The Mathematics Enthusiast

Volume 5
Number 2 *Numbers 2 & 3*

Article 10

7-2008

A Case Study Using Soft Systems Methodology in the Evolution of a Mathematics Module

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Abstract

This paper describes the application of Soft Systems Methodology as a tool for facilitating the review of a taught mathematics module so that the views of those engaged with the module could be captured and conflicting expectations and views highlighted. Checkland's Soft Systems Methodology is used since it enables the capture of stakeholder views and addresses both 'hard' and 'soft' aspects of the learning experience. Stages in the application of Soft Systems Methodology are illustrated including the development of a rich picture and conceptual models and the work was conducted using a stakeholder group that included students taking the module (surveyed by questionnaire) and discussion with staff involved in the design and delivery of the material. Changes made to the delivery of the module are described particularly in the way that student support is delivered. The benefits derived from the application of this methodology are illustrated together with module monitoring and control mechanisms that help to trace the development of students. The paper argues that the application of this approach can enhance the understanding that faculty members have of student perceptions of a module, allows individual views to be understood and challenged and that this type of learning cycle undertaken periodically can be used to structure the evolution of a taught module.

Keywords: assessment of instructional modules; beliefs; student perceptions; soft systems methodology; mathematical modules; module monitoring; stake holders

Introduction

A recent article in The Montana Mathematics Enthusiast (Latterell, 2007) it was argued that undergraduate mathematics professors need to have a better understanding of their students' perceptions, the pressures on their lives and their preferred learning styles as each of

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The Montana Mathematics Enthusiast, **ISSN 1551-3440, Vol. 5, nos.2&3**, pp.269-290

these are subject to change over time. This paper fully supports that argument and extends it further to suggest that professors need to understand not just their students' views and expectations, but also those of their fellow professors and the external pressures from government or relevant professional bodies that may impinge on the design and delivery of a mathematics module.

The teaching of mathematics at university level, either as a single subject or as support for another subject area such as computing, requires a good deal of reflection on the part of the teaching staff as there are changing and challenging external influences at work which require corresponding change to mathematics curricula and to learning and teaching strategies. As we describe below, the need for reflection is probably as acute in mathematics and the related disciplines as in any other subject area. Unfortunately, there is often little time within a crowded academic calendar for such periods of reflection to be regularly undertaken. What seems to be more likely is that little change occurs until there is some sort of 'Kuhnian crisis' (Kuhn, 1996) with the module which is to say that the existing learning and teaching philosophy is recognised as critically failing to engage and inform the students and a radical re-think is required as opposed to a gradual evolution of current thinking. Rather than lurch into such radical change, it would be advantageous to set in place a framework which could be used to structure reflective thinking about a module on a regular basis. There are a number of ways in which we might approach this but a key underlying characteristic is that the process must be able to capture the views of all participants if it is to be comprehensive.

This paper describes a reflective review of a mathematics module which forms part of the first year curriculum of an undergraduate computing studies programme at London South Bank University (LSBU). In order to ensure that the views of all participants were captured the review incorporated the use of Soft Systems Methodology and this paper describes some of the findings of the review generated from two contrasting perspectives – that of the lecturer and the student.

Some Current Issues in the Teaching of Mathematics in UK Universities

A wide range of UK commentators have expressed concern about the decline, over the last 15 or so years, in the numbers of students who are taking mathematics (and other related subjects such as Physics and Engineering) at university level. This is coupled with concern over the general mathematical abilities of students at school level and those arriving at university to undertake mathematically related courses or courses requiring mathematics as a support topic (Goodfellow, 2006). The mathematical knowledge and skills exhibited by students entering the UK higher education sector has been a matter of some concern and debate for a number of years (Henry, 2004) and this concern has been felt not only in terms of the mathematics required for general university entrance (usually GCSE mathematics at grade C or better) but also on courses for which mathematics is a primary requirement (Engineeringtalk, 2001).

In 2001 the UK Government commissioned a review of the development of science and engineering skills in the UK (Roberts, 2002) and this review reported that among young people many have a poor experience in science and engineering education and that many have the impression that mathematics is boring and irrelevant. These concerns regarding mathematics gave rise to a further study (the Smith Report) which this time concentrated on post-14 mathematics education (Smith, 2004) and among the many issues raised by the report was that there was a " … failure of the current curriculum and qualifications framework to meet the requirements of learners, higher education and employers …" (Smith, 2004, p. 9). Following this a number of other studies have attempted to audit the skills of school leavers and those applying for university places and it has been reported that among UK higher education lecturers and admissions staff there are " … underlying concerns about basic numeracy and literacy, and perceived problems with higher level mathematical skills, essay writing and independent learning skills." (Wilde et al, 2006, p. 6).

The Smith Report is by far the most comprehensive recent examination of the UK mathematics education system and it concluded that there are a number of possible reasons why students choose not to continue studying mathematics after the age of 16. These included the impression that students have of mathematics being more difficult a subject than others (although perceptions of difficulty can have many causes and indeed manifestations) and that the mathematics curriculum lacked the ability to interest and motivate students.

Turning now to my own institution, London South Bank University is an inner-city university and it has a truly cosmopolitan student body (London South Bank University, 2006). For example, of its 21,000 current students 60% come from black and minority ethnic backgrounds, 66% are aged 25 or over and only 20% arrive at the university with what would be regarded as 'traditional' entry qualifications ('A' level qualifications gained in the UK for example). Representing over 80 different countries, students arrive at the university with an eclectic mix of qualifications from both the UK and overseas and a variety of educational experiences in their previous schooling. Those students who enrol onto courses with a significant mathematical content do so with sometimes very mixed mathematical experiences and degrees of success. As a colleague has written "The main problem we have at LSBU is that student's previous mathematical ability is varied, and the mathematical skills that the student enters university with are extremely diverse." (Starkings, 2004, p. 22).

It is clear that UK institutions at all levels face a number of challenges in devising mathematical curricula and associated learning and teaching strategies, and in providing academic support for those students who find the transition to higher levels of study difficult.

The Need for Review

The teaching of mathematics as part of the first year computing studies curriculum at LSBU has been subject to periodic review for a number of years. Although the mathematics modules in their various forms have had pass rates that were viewed as acceptable by the faculty in comparison with other first year modules, there is no doubt that many students struggle with the subject material and frequently require additional support, over and above the normal timetabled tutorial sessions. Many universities provide mathematics support to students in addition to their timetabled class time and there have been a number of models of support provision tried (Perkin and Croft, 2004). At LSBU, students who had performed badly in their first mathematics assignment were routinely directed to the support sessions run by the university's Centre for Learning Support and Development (CLSD) and were able to get group or individual help from CLSD support staff. These were, however, voluntary on the part of the student and monitoring of the usage of support sessions produced evidence that the take-up was generally poor. Although acceptable numbers of students were passing the mathematics module and student evaluation of the module was generally good (so that traditional quality measures of the performance of the module were indicating no problems) there were a number of issues that teaching staff felt needed to be addressed or at least examined:

- Some students failed to engage with the modules at all, attended poorly and would then fail the module;
- Students were identified as needing support but then declined to take up support when it was made available;

- Although pass rates were acceptable, average scores on assignments were low. It was felt that students could do better if they were better motivated and took advantage of support. Motivating students was seen as an issue;
- It was felt that students did not want to study mathematics. They were here to study computing and did not see the need for mathematics;
- On the other hand, employers have bemoaned the lack of quantitative skills exhibited by many job applicants from both schools (Smithers, 2006) and universities (Blair, 2006) across the country;
- It was difficult to cater for the mixed abilities of students being taught, good students were finding the work easy and were also then de-motivated.

These views were due partly to the literature already described providing a rather negative environment in which to teach mathematics and partly were the result of teaching experience over the years with the students on the computing programme. It was clear that in addition to the views already expressed, student views needed to be captured if a complete picture of the module and its operation was to be seen, and in order to accommodate all these views, Peter Checkland's Soft Systems Methodology (SSM) was used as a tool with which to try and capture some of the problems and issues associated with the teaching of these mathematics modules.

Soft Systems Methodology

Scientists and engineers have traditionally been raised on the principle of reductionism so that analysis of a problem focuses on structure and decomposition that reveals how things work. The process focuses on decomposition, explanation and finally synthesis (Hitchens, 1992). Whilst it is true that certain types of investigation can be undertaken by the application of this 'scientific method', the desire to study observed phenomena that extend beyond the foundation sciences of physics, chemistry and biology into psychology and the social sciences has caused researchers to question whether existing modes of thinking are appropriate in capturing the influences and interactions that underpin some of these phenomena (Rosenhead and Mingers, 2001).

The systems movement, on the other hand, contends that system ideas can provide a source of explanation for many kinds of observed phenomena which are beyond the reach of reductionist science. Checkland views systems thinking as a holistic reaction against the reductionism of natural science. This has led to the manifestation of Systems Thinking which tackles the issues of irreducible complexity through a form of thinking based on wholes. Furthermore, systems thinking is based on two pairs of ideas: emergence and hierarchy as one pair, and communication and control as the other (Checkland, 1981; Checkland and Poulter, 2006).

Soft Systems Methodology places an emphasis on human activity systems i.e. humans involved in purposeful activity within an organisation of some sort. The methodology provides a window through which the complexity of such human interaction can be investigated, described and hopefully understood. Once an understanding of the situation under study has been achieved then the methodology allows the identification of change that is both systemically desirable (in that it will alleviate some of the problems and issues) and culturally feasible (in that actors within the system will be inclined to engage with the changes proposed and the change process itself). SSM encourages learning and understanding which will hopefully lead to agreed change and the resolution of problems.

The need to make sense of the complex and dynamic interacting web of ideas, issues and views that characterise many social problems has seen the emergence of SSM through 30 years of reflective intervention experiences – experience dealing with what Ackoff termed 'messes'

(Ackoff, 1974). During this period of evolution, the process model of SSM has emerged and the main stages of the process are described in Table 1.

Stage	Stage Objective
1 and 2	Attempt to build the richest possible picture of the situation.
3	Aims to describe the nature of the chosen system.
4	Produces conceptual models of the defined system.
5	Compares conceptual model with actual situation in order to generated debate with the stakeholders.
6	Outline possible changes that are desirable and feasible.
7	Involves taking action based on stage 6.

Table 1. Key stages of Soft Systems Methodology

Some applications of systems thinking to educational development have been made (Ison, 1999) although SSM has not, seemingly, found wide acceptance. The benefits that can be derived from its use are primarily that with its ability to focus on 'soft' issues, a systems view is generated that contrasts nicely with the rather more quantitative results-driven and analytical quality assurance processes that are traditionally used to assess the effectiveness of a module. As stated by Patel (Patel, 1995, p. 13):

> … the methodology is unique because it enables the analyst to embark on a process of learning about the real world situation being investigated, while simultaneously seeking to improve it by analysing the situation … and suggesting recommendations for further action to improve the problem situation.

The systems approach has also been applied to more general issues related educational management (Bell and Warwick, 2007) but here we restrict ourselves to thinking about a single taught mathematics module. In this paper we contrast two key views of the situation – that of the lecturer (influenced by the published views of colleagues, Government sponsored reports and personal experience) who takes responsibility for the design, delivery and assessment of the module and that of the student who has to engage with the unit and, hopefully, pass.

The Application of Soft Systems Methodology

We now describe the stages of SSM in terms of the work undertaken on the review of the mathematics module and the outputs produced.

Stages 1 and 2

In order to develop a rich picture of the situation under study, a number of sources of information were utilised to capture views of the module from the perspective of the university, the faculty and the lecturer. These included government and university documents that describe the requirements of module design at various levels of study (SEEC, 2003), discussion with colleagues as to the required syllabus (this module was providing support for studies in computing) and documents already referred to that describe the general environment of mathematics teaching and possible remedies. In order to capture the student perspective, it was necessary to try and elicit student views both through questionnaire and then follow-up discussion with a smaller group of students to confirm findings.

A questionnaire was distributed to a sample of 62 new students joining the computing programme and who would be taking the mathematics module. Since the objective of the module was to provide a relevant and useful syllabus that students were equipped to study and for which additional support could be provided, it was decided to structure the questionnaire around three factors. The first was 'mathematical self-efficacy', the second was 'previous educational experience in mathematics' and the third was 'the perceived relevance of mathematics as part of the course of study'.

The first of these factors relates to an individual's self-efficacy beliefs and these are conjectured to be oriented around four core concepts: 'performance experiences', 'vicarious experiences', 'verbal feedback', and finally 'physiological and affective states'. Each of these contributes to the individual's ability to organise and execute effective learning and can be tailored to specific subject domains. To give a little more detail we can turn to descriptions taken from the literature (Phan and Walker, 2000). 'Performance experience' relates to indications of capability based on performance in past assessments that the student may have undertaken, or performance on previous courses etc.; 'Vicarious experiences' relates to evidence based on competencies and informative comparison with the attainment of others i.e. the student's performance in relation to their peers; 'Verbal persuasion', as its name suggests, refers to the student's response to verbal feedback from those in a position of greater authority such as teachers or adults; 'Physiological and affective states' are judgements of capability, strength and vulnerability to dysfunction.

The second factor, 'Previous educational experience in mathematics', was related to how the students perceived their past education in mathematics and so had a broader context than the self-efficacy criteria described above.

The third factor, 'The perceived relevance of mathematics', was included since it was identified in recent studies as a reason why students were 'turned off' mathematics. The perceived relevance of the subject could well effect the degree of motivation and time allocated to study of the module by students.

Thus the questionnaire was constructed to elicit views across six criteria – four relating to mathematical self-efficacy together with previous educational experience and perceived relevance of mathematics. Each student was given a questionnaire consisting of 24 statements relating to the six criteria and asked to indicate the extent to which they agreed with the statement on a 7-point Likert scale ranging from 1 (not true) through to 7 (very true). There were four questions relating to each of the six criteria with some expressing a positive sentiment and some a negative sentiment.

In the questionnaire results shown in Table 2, the statements have been sorted by average (arithmetic mean) Likert score and the middle third of the statements are those for which there was neither strong agreement nor disagreement having average scores in the range 3.5 to 4.5 approximately.

	Text of the Statement	**Average Score**	
1	Mathematics is useful for anyone's life	6.27	General to strong agreement
2	I find it useful to be able to improve my mathematics	6.11	
3	I like to get verbal feedback from my teacher	6.00	
4	Mathematics is important in studying IT	5.92	
5	I enjoy learning new mathematical facts and ideas	5.66	
6	Mathematics is interesting	5.47	
7	When my teacher praises me I want to do well in mathematics	5.23	
8	It has been a long time since I studied mathematics	4.68	
9	I was always encouraged to improve my mathematics	4.61	Neither agreement or disagreement
10	I am always worried about mathematics	4.21	
11	I don't have anyone to help me with mathematics	4.15	
12	My classmates have generally been good in mathematics	4.15	
13	I have a close friend who is good in mathematics	3.92	
14	I have been able to access good mathematics resources	3.76	
15	I struggle to pass mathematics assessments	3.66	
16	I am generally pleased with the mathematics results I get	3.53	
17	Compared with other students I am weak in mathematics	3.35	General to strong disagreement
18	I always get good marks in mathematics	3.26	
19	My friends tell me I am good in maths	3.21	
20	I am not good in mathematics	3.21	
21	I've never had a good mathematics teacher	2.81	
22	I get put off when I am told I am wrong in mathematics	2.69	
23	I hate mathematics	2.66	
24	I know enough mathematics without studying more on this course	1.84	

Table 2. Average Questionnaire Results for Each Statement

An examination of this sorted list of statements suggested a number of interesting observations regarding student views.

- In terms of perceived relevance of mathematics, questions 1, 4, 5 and 24 gave a strong indication that students did see mathematics as useful, that they accepted the requirement to study mathematics as part of their course and that they accepted the limitations of their current knowledge. This was unexpected as it was felt by staff that students did not see the module as adding much to their course of study i.e. that it was largely irrelevant to their study of computing.
- Questions 3, 7, 19 and 22 related to students' reaction to positive and negative feedback. Again there was an unexpectedly strong reaction to these questions and the responses emphasised the

importance of giving feedback regularly (this could be summative or formative) and that students were not averse to receiving negative feedback.

- Questions 11,12, 13 and 17 reflected the students' vicarious experiences and these responses were grouped in the middle of the table. On initial inspection this seemed to indicate that students had no strong feelings either way but in fact the scores for these questions were clearly bi-modal with some students strongly agreeing and others strongly disagreeing and producing a rather deceptive average result. For example, in response to the statement "I don't have anyone to help me with mathematics" 34% of the sample strongly disagreed (indicated 1 or 2 on the Likert scale) and 39% strongly agreed (indicated 6 or 7) so there were clearly groups of students who have support available among their friends but a larger group who do not and therefore would require support.
- Finally, in terms of previous educational experience, questions 15, 16, 18, 20 indicated that although the students generally acknowledged that they were not good in mathematics (40% indicating 1 or 2) there was a reluctance blame this on poor mathematics teaching since 57% strongly disagreed (indicating 1 or 2) with the statement that they had never had a good mathematics teacher.

Much of this information was represented as a rich picture which is one output from stages 1 and 2 of SSM. The rich picture gives a pictorial description of the situation under investigation and provides a focal point for further discussion and analysis. A rich picture was constructed and is shown in figure 1. From this rich picture we can began to draw out some issues and problems which seemed to be emerging. In our case study, three issues seemed to be particularly key:

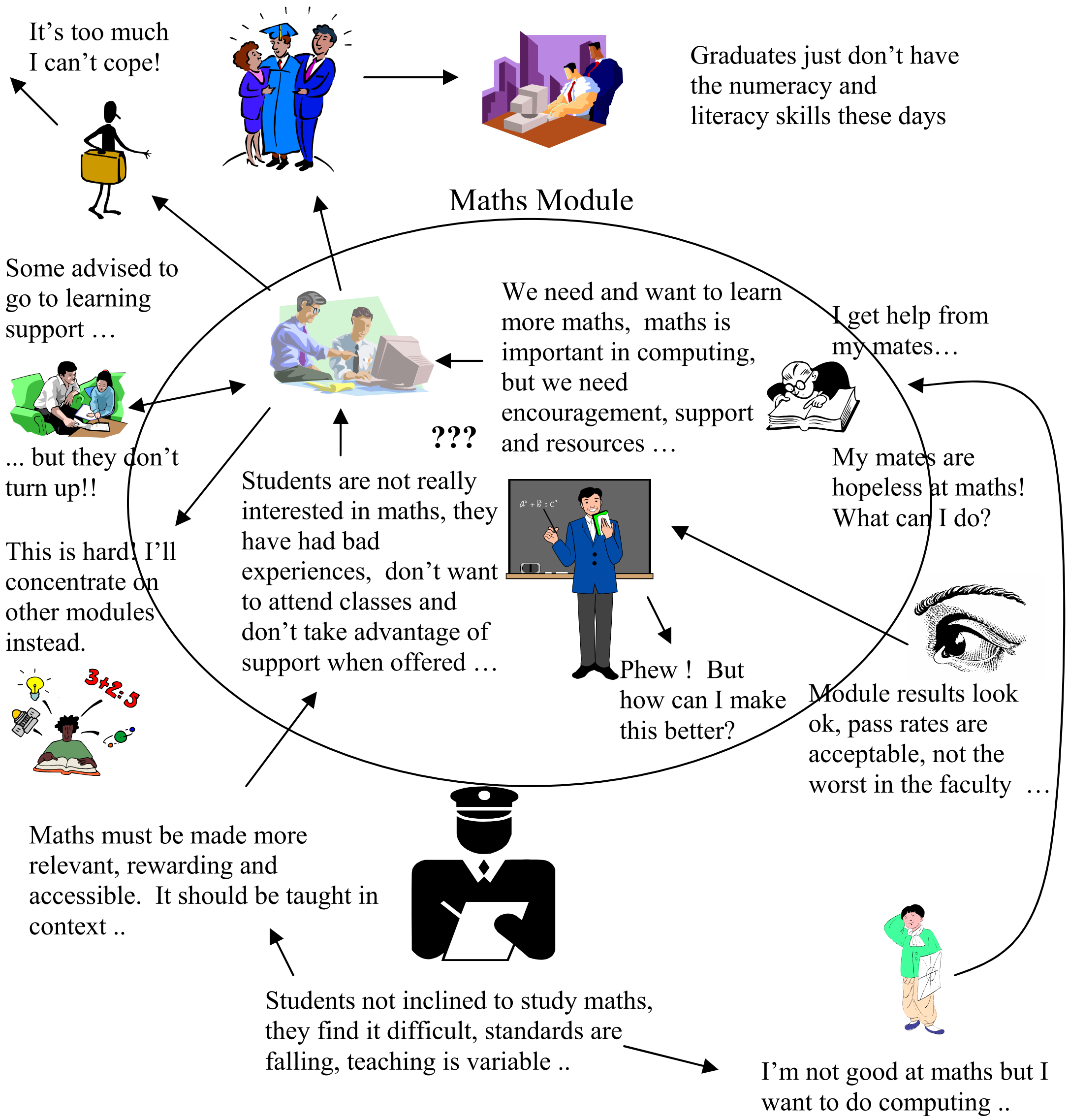

Figure 1. A Rich Picture

- There was a clear perception among staff that students were not using the support services offered by the university and evidence seemed to indicate that this was true. How could support be structured to make it more effective?
- There was an issue with the motivation of students. Attendance often dropped during the module yet students claimed to be motivated to learn mathematics on entry and saw it as important to their studies;
- Many students, by their own admission, were not good in mathematics and did not have access to resources outside the classroom. How could this be improved?

Having identified some key issues, we now began to think in soft systems terms about how we could resolve these issues i.e. we began to develop relevant systems that would address these issues. Here we give examples of three relevant systems which related to: how the module was formally described, how additional support and tuition for students could be provided and how best to motivate and encourage student engagement with the module.

Stage 3

Having established from the rich picture a number of relevant systems that need investigation, stage 3 required a root definition of each system to be constructed. The root definition should contain sufficient information for a conceptual model to built of the system based on the root definition alone. The well-known mnemonic CATWOE was used to identify elements of the root definition.

Element of CATWOE	**Description**
Customers	Who are the victims or beneficiaries of the transformation?
Actors	Who makes the transformation happen?
Transformation	What are the inputs and (transformed) outputs?
Weltanschauung	What makes the transformation meaningful in context?
Owners	Who could stop the transformation process?
Environmental Constraints	Which elements outside the system are taken as given?

Table 3. The Elements of the Root Definition

We began by developing a root definition for three relevant systems each described using CATWOE: a system to deliver and assess a university approved module; a system to provide additional support and tuition for students who require it; a system to motivate and encourage student engagement with the module. Tables 4, 5 and 6 below illustrate the three root definitions.

Element of CATWOE	**Module Description**
Customers	The students enrolled onto the module.
Actors	The module lecturer(s).
Transformation	The need for students to be able to {insert aims of the module} transformed to the need met by attendance at a series of lectures and the successful completion of assessments designed to test achievement of {insert learning outcomes}.
Weltanschauung	The further study of mathematics in year 1 is essential for students entering with GCSE mathematics, with module content designed to mesh with studies in computer hardware, software and business applications as specified by programme tutors, employers and professional associations.
Owners	Dean of Faculty or Head of Department
Environmental Constraints	Library, web and other online learning resources specifically required by the module, other general physical and human resources required for effective learning and student support.

Table 4. System 1 Root Definition

Element of CATWOE	**Module Description**
Customers	The students enrolled onto the module.
Actors	The module lecturer(s) or university support staff
Transformation	The need for students to be identified who have specific weaknesses in core mathematics which must be remedied transformed to the need met by appropriate student evaluation and support organised during the running of the module, the provision of resources and plans to address the students' specific weaknesses. Student attendance must be ensured to enable the transformation
Weltanschauung	Although students meet general entry requirements, many have specific weaknesses in mathematics, lack confidence in the use of mathematics and need to strengthen their core mathematics skills to increase their likelihood of passing the module.
Owners	Dean of Faculty or Head of Department, Module Leader.
Environmental Constraints	There are limited resources available for additional support provision – some may be provided by the university and others may be local to the faculty.

Table 5. System 2 Root Definition

Element of CATWOE	**Module Description**
Customers	The students enrolled onto the module.
Actors	The module lecturer(s).
Transformation	The need for students to remain motivated and to attend and engage with the mathematics module transformed to the need met by appropriate content, delivery processes and assessment regimes.
Weltanschauung	Student willingness to study mathematics must be nurtured by appropriate content and assessment that gives continual feedback and support to all students.
Owners	Dean of Faculty or Head of Department, Module Leader.
Environmental Constraints	Students need to acclimatise to university life and deal with a range of studies in their first year. Assessment demands of other modules, the schedule of work and outside commitments (part-time work, family etc) often restrict time for study and force compromises.

Table 6. System 3 Root Definition

Stage 4

Once the root definition for a system had been established then stage 4 required the construction of a conceptual model which described the activities that must take place in order to achieve the transformation and also how the operation of the system was to be monitored and controlled. Monitoring and control activities usually revolve around the three Es of efficacy, effectiveness and efficiency. Efficacy requires that the system has a purpose to fulfil (i.e. that the transformation is still necessary within the broader view), effectiveness requires that the system is designed correctly to fulfil its purpose (carry out the transformation) and efficiency requires that the system carries out the transformation with efficient use of resources. Conceptual models are generated with reference only to the root definition and not to activities taking place in the real world. They are, then, theoretical models of systems that can bring about the stated transitions and their value lies in comparison with the real world activities.

Of the three root definitions presented above, the second and third are illustrated with conceptual models. The conceptual model derived for system 2 is shown below in Figure 2, and for system 3 in Figure 3.

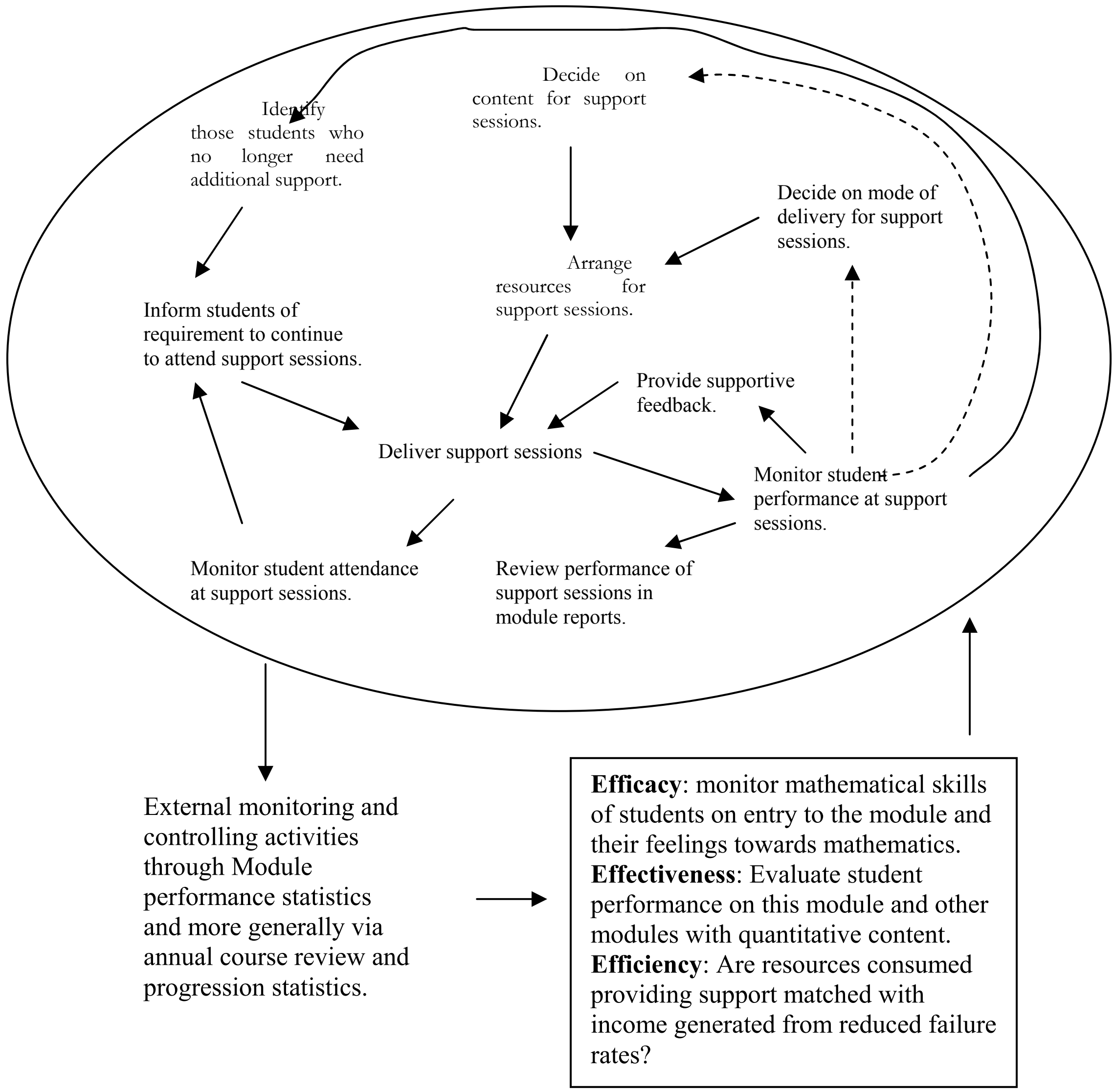

Figure 2. Conceptual Model for System 2

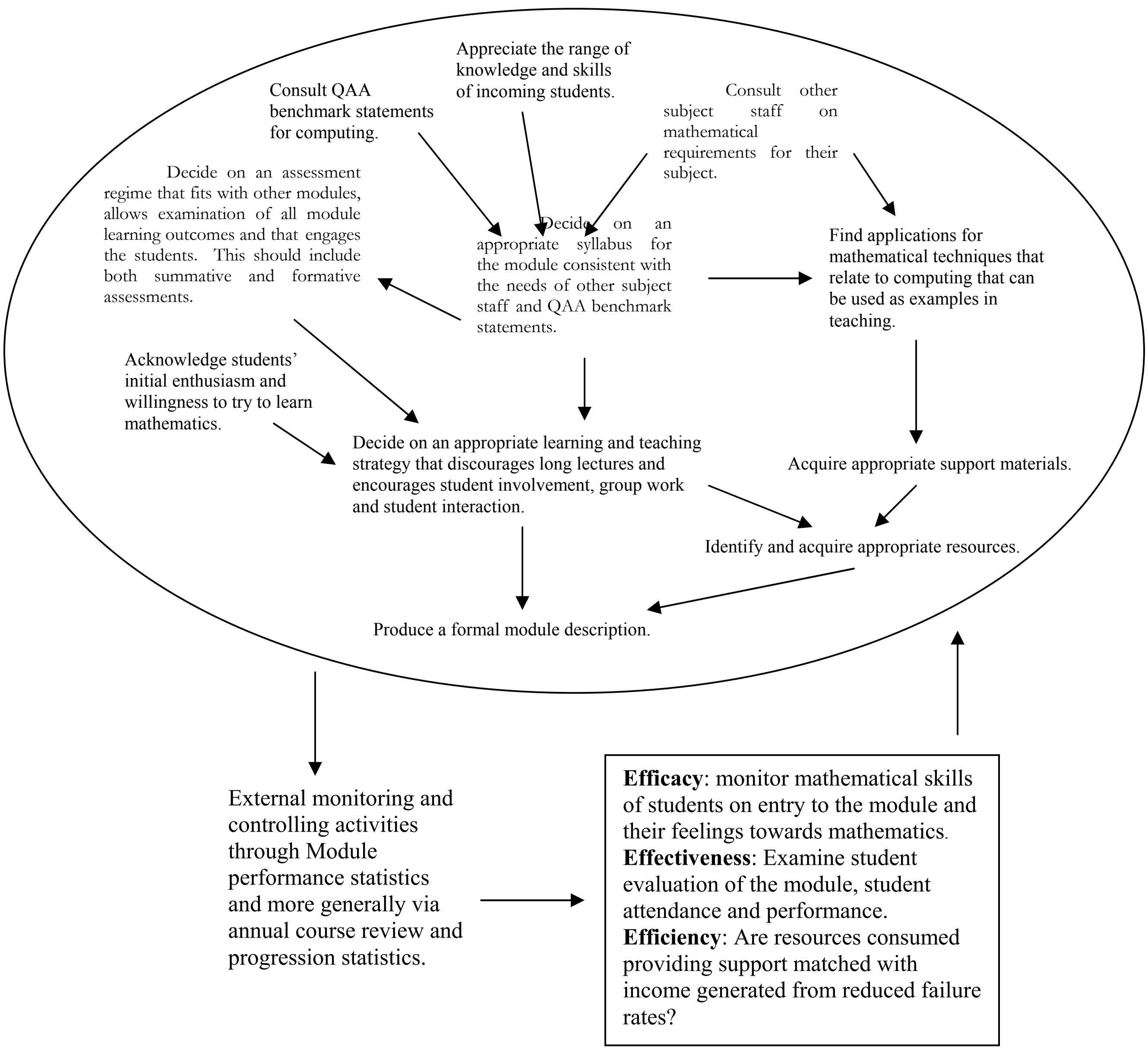

Figure 3. System 3 Conceptual Model

Restricting our discussion to system 2 only, we consider Figure 2. In order to address the issue of attendance at support sessions it was decided that all students should attend support sessions at least initially but that students with the necessary mathematical competencies would be later excused attendance at the sessions. It was also desirable to provide students with regular feedback on their progress and areas of continued weakness and improvement. The dotted lines indicate some feedback links which could be possible during the running of the module but these would be minor alterations only. The activities (or indeed groups of activities) described in these conceptual models were themselves explored more deeply by considering them as sub-systems and developing lower level conceptual models. For example, the attendance and feedback actions were further developed as shown in Figure 4. This now gave a more detailed picture of the operation of these inter-related actions. This conceptual model included the notion of a series of student self-tests which could be used to monitor performance and provide rapid feedback to students.

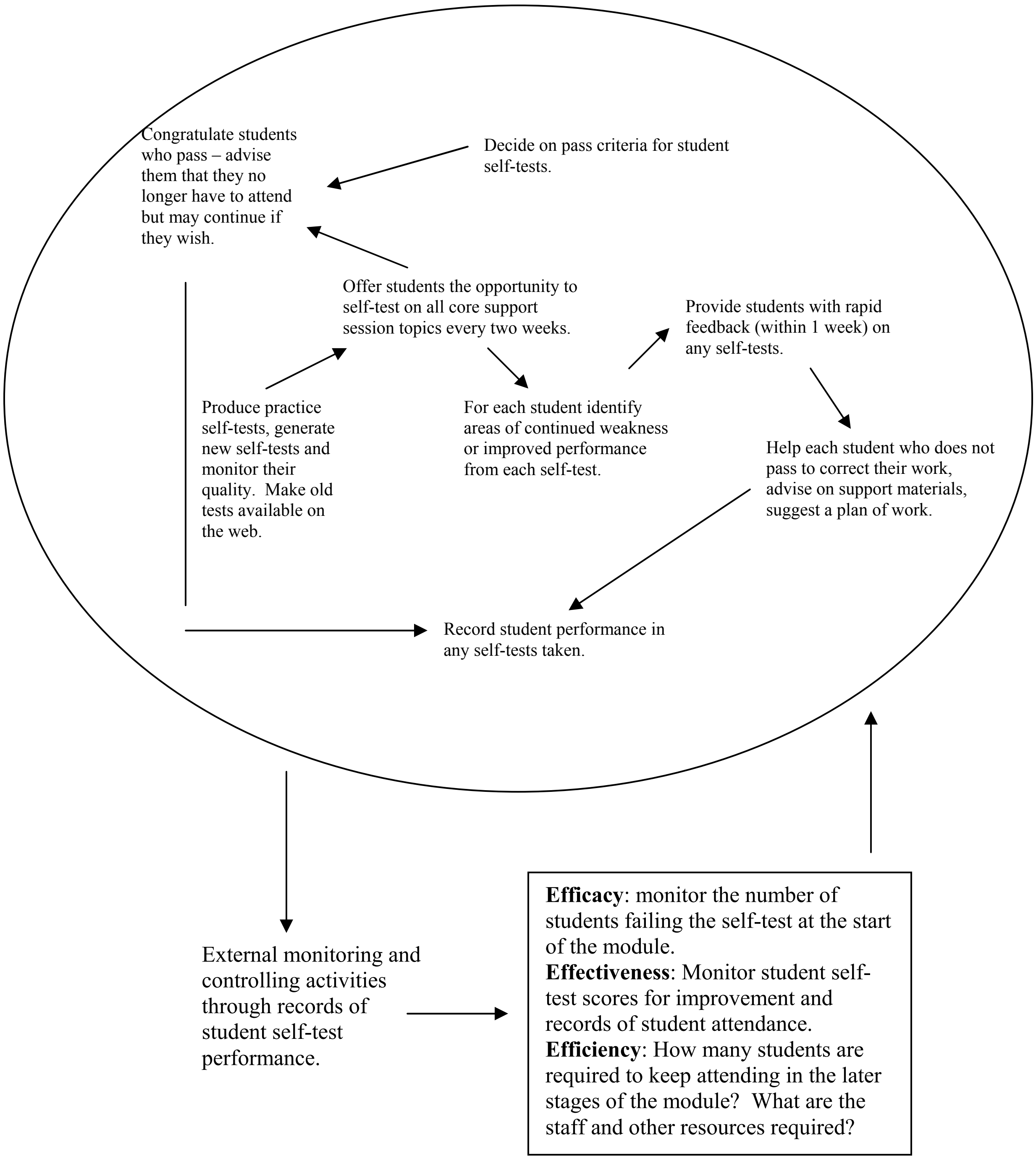

Figure 4. 'Monitoring Student Performance' Conceptual Model

Stages 5 and 6

These stages of the process involved comparing the conceptual models with reality and using any observed differences (or indeed similarities) to generate discussion and debate among the reviewers as to why the differences had occurred. This helped to identify desirable and feasible change. In terms of the evolution of the mathematics module, these stages are illustrated here in terms of the System 2 conceptual models. The module in its original form had a formal set of lectures and tutorials but mathematics support was organised on a voluntary basis via CLSD. The development of conceptual models caused a re-think of the support process and in its new and revised form the module now has a timetabled support session which all students must attend until they can pass a self-test which covers all the support topics and which is offered every two weeks. Students who take a self-test but do not pass have the test returned by the tutor and are given individual feedback on their performance, their strengths and weaknesses. Suggestions for further work and suitable resources are also made by the tutor.

Stage 7

This final stage involves implementation of the changes identified. The redesign of the mathematics module was accomplished over the summer of 2006 and ran for the first time in September 2006 having been formally approved by the university. Changes made to the content and running of support sessions were all adopted within the new version of the module as were a number of other changes not referred to in this paper.

The Validity of Conceptual Models

As we should with any investigation involving modelling, we now turn to the question of validity of the models developed as part of an SSM enquiry. The requirements for establishing the validity of any model depend on the type of model being constructed and the use that is to be made of it. Validity is commonly described as the extent to which the model can be said to be an adequate representation of reality, but in the case of SSM, the conceptual models built may be of systems that are not actually in existence at all. Thus conformance to reality is not an appropriate question to consider. Examining the validity of any models generated as part of a soft systems enquiry is difficult and Checkland (1995) suggests that there are really only two aspects that can help differentiate a good model from a bad one and these relate to whether the models as developed are in any sense relevant and whether the models are competently built. The question of competence relates to ensuring that the root definitions and conceptual models have been derived systematically from the rich picture and the issues identified within it and also that the conceptual models are built only from the root definition. The relevance of the models is a matter for the participants to determine and is related to the extent to which the models generated improve the understanding of issues and the generation of subsequent actions.

This investigation resulted in a number of changes to the module particularly to the way in which support sessions are organised. We feel that we now have a far firmer understanding of the needs and expectations of our students which we feel gives considerable validity to the models that have been developed. Furthermore, the issues described within the rich picture were agreed with a small selection of students from the original sample and the subsequent changes made to the module were formally validated through the university quality assurance process. It is too early to tell whether the overall performance of students has been enhanced by the changes made to the module, but anecdotal evidence from students seems to confirm that the support sessions are appreciated by the students and there is a gradual flow of students who are improving their self-test scores and passing out of the support sessions. Full evaluation will only be possible at the end of the academic year in July 2007 when further module reflection and evolution using another iteration of SSM will be possible.

Conclusion

Most educators would acknowledge the importance of exploring the views and opinions of professional colleagues and students in order to improve the design and delivery of mathematics modules. Unfortunately, the crowded academic calendar can leave little time for reflective thinking on the learning and teaching process and although academic staff do make changes to modules from time to time such changes are generally rather ad hoc, restricted in scope and often reflect only the immediate experiences of the teaching staff.

As we have seen in this paper, the opinions of staff can often be incorrect, particularly when staff make assumptions about the views and expectations of their students. By employing a systems based methodology such as SSM we have been able to see the value of trying to capture the different perceptions of all participants in a module's design and delivery. The particular strengths of the approach that this case study has demonstrated are:

- Academics are often guided by the findings of professional body or governmental reports and pay too little attention to the views of their students. When student views are elicited, it is often at the end of a module for quality monitoring purposes and they do not reflect the views and expectations of students starting a module;
- Comparing the views of all participants reveals inconsistencies between students' expectations of a module and the real experience of a module. In addition, when students fail to engage with parts of the system (such as centralised support services) then it is important to determine why this is happening;
- The root definitions allow a description of the defining features of a system, in particular the transformation which defines the purpose of the system. Building a conceptual model based only on this root definition allows the modeller to view the system from differing viewpoints and to describe system processes that achieve the desired transformation. This gives a clarity of thinking to the modelling process which can be quite revealing when compared to the real systems which have evolved over time. Furthermore, the hierarchical structure of the conceptual models allows the emergent properties of sub-systems to be seen as they contribute to the emergent properties of larger systems (the 'emergence and hierarchy' stream of SSM activity). For example, the system for monitoring student performance (Figure 4) had emergent properties that allowed students to know their self-test scores, get rapid feedback on their performance and a plan of future work. This contributed to the wider system for the provision of a support service (Figure 3);
- SSM is often described as a process of investigation and learning and in reality continually loops around the seven stages. Thus the effect of implementation of system changes will generate new insights and promote further investigation and change. As an example, in the module review described it has been interesting to witness student responses to the support sessions. Some have just wanted to attend without taking the self-tests, others have passed a self-test but still want to continue attending. A further group are gradually improving their scores and will pass a self-test soon and yet another (smaller) group are not making significant improvement. All of these observations will feed into further review so that the support sessions can be modified next time the module is run to give greater support to this last group;

- For each of the systems described by conceptual models, thought had to be given to external monitoring and control from the perspective of the three 'e's of efficacy, effectiveness and efficiency. This resulted in the description of monitoring activities through which student progress and module performance could be monitored rather more closely than just with assessment results. The rapid and continual feedback given to students through the self-tests was felt to be key in helping students to concentrate on their weaknesses and recognise their strengths. This is typical of the 'communication and control' ideas of SSM.

Any change to a system requires that changes be desirable from the systems perspective but also culturally feasible. In this application, academic staff have been required to work closely with students in the support sessions which is quite a different skill to lecturing to larger groups. This will require staff development sessions to be organised through which such skills can be enhanced so that this way of working truly complements the more formal lectures and is of value to the students who have less confidence in the application of mathematics.

It is hoped that this type of review will continue on a yearly basis and that the module will continue to evolve under the influence of all participants – including the students.

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