and preservation of Australia). At the same time we try to incorporate these problems into their every day lives.

In addition to the key factors listed above, other associated issues have to be considered before adult learning can be effectively implemented in the classroom or in an online situation. For this reason it is essential to present material in forms that can be represented in ways that aid student and adult learning. In this paper, we analyse a unit offered in the Faculty of Science at the Queensland University of Technology, Australia. The unit *Introduction to Supercomputing* (one of four in the course) concerns supercomputing techniques, where the content and skills are developed through various assessment strategies and scientific case studies. The unit consists of three modules, where each module employs a different approach to adult learning.

In the *Introduction to Supercomputing* unit, the first module is based on background information, and is very factual. The second module is very much problem based: the students are engaged in solving real-life problems using introductory techniques. The third module focuses on application. It requires the student to solve certain aspects of specific real-life problems using efficient supercomputing approaches. Throughout the learning process, the learner's generic skills are enhanced by the use of strategic, thought-provoking and skill-development assessment items.

Building generic capabilities is a main focus of the curriculum structure behind adult learning. In Australia, TMP (formerly known as Morgan and Banks Employment Agency) claims that future jobs will harness the generic capabilities and skills of students in today's classrooms (MDU, 2001). These skills can be summarised as (1) the ability to work in a team, (2) commitment to life-long learning, (3) superior problem solving ability, (4) the ability to identify issues and (5) solving these issues intelligently. TMP has predicted also that 70% of children starting school this year will have job classifications after finishing tertiary education that we have not yet heard of, or which have yet to be categorised as employment opportunities. This statement by TMP enhances the need to produce graduates with generic capabilities and skills in the form of, for example, information literacy, creativity, critical thinking and the ability to engage in life-long learning.

Five guidelines for good curriculum design

Before we can develop any educational materials for teaching purposes, we must understand how learners learn, and how they acquire knowledge and skills. In this paper we offer a set of five guidelines that together form the basis of a practical approach for the development of well designed learning modules.

The first guideline concerns the application of a common sequence of events for how learners learn. In brief, the sequence should move from acquisition to assimilation to application. That is, learners acquire knowledge before they fully understand it. Then the learner can move on to application, which demonstrates their ability to apply their understanding to specific applications (see for example Kolb, 1976, 1981; Ramsden, 1988; Merriam and Caffarella, 1991; Laurillard, 1993; Marton and Booth, 1997). Consequently, we have the first guideline for good curriculum design, in which learners' first acquire 'facts'. As facts are acquired, they are transformed and assimilated into the learners' existing/developing cognitive structures (i.e. they learn to understand the facts). As a result, the acquisition of information should ideally relate to what learners already know (i.e. past experiences) and should be presented accordingly[1].

Once a body of knowledge or collection of facts is understood, learners can learn how to apply that understanding.

Accommodation of different learning styles is the second guideline in good curriculum design. As good practice, the educator or teacher should accommodate and adopt different learning styles in the classroom and online (Smith and Kolb, 1986; Manner, 2001; Smith, 2001). These learning styles

[1] The authors are aware that learning is mediated through the making of meaning and would like to make clear that acquisition is therefore a process which occurs *hand in hand* with a learner's developing understanding. The main point here is that a learner needs to understand some thing which exists within a disciplinary context. A secondary point is that initial understanding may be limited, particularly if a learner initially adopts a surface approach to learning.

include: (a) aural, where learners prefer to learn by listening; (b) kinaesthetic, where learners prefer to learn by doing; and (c) visual, where learners prefer to learn by use of illustrations, visualisations and graphical representations.

The third guideline in good curriculum design has to do with stimulating the learner to evoke interest in the content material being taught. This is underpinned by a purposeful approach to teaching and learning. In the literature there is a common distinction between surface and deep learners (Säljö, 1975; Entwistle, 1984; Chickering and Gamson, 1987; Entwistle and Tait, 1990; Ramsden, 1992, 1993; Tang, 1994; Kember, 1998). The literature also refers to 'strategic' learners (Richardson, 1994). Surface learners seek to obtain knowledge through memorisation, and accordingly, their preference is to be told the 'facts' related to a certain topic of study. Surface learners do not seek to understand, rather they memorise and regurgitate these 'facts'. Conversely, deep learners seek to learn through understanding. They are more likely to find the content intrinsically stimulating and interesting, and are more likely to want to be made to think for themselves. Finally, strategic learners will (in principal) do anything within their ability to either (a) obtain marks, or (b) get whatever else it is they want from the learning experience (e.g. real-life applications). They will interpret the demands of the current learning situation, weigh that against their strategic objectives and desired outcomes, and then decide on an appropriate learning strategy. In summary, it is important to express a clear purpose when teaching as this will assist the learners' learning. The best kind of learning outcome will be achieved when the learners share that purpose. Ideally, the learners and educator will have a common learning objective. Motivation of the students is subsequently an issue, and can be maintained by making the student perform certain tasks through assessable items.

To motivate adult learners, weighted assessment that contributes to a final mark should be used in such a way that emphasis is placed on the most significant learning outcomes. For this reason, the fourth key guideline is the use of assessment as a central driving force in curriculum design and implementation (see for example Biggs, 1987, 1999; Boulton-Lewis, 1998; Brown and Knight, 1994; HERDSA, 2000). Assessment is also used to organise the learning material leading to coherence in the teaching and learning approach. It is arguable that assessment is the only activity that students have to complete, since it is the only way they can accumulate marks. All other activities may or may not lead to gaining more marks. Students will perform and engage in activities that they know will result in the obtainment of marks, or assist with the achievement of their own strategic objectives and/or initiatives. Good curriculum design aligns the assessment and the associated activities needed to complete that assessment, to capture the learning that the educator sets out to achieve. This will lead to an obligation for the learners to behave in ways that lead to the desired learning outcomes. If we choose to accept such an argument, then the types of assessment used, the timing of assessment items and the integration between items are all of vital importance.

There is an increasing emphasis being placed on the development of generic graduate competencies and skills over and above discipline content knowledge (Leonard, 2000; Pearsall, Skipper and Mintes, 1997; Down and Stewart, 2001). TMP in Australia has identified a number of key competencies required of graduates (MDU, 2001), some of which include (a) teamwork, (b) problem solving, (c) critical thinking, (d) information literacy, and (e) life-long learning. Such skills are increasingly important – perhaps essential – given that a person is currently expected to hold approximately seven different full-time jobs within their working careers. The incorporation of the development of generic capabilities is therefore crucial to good curriculum design, and is regarded as the fifth fundamental guideline.

In summary, the days in which tertiary institutions can run courses that produce graduates with a simple understanding of a particular body of knowledge are gone. What is needed now are courses which produce graduates who are able to make good use of their understanding, and to be able to do this within the socio-political context of the workplace.

Three illustrations of the five guidelines for good curriculum design

In this section three modules from a second year *Introduction to Supercomputing* unit of a Bachelor of Applied Science undergraduate degree at the Queensland University of Technology are discussed. The three modules together form the core content material for this unit. Each module has associated with it assessment items that assess content material and develop certain generic skills.

The first module is called 'Supercomputing: Background, Trends and Concepts'. Figure 1a illustrates the concept map (outline of content and assessment) for the first module. Similarly, Figures 1b and 1c illustrate the concept maps for modules 2 and 3, 'Introduction to Scientific Computation in Matlab' and 'Introduction to Parallel Processing in Scientific Computation', respectively.

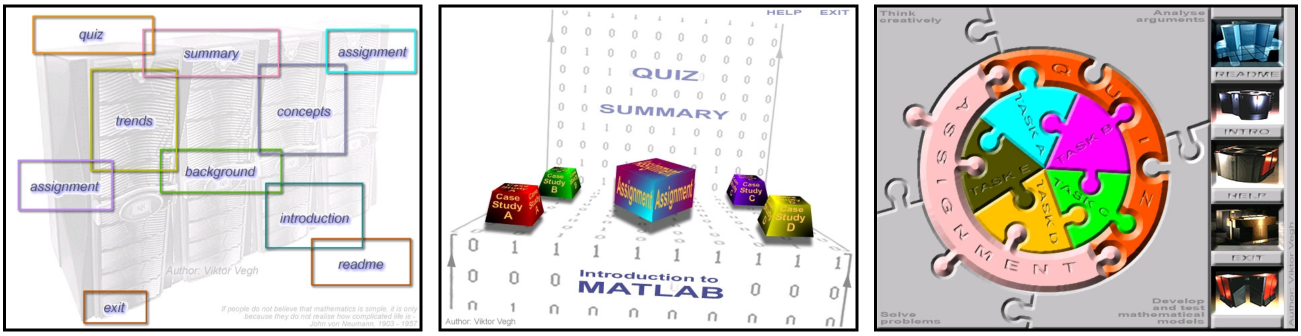

Figure 1. The concept maps for the three modules (a) Supercomputing Background, Trends and Concepts, (b) Introduction to Scientific Computation in Matlab, and (c) Introduction to Parallel Processing in Scientific Computation

This section identifies how each module relates back to the five guidelines of good curriculum design and how they collectively integrate the content of the entire unit. First, each module is outlined separately, after which the global effect is studied.

In Table 1 the five guidelines of good curriculum design are highlighted and are examined in relation to the modules. To some extent, each module relates to all five guidelines, however, each differs in emphasis. Module 1 consists primarily of introductory content material, which is presented in an interesting but primarily factual manner. The different backgrounds of the students within the unit are acknowledged, and hence the learning process within the modules aims to accommodate the different learning styles expected from the students. A purposeful approach is adopted by relating the background, trends and concepts to real-life scenarios. These real-life scenarios are presented within the context of the course. Therefore, the students can relate, and make a connection with, the content material studied. The assessment tasks act as a glue to hold the different pieces together and also builds student generic skills in the form of information literacy and research.

Module 2 shown in Figure 1b focuses on the delivery of the content material through real-life case studies from scientific applications. The case studies are carefully chosen from various disciplines within science, and in some cases are related to problems that can have an effect on the students' lives. The purpose of this module is clearly stated throughout the learning process by linking the concepts of supercomputing solution strategies to the case studies. The five case studies are diverse, and each is presented in a different way to help aid the various learning styles of the students. Assessment of this module is done via an assignment and a quiz. The assignment enhances student ability in problem solving, critical thinking and teamwork (see Table 1). The quiz is aimed at testing the technical knowledge gained and obtained in the course of study.

Curriculum Design Guideline	Module 1	Module 2	Module 3
Application of a common sequence of events	Concepts in this module have an introductory nature, material is mostly factual	Case studies are explained in detail to build understanding	Takes simple to complex ideas from the case studies and develops problem solving skills for certain aspects, thus this module focuses on application
Accommodating different learning styles	A student may elect to take a different path in studying this module (for example student A may go to trends before concepts, and student B may choose the opposite)	All case studies are different, and they do not necessarily need to be completed in any given order	A number of different solution strategies are demonstrated via the delivery of the materials
Adopting a purposeful approach to teaching and learning	Real-life scenarios are used to gain their appreciation of the need for such tools	Case studies identify the need for supercomputing tools, techniques and skills	Purpose is linked back to the case studies and the introductory background content
Using assessment as a central driving force in the curriculum design	Students have to cover the main areas of this module to obtain marks (i.e. trends, concepts and summary)	The main elements of the case studies are captured in the assignment in relation to the appreciation of supercomputing, the quiz tests technical knowledge	Assessment incorporates their previous knowledge, requiring them to evaluate and identify with certain problems critically
Development of generic graduate competencies	Assessment is constructed in a way that builds information literacy and research skills in the learners	Problem solving skills and teamwork are developed in this module	The learners are required to reflect on the problem studied, and identify how to better the solution strategies, problem solving and critical thinking skills are developed here

Table 1. The relation of the modules to the five guidelines of good curriculum design

Figure 1c illustrates the last module in the *Introduction to Supercomputing* unit. This module collectively brings together the concepts learnt so far. Students are required to apply their background knowledge, understanding and appreciation of the need for supercomputing. The third module consists of tasks that the students have to complete, i.e. it focuses on application of understanding. These tasks have been identified as critical problems that need to be solved within the different case studies. Table 1 highlights the five curriculum design guidelines achieved in this module for adult learning.

When considering the student outcomes for the whole unit, the first guideline (acquisition to assimilation to application) is addressed clearly. In the context of the unit, module 1 aims to build knowledge for the student, whilst module 2 tries to make the student understand why it is that we need this knowledge. The last module requires the students to apply their acquired knowledge to certain aspects of the different case studies and problems that they have studied in this unit. The final grading for each student includes three quizzes, one for each module. The quizzes accumulate approximately 30% of the final mark. Every quiz is weighted differently, depending on which step of the learning process the quiz is examining. When finalizing the marks, most emphasis is placed on application, followed by assimilation. Each module also has associated with it an assignment that is weighted in the same way as the quizzes. Accordingly, a large portion of the student's mark is made up from module 3, which is the most important in terms of the unit's learning outcomes.

Conclusion

In this paper we have identified five critical curriculum design guidelines and shown how these can be applied through illustrations from a science unit. These guidelines are based upon fundamental educational theories that are readily available in the literature. We argue that together the design guidelines discussed in this paper encapsulate, inform and characterise good teaching practice and together they form a basis of a practical approach for the development of well designed learning modules, not just in science, but in a wider context.

We have argued that the student's understanding of the content material being taught must be prefaced by the acquisition of the underlying factual knowledge. Hence, the first step is the provision of factual content. Only after the student has acquired factual content and developed an understanding of the material being presented, are they able to apply it to a particular problem. This is the basis of the first guideline – the application of a sequence of events for how learners learn.

It is well known that students display a range of different learning styles. The focus of the second guideline is to address this issue by the incorporation of interactive, visual and auditory learning materials. In addition, this should be supported by a teaching approach that exhibits a common purpose between the teacher and student. This helps to stimulate and enthuse the student, which can lead to improved teaching and learning outcomes. The third guideline is based on this approach.

Students are necessarily driven by assessment. Thus, the strategic use of assessment items with respect to content and placement will collectively guide student learning and the resulting knowledge and understanding. The use of assessment as a driving and organising device is therefore recommended, and leads to the fourth guideline. The fifth and final guideline recognises the increasing emphasis that is being placed on the development of generic skills. Examples of how this guideline can be incorporated into learning modules, and indeed all other guidelines, are illustrated in the science unit discussed in this paper.

In conclusion, this paper has drawn together a number of important educational issues that have been structured into five guidelines. The authors believe that these form the basis of a practical approach for the development of well designed learning modules.

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