An Action Research Approach to the Design and Implementation of an On-line Course in Applied Mechanics

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ABSTRACT

Since the establishment of democratic government in South Africa, tertiary education has been experiencing profound changes in its structure, governance, demographics and environment. This paper describes an action research approach to the design and implementation of an on-line course in Applied Mechanics, during rapid change in structural, human and technological environments. The action research approach enabled the design to be responsive to the environmental change, and to direct the design while serving as a working example of action research for professional development. The project was carried out as part of an on-line collaborative professional development programme. It has also been valuable as a means of documenting and viewing the design.

Keywords

Action research, instructional design, engineering education, professional development.

INTRODUCTION

Technikon Natal is an institution for tertiary vocational education situated in the province of KwaZulu-Natal in South Africa. A technikon is similar to a university in that it provides education at a tertiary level, but differs in its outlook. The purpose of technikon education is to provide and develop personpower to promote and practise technology (South Africa, Department of Education Higher Education Group, 1997). The aims of government policy regarding technikons include the integration of education and training, and the promotion of lifelong learning. During the period 1995 to 1998 there was a large increase in enrolments in the Department of Civil Engineering and Surveying. In addition, a substantial proportion of classes consisted of students repeating courses, sometimes three or four times over. Consequently, classes were overcrowded and resources stretched. In order to make sure that there were adequate facilities for first-time students, the Department adopted a rule which permitted students to repeat a course only once. Students who failed a course twice were excluded from full-time attendance of courses. However, the opportunity was provided for them to continue with subjects that they had failed by studying part-time. Students studying part-time were given the necessary printed study materials, attended tests and examinations, but did not attend full-time classes. Once the necessary courses were passed, the affected students were permitted to rejoin the full-time classes.

The purpose of developing an on-line course in Applied Mechanics I, a first level course of the "National Diploma: Engineering: Civil", was to provide additional learning opportunities on-line both for students who had been excluded from attending full-time and were therefore registered part-time, and for students who were registered full-time. There is no intention at this stage to present the on-line course independently of any other materials, but should the opportunity arise of acquiring students who would not be able to journey to the technikon, then the possibility of presenting it entirely on-line would be considered. At the time that the decision to develop the on-line course was made, the Department had no experience or expertise in the development of on-line courses, so another purpose of developing this particular course was to acquire and record experience to assist professional staff development.

A number of problems had to be faced. There was some institutional knowledge of on-line learning residing in the Technikon's On-line Learning Centre. How could this knowledge be accessed and put to use? How could knowledge be built from developing the on-line course in Applied Mechanics, and be shared, recorded, evaluated and made available to all who needed it? The environment in which teaching took place was continually changing. Originally a single campus institution, the Technikon has opened new campuses in some towns and cities, and acquired campuses in others through the closing of teacher training colleges. It is about to merge with a neighbouring technikon and acquire a new identity – the Durban Institute of Technology. Outcomes-based education has been introduced, requiring restructuring of syllabi, teaching methods and assessment. How can development be managed in such a rapidly changing environment? On-line teaching is not face-to-face teaching grafted on to a computer. How must teaching and assessment methods be changed in order to benefit from the characteristics of the technology? What instructional design methods are suitable for on-line courses, and that are appropriate for engineering courses? This paper is about how action research was introduced to address these problems and to develop the course.

First steps

The initial stages of the project to design and implement the on-line course in Applied Mechanics were carried out without any structure. An attempt was made simply to convert existing printed materials (which were available electronically as word processor documents) to a website. Self and peer evaluation indicated that the result was unsatisfactory, and it was not made available to learners. The evaluation showed that the design was inappropriate to the medium, and that no advantage had been taken of the characteristics of the medium to improve learning. From the evaluation came the realization that the project required structure in order to progress, and also that both the pedagogical design and the implementation required structured design methods. In order to structure the project, it was decided to treat it as a qualitative research project, and to apply qualitative research methodologies to it. There are many qualitative methodologies available. However, since the project entailed the development of new ways of doing things, a process of change within a community and evaluation of change, the action research methodology was adopted. This was facilitated by the fact that the initial steps taken in the project, namely the recognition of a problem, the planning of a "solution" to the problem, its implementation and evaluation corresponded very closely to the action research cycle.

Action Research

The purpose of applying action research to the development process was to direct the development in a structured way, as a way to learn about learning and teaching on-line in an institution whose dominant activity is face-to-face teaching, to build up a body of local knowledge about using action research for the development of on-line courses, and to provide an example of action research to help in professional development for practitioners of on-line learning. The model of action research adopted was that described by McConnell (2000, p.122) as "action learning" or "action learning or research". He describes the process as posing and diagnosing a problem, which leads to conceiving a series of action steps required to investigate the problem that are then implemented. The outcomes of the implementation are evaluated, and this leads to the re-examination of the issues involved and a new cycle is initiated.

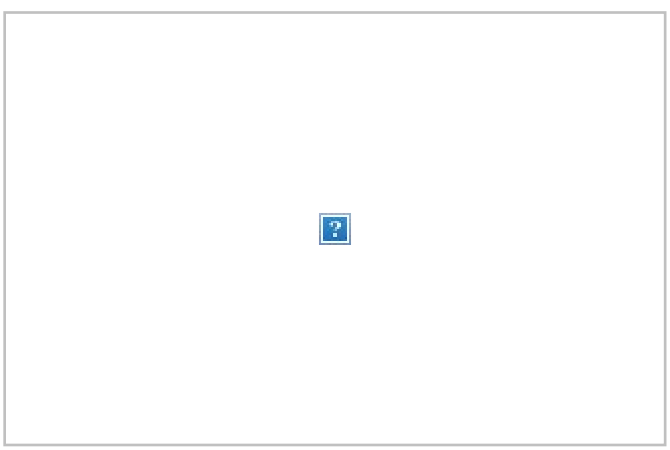

Figure 2 *Action research cycle (modified after McConnell 2000)*

The intent of adopting action research, or action learning, was to facilitate learning by experience – experience gained within the project, and from others engaged in similar projects. Dick (1997, p.1) states of action research that "it is commonly done by a group of people, though sometimes individuals use it to improve their practice". This project is an instance of action research being applied by an individual to improve practice, that has been carried out as a cooperative process with a variety of "action learning groups" (McConnell, 2000, p.121) starting with face-to-face cooperation with colleagues, followed by computer supported cooperative learning while the author was a participant in an on-line M.Ed. programme, and since then with a mix of face-to-face and computer supported cooperative learning on campus as part of a professional development programme in on-line learning. The cycle illustrated by McConnell (2000, p.123), was used, with adaptations to emphasize a starting point followed by an indefinite number of cycles and the influence of changes in environment during re-interpretation of the problem/issue (See Figure 2) .

Although at the time that this portion of the development was carried out no conscious decision had been carried out to apply action research, it is still possible to **view** the activities performed within the framework of action research, as illustrated by Table 1.

Table 1 First steps taken to design the course viewed as the first cycle of an action research project

problem/issue posed and diagnosed	the need for an on-line course in Applied Mechanics is recognised
action steps imagined and planned	a portion of the Applied Mechanics course is planned as an on-line instructional event, but no formal instructional design is carried out - existing material is converted to on-line format
action carried out	the instructional event is implemented, and published on our open learning website
outcomes evaluated	peer, self and informal evaluation is carried out.

The second cycle of development

The issues posed in the second cycle of development were

how to add structure to the course

how to take into account the introduction into the technikon of Outcomes-based Education (OBE).

This cycle was exploratory in nature, and its purpose was to identify and experiment with an instructional design method or strategy that would add structure to the course, and also at least be compatible with OBE which at that time was in the early stages of being introduced. There are many instructional design methods available. For a comprehensive list of instructional design methods Kearsley (2001) can be consulted. The criteria used to select the instructional design method were that it should be simple to implement, it should take into account that the course material is well-defined and elementary, and it should be supportive of outcomes-based education. Of the many design methods available, the model of Gagné and Briggs for Intellectual skill as described by Aronson and Briggs (1983) was adopted.

Gagné and Briggs Model

Learning, according to Gagné, takes place when a person acquires a capability to do something. Observed behaviour of the person that demonstrates the new capability shows that learning has taken place. Gagné lists five categories of different types of learned capability: intellectual skill, motor skill, verbal information, cognitive strategy and attitude. Each category of learned capability is demonstrated by its own type of outcome. He argues that different instructional methods are needed for each of the five categories of learned capability. The category of learning appropriate to the Applied Mechanics course is "intellectual skill". The performance associated with this category are "using concepts and rules to solve problems; responding to classes of stimuli as distinct from recalling specific examples" (Aronson and Briggs, 1983, p.81). Intellectual skills are divided into a further five sub-categories. In applying the method outcomes are stated as "instructional objectives". A learning task analysis determines essential and supporting prerequisites of an objective. Relationships in the domain of intellectual skills can be represented diagrammatically as a "learning hierarchy". The prerequisites are selected as enabling objectives, and are ordered according to the learning hierarchy to define the sequence of instruction. The structure of the learning activities is shaped by nine "instructional events" that implement external conditions of learning. External conditions of learning are events that support the internal processes of learning.

Reasons for adopting the Gagné-Briggs approach

The Gagné-Briggs model is appealing because it provides a clearly defined structure to the design process in the form of the nine instructional events, it provides a means of sequencing the instruction, and part of the methodology consists of classifying objectives in terms of learning outcomes. The instructional objectives of Gagné were equated with learning outcomes in the sense used by the South African Qualifications Authority (SAQA) (Mehl, 1998), although it was recognised that the SAQA outcomes were more general in nature than instructional objectives. The idea that learning outcomes might be used seamlessly in a methodology for instructional design was especially attractive since this would support institutional plans to introduce OBE. Another feature of the Gagné-Briggs methodology is that "Briggs recommended that media be selected after the requirements for providing the instructional events for a given instructional sequence had been determined" (Aronson and Briggs, 1983, p.96). The merit of this is that it reduces the complexity of the task of designing instructional events by applying the "principle of separation of concerns" (Heninger, 1980, p.4). Separating concerns in this context separates the instructional design from the media design. Moreover, it promises an economy in that a single design can be implemented subsequently in a variety of situations, an important consideration because the course is presented both on-line and in the classroom. For example, a learning activity might be rendered by carrying out an experiment in the classroom version of the course, or by computer simulation of an experiment in the on-line version. Lastly, Aronson and Briggs (1983, p.97) state "…the procedure is appropriate whether instruction is presented by conventional teaching methods or by self-instruction modules."

The design

A comprehensive design document following the Gagné-Briggs methodology was produced, from which some experimental Web pages were developed. The design is illustrated by two tables, Table 2 and Table 3. In Table 2 a partial list of instructional objectives is presented as a hierarchy. Column A contains a learning outcome for the section which requires the prerequisites shown in column B, which in turn require the prerequisites in column C. Each objective is accompanied by its sub-classification of intellectual skill. The table was derived from a learning hierarchy diagram.

Table 2 Instructional objectives for section dealing with vector algebra (partial list)

A	B	C
1. use vector algebra to add forces found in coplanar structures and find their components (**Higher Order Rule**)	1. represent a force in a coplanar structure as a vector (**Rule**) 2. add forces using the parallelogram of forces (**Rule**)	1. define a vector quantity (**Defined Concept**) 2. define a scalar quantity (**Defined Concept**) 3. discriminate between scalar and vector quantities (**Rule**)

The section was organised into lessons, each addressing one or more of the instructional objectives, structured according to the nine instructional events, and sequenced according to the learning hierarchy diagram. Each lesson was planned and written down as illustrated in Table 3 which shows a portion of the plan for Lesson 1.

Table 3 Portion of a lesson plan

Title of learning event **Vectors and Forces**	
Lesson 1 **Instructional objectives:**	
C1. define a vector quantity (Defined Concept) C2. define a scalar quantity (Defined Concept)	C3. discriminate between scalar and vector quantities (Rule) C4. represent a vector diagrammatically using an arrow (Defined Concept)
Approach: By drawing an analogy between the layout of square city blocks and travelling through the city, give an intuitive idea, using prior or implicit knowledge, of the nature of a vector. From this follows the formal	

<table>
<tr><td colspan="4">definition of a vector, which is contrasted with scalars. Using this, the method of representing vectors by arrows is introduced.</td></tr>
<tr><th>Gagné Instructional event</th><th>Activity or Product</th><th>Cognitive Strategy</th><th>Comments</th></tr>
<tr><td>Gaining attention

Stimulating recall of prior learning</td><td>Activity 1

Vectg03.htm</td><td>Metaphor – analogy

It draws an analogy

1. implicitly between a rectangular city block layout and Cartesian co-ordinates

2. implicitly between distance travelled east-west and north-south and components

3. explicitly between scalar distance and distance walked

explicitly between distance apart and direction, and vector</td><td>Attention is gained and maintained by posing questions that the learner can answer by referring to prior knowledge and making deductions from this. It presents a hypothetical situation with the idea of inviting the learner's curiosity.</td></tr>
</table>

Collaboration and evaluation

This cycle and the third cycle were carried out as part of a "small scale action research project" (McConnell, 1998, p.v.iv). Part of the evaluation was by collaboration on-line with other members of the action learning group, and part was by collaboration with interested colleagues. No evaluation was carried out by students because the cycle was purely exploratory to see if the design method worked and what the design might look like. It was found that individual Web pages were easy to design following the instructional design that was written down in a tabular format, although the design was tedious and time consuming to write down. At the micro level the instructional design was of help in creating a logical structure, but at the macro level it was disjointed. The design method was capable of structuring components of the instruction, but was unable to take advantage of, or even take into account the relationships between them. However, the result was better than that achieved in the first cycle of development.

The third cycle of development

The issues posed/diagnosed in the third cycle of development were

how to integrate the design to avoid the disjointedness experienced in Cycle 2

how to take into account student perceptions and approaches to learning

integrating OBE into the design

integrating knowledge of learning.

A change of environment was experienced. There had been a reduction in the number of part-time students enrolled from 30 at the time that the on-line course was conceived to 3 at the commencement of Cycle 3. In response to this the focus of the design shifted from students who might have to learn at a distance to providing on-line material that would be a useful supplement for full-time students.

Towards a more integrated design

Laurillard (1993) criticizes instructional design methods of the type advocated by Gagné and Briggs because the analysis of teaching and learning components is not followed by any synthesis, and moreover the addition of "integrative goals" to an existing design theory cannot bring about a synthesis. The overall structure of the course was revisited, and the Gagné-Briggs approach was used only for the detail design of lessons after the overall structure had been determined from the outcomes defined in the document submitted to SAQA for the registration of the Diploma. In order to bring about some integration of the learning material a unifying theme was included. The theme was that of bridge design, and each of the lessons referred to bridge design. Each lesson was given an introduction which was used to connect what had already been learned with the lesson contents, and explained how the lesson related to the subject taken as a whole. Jonassen (1994) contends that the better use of technology is as cognitive tools rather than conveyors of knowledge. Some lessons use the computer as a cognitive tool, for example the student is introduced to some important principles by carrying out simulated experiments.

Attitudes towards learning and learning styles

Students approach learning in different ways. There are three approaches to learning commonly used by students. Biggs (1988) characterises the surface approach as learning being a means to some end, for example the obtaining of a qualification. The deep approach is characterised by an interest in what is being learned. The achieving or strategic approach is based on the student obtaining motivation from being in competition, either with others (achieving higher grades than the "competition") or with himself or herself (achieving the highest grades possible).

Observations from practice at Technikon Natal

It is clear from studies carried out in the Faculty of Engineering that both deep and surface approaches to learning are adopted, but the surface approach tends to be favoured by the majority of students. Many of the "best" students (regarded as those who obtain the highest marks or the greatest number of distinctions in examinations) are the most competitive, and achieve "success" because of their competitive nature, and by inference adopt a strategic, or achievement approach.

Learning styles too are an important factor to take into consideration in designing on-line courses. Felder (1993) lists the dimensions of learning style as

- Sensing and Intuitive Perception
- Visual and Verbal Input
- Inductive and Deductive Organisation
- Active and Reflective Processing
- Sequential and Global Understanding

A survey of engineering students' styles of learning was carried out using a questionnaire devised by Soloman and Felder (undated). The conclusions drawn from the survey were:

> On average, the preferred learning styles of the students surveyed were
>
> visual input is preferred to verbal input – learners are able to understand and assimilate information from a picture or diagram much more readily than from a verbal explanation
>
> sensory perception is preferred to intuitive perception – learners tend to obtain more information from what they can touch and see and hear than from their thinking, such as ideas and feelings
>
> active processing of information is preferred to reflective processing – learners prefer to manipulate and work with physical things, such as numerical examples and practical work, or discussion, than to work by "thinking things over"
>
> students prefer to reach understanding sequentially rather than globally.
>
> It cannot be assumed that generally students show the same preferences for learning styles.
>
> Individual students' preferred learning styles might vary according to the context in which learning takes place, and might vary over time.
>
> Students' learning styles may be markedly different from a teacher's learning style, which emphasizes the need to be aware of students' preferred learning styles.

The surface approach favoured by most students was taken into account by adopting a "no-nonsense" approach to preparing the learning materials. The text was simply written, much of it in point form, and very focussed in order to keep the attention of the surface learner. Interactive exercises require the learner to participate were added. Additional material that might be attractive to deep learners, or that might encourage surface learners to become deep learners was provided through hyperlinks to material on this and other websites.

Outcomes-based education

An attempt was made in Cycle 3 to base the design on Outcomes-based education, and advantage was taken of the similarity between performance indicators (*OBE*) and instructional objectives (*Gagné-Briggs*):

> both consist of behaviours that can be observed
>
> performance of a behaviour demonstrates that a capability (*Gagné-Briggs*) or a competence (*OBE*) has been achieved
>
> both can be arranged as a hierarchy.

However, outcomes used in the sense intended in outcomes-based education appear to be much more general than outcomes used in the sense intended by the Gagné-Briggs model. Specific outcomes (*OBE*) are modified by a set of general critical outcomes in the model of OBE adopted by SAQA, and embedded knowledge, that are not made explicit within the specific outcomes. Outcomes, or instructional objectives (*Gagné-Briggs*) on the other hand are self-contained. Critical outcomes, related to the general development of the learner, cannot be decomposed into performance indicators. The achievement of critical outcomes relies upon performance indicators of specific outcomes supporting critical outcomes as well.

Embedded knowledge of learning

Knowledge of how to learn is obviously a necessity to a learner, but providing this knowledge is often neglected altogether, or provided in some sort of remedial course. The learner really needs to have guidance provided within the learning materials themselves. Provision of knowledge of learning supports one of the critical outcomes:

> "In order to contribute to the full personal development of each learner and the social and economic development of the society at large, it must be the intention underlying any programme of learning to make an individual aware of the importance of:
>
> > 1. Reflecting on and exploring a variety of strategies to learn more effectively;
> >
> > …". (South African Qualifications Authority, 1997, p.6).

Embedded knowledge of learning was incorporated explicitly through hyperlinks (although disguised as "Coach's Tips", taking advantage of the immense popularity of various sports with South African students) and implicitly by using many learning strategies, such as repetition, exercises and problem-solving within the lesson material.

The fourth cycle of development

The fourth cycle of development saw the introduction of WebCT, which provides an environment within which on-line courses can be presented and managed. It provides facilities for the registration and management of students, assessment, synchronous and asynchronous communication, and the inclusion of lesson content. An early decision was made not to incorporate the website within WebCT, but to create a "wrap-around" course that would refer to the website and to other materials. This was achieved by creating links from WebCT to the Website. This decision was made because the methods for handling content internal to WebCT are unwieldy. This does mean that the website is open to the general public, but this is seen as good publicity for the institution. A new section of the course was designed following the principles evolved during Cycles 2 and 3, and added to the website. Facilities have been made available for conferencing within WebCT to allow students to discuss the course on-line, but after the initial contributions to the discussions made during training, students did not use them. Students have said that they find it simpler to meet face-to-face. Collaborative problem solving in mathematics related subjects on-line is difficult because conferencing systems do not support the use of mathematical symbols, equations and sketches.

On-line collaboration in design

Advantage was taken of the conferencing facilities of WebCT to collaborate in the design of the course on-line. Technikon Natal has an On-line Learning Centre which has a policy of supporting the development of on-line learning through staff development (Peté, 2001). With the introduction of WebCT, staff development has taken the form of a hybrid face-to-face/ on-line course in on-line learning and WebCT. It consists of a four day face-to-face introduction, followed by fairly regular face-to-face meetings. However, the main work of the course has been carried on on-line through the medium of the WebCT threaded discussions. Most of the collaboration in developing the Applied Mechanics course has been done in this way. Although it would be possible in principle to do this face-to-face, the collaborators are separated by time because it is nearly impossible to schedule meetings of all concerned at convenient times. It has also been found that the asynchronous nature of the discussion has allowed measured and thoughtful contributions to the design that might not have occurred in face-to-face meetings. There is also a lasting record of all contributions to the discussions. It is interesting to note that although this course is not part of any qualification, and there are no "rewards" other than personal development, the activity on-line has been voluminous and of high quality. This is attributed to the perception that the on-line discussion performs a function that is of practical use in helping individuals design their on-line courses, and meets a real, practical need. By contrast, although conferencing facilities were provided as part of the Applied Mechanics course, they were used infrequently because participants did not perceive a need for them, since face-to-face meetings were so easy to have.

findings and conclusions

Student response to the on-line course in Applied Mechanics has been positive. Although it is purely voluntary, one third of the students enrolled for the full and part-time course have made regular use of it. They feel that it has been useful to them by expanding on the classroom activities, and by giving them the opportunity for self exercise and assessment that they would not otherwise have had. One unlooked for benefit is that students see the provision of a supplementary on-line course as a manifestation of concern for them.

Action research as a methodology for implementing a new way of working has kept the design work focussed while allowing the flexibility needed to cope with rapid change. The periods of evaluation and reflection have resulted in planned change and visible improvement. The collaboration that is such a necessary part of the action research methodology has been made very easy through the use of on-line conferencing, and has made the project much more dynamic than if it had been necessary to rely on periodic face-to-face meetings. It has also allowed a much wider participation. Institutional knowledge was made available and contributed to through computer mediated collaboration. It is however disappointing that the student users of the course have not taken advantage of the opportunity afforded by on-line conferencing to contribute to the design process – this is something that will be investigated.

The instructional design has required a lot more time and effort than the physical design of the course in the form of web pages, assessment, simulations and so on, which almost seemed to fall out of the instructional design by themselves. Having developed a format for the instructional design, adding to the course or developing similar courses has become a lot easier, and the format is available for use or modification by others. Whether the instructional design methodology adopted is the best fit for the particular circumstances is yet to be determined, but it is almost certainly better to use some sort of instructional design than none. For this particular case of a relatively low-level course that requires certain skills to be developed as much as principles to be learned, the Gagné-Briggs approach, in spite of being one of the older methods, appears to be satisfactory. However it does not promote the use of on-line discussion in the learning process. It has been found (Case, 1997) that collaborative problem solving supports effective learning in the classroom. In order to implement collaborative problem solving on-line and evaluate its worth, two practical problems need to be solved: how to write mathematical symbols and place drawings into conference postings, and how to present the problems so that students will perceive a genuine need to be able to solve them on-line in a campus environment.

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