A case study in using Theory of Change to improve teaching practice in a control department

J.A. Rossiter, L. Gray, G. Diercks-O'Brien

Department of Automatic Control, Mappin Street, University of Sheffield, S. Yorks, S1 3JD. UK

e-mail: j.a.rossiter@shef.ac.uk, l.gray@shef.ac.uk

Abstract **- This paper makes two major contributions. First it describes the introduction of a `Theory of Change' approach for the evaluation of learning and teaching projects which the University of Sheffield has adopted from the social sciences. Secondly it discusses how this has been implemented within a control engineering department to tackle the issues arising from the rapid growth in degree programme options in combination with academic staff who are rewarded primarily for research performance. The paper is completed by some reflections.**

Index Terms – Evaluation, team teaching, culture change.

1. INTRODUCTION

Within the UK and elsewhere [1] there is a recognised tension between research and teaching. Funding mechanisms such as the research assessment exercise (RAE) have provided income incentives to achieve a high research rating, for instance by increased publications, external recognition and research income. Paradoxically, teaching assessment (now stopped) provided no cash incentive and merely gave successful departments good advertising material. Moreover, the teaching assessment was focussed on quality assurance (QA) (e.g. effective paper work) and much less emphasis was placed on quality enhancement (QE). University promotion structures mirrored this funding scenario and as a consequence staff have been highly motivated to develop their research but see little individual benefit, apart from personal satisfaction, in improving teaching quality.

Nevertheless, there is a growing awareness within the community that this pattern is not desirable and initiatives that recognise teaching excellence have developed in the background. More recently these have been consolidated through the higher education academy (HEA) and the associated subject centres. Some research led universities are also re-introducing career paths for academics who focus on teaching and learning as opposed to subject discipline research; until recently, promotion to the senior ranks was based solely on a strong discipline research profile. However, the majority of academics and heads of department still think that only research counts and it may be a while before the culture adapts to the changing environment.

This paper takes its motivation from this research led context and looks at the repercussions on student experience, especially in year 1 where students are most vulnerable [16,22] and need better support [2]. Specifically, a major aim for the authors is to put the needs of undergraduate students at the centre of the university again, while accepting that the majority of staff priorities will differ. In other words [7], how, in the teaching context, do we get the most out of staff who are unashamedly research focussed?

A secondary aim of the paper is to present a pilot of the `Theory of Change' (TOC) approach [3]. TOC is an evaluation approach originating from the social sciences which has been adopted by the Learning Development Unit (LDMU) at the University of Sheffield for the purpose of evaluating curriculum development initiatives and projects [4]. Although the focus is on evaluation, the approach can sharpen the planning and implementation of a project or initiative. The Department of Automatic Control and Systems Engineering (ACSE) has been among the first three departments in the University to pilot the new approach to evaluation. Thus the case study will be of interest to other engineering academics wishing to evaluate teaching developments within their own faculties.

Hence, this paper first describes the scenario that existed within the authors department (ACSE) and the drive for change. Next, section looks at project planning and gives an overview of the TOC approach adopted. Section 4 gives more detail on how the TOC approach was applied and the following section summarises a corresponding interim evaluation. The paper finishes with conclusions.

2. ASSESSMENT OF THE STATUS QUO WITHIN ACSE

ACSE is typical of many University Departments in that market forces have encouraged a rapid move from delivering just a few degree programmes to several alternative programmes. These programmes generally share a common core, but that core is becoming smaller as the number of optional streams increases (recently introducing engineering with Business Skills necessitated a loss of 2 first year core modules to make space for Business modules). Moreover, it is common, due to the relatively small numbers on each stream, to make greater use of service teaching where possible. So, for instance, ACSE students on a mechanical systems degree will take two mechanical modules per year with students from the Mechanical Engineering Department.

Effects of modularisation

This approach is very efficient from the institution's perspective and also should ensure high quality teaching within individual modules, because it keeps a tight rein on the number of modules a department needs to deliver.

However, the flipside is that the year 1 curriculum can become fragmented, especially with the gradual, but independent, evolution of individual modules. Thus departments have the conflicting pressures of trying to ensure a large number of coherent programmes based on a small core and many specialist modules from a variety of sources. This, in combination with changes in the student intake [10,21], can easily cause a situation where a sizable minority of weaker students struggle [11,17] to see their programmes as coherent; some became disenhanted and others simply fail and drop out.

This general pattern was replicated within ACSE [7] and moreover staff had become accustomed to having very little overview of the entire programmes and were generally content to deliver modules in isolation, as this amounted to minimal effort and allowed them to dedicate more time to research. Although staff usually delivered modules very professionally, the modularisation effect was such that students had to create links between modules themselves. Many students were simply unable to do this in their first year and needed more support [19]. ACSE was keen to give students the best possible experience and optimize their learning and thus there was a large immpetus for action.

First year team project

The First Year Staff Team Project was first formulated in early 2004. The first two authors and the then head (Neil Mort) of the Learning and Teaching Committee (LTC) had concerns about the fragmentation of the year 1 curriculum and the knock on effect for students, some of which was being reflected in student feedback [7].

Consequently, their key objectives were to engage staff more in taking ownership of the entire curriculum and not just their own modules. By encouraging such ownership it was hoped that improvements would arise naturally from the lecturers. Such improvements were expected to include: embeding of frequent and explicit linkages between modules, to ensure a proper balance of assignments and skills development, to give better co-ordination of industrial input, to ensure coherence of each degree programme. In fact one might argue that any department should be doing all these things [15,20], however, in practice, the activities happen more sporadically in research led departments and the efficacy seems more dependent on individual champions or external pressures rather than departmental policy.

In summary, the authors felt that by creating a team approach to teaching, staff would become more aware of their responsibilities beyond delivery of an individual module and more proactive in bringing about positive change. Thus, they sought to obtain funding for a project whose main aim was to create a team where staffs' contributions to year 1 teaching were through the team. As the reader may guess, this is a substantial culture shift from the typical academic who wants independence and to be left to `get on with it'; a shift many staff could resist very strongly. Hence, the next section gives insight into a strategy for planning the project in such a way that one has a good chance of success.

3. PROJECT PLANNING

Within the University of Sheffield, there is an established fund for supporting projects within learning and teaching. The monies available are relatively small, but nevertheless to ensure efficacy there is assistance from educational advisors available to help academics write their applications. The process is such that guidance is given simultaneously in what might be achievable and make good pedagogical sense.

For the project discussed here, the educational specification (or bid) [8] was written over a course of a year and without awareness of the TOC approach. However, the TOC approach [4] was being developed simultaneously and hence was ready shortly after the project commenced. Hence, it was logical to incorporate the TOC approach into detailed planning and evaluation of the project thereafter; this also gave a good test bed to pilot evaluation and project management using TOC. Hence, this section gives an outline of a typical timeline and outcomes that were considered in applying the TOC approach to the ACSE project.

Overview

The key to the TOC approach is to look at a project over the entire lifespan and be clear at the outset about the desired long term impact. The desired impact gives a benchmark for evaluation and thus for planning and monitoring. This impact may of course vary both in time and for the different stakeholders within any project, which for this paper are most logically students and staff. The desired impact is mapped backwards (table I) in time onto more detailed aims and objectives (short-, mid- and long-term outcomes). Other essential aspects to support the desired outcomes may be ongoing throughout the project. The intent is to manage the project using the key elements in table I as a convenient way of identifying and grouping what needs to be done.

TABLE I
TYPICAL THEORY OF CHANGE TIMELINE FOR ACSE PROJECT

Months	Phases	Ongoing aspects
0	Analysis of current situation/ problem	Enabling factors and resources, processes and activities.
12-24	Short term outcomes	
24-36	Intermediate outcomes	
36-60	Long term impact	

Unpacking the detail

Each project would elaborate on the outline in different ways. The list of Table II illustrates how the different phases/aspects might be expanded. The focus is on looking for effective tools to assess the impact of a project across the whole institution, thus to enable planning to direct funds in order to maximise benefit. The following section will demonstrate how this approach was mapped to the learning and teaching (L&T) project within ACSE.

TABLE II
TYPICAL ISSUES TO CONSIDER

Current situation	Awareness of existing excellence, L&T valued less than research, always the same people doing the work, funding for innovation small/hard to get,

	sharing good practice poor, most staff don't know how to get things done.
Enabling factors/ resources	Is project strategic, innovation or development? Is there effective project management? Does project meet student/staff needs? Are leaders aware of support available? Is there formal recognition for teaching developments? Are there funds available? Is there good guidance available?
Processes/ activities	Are there strategic processes already in place? What can central support services offer? Can other departments help? Students participate in new activities. Dissemination of good practice. University supports wider strategic view.
Short and intermediate outcomes	Improved L&T, staff gain experience, University meets external needs, staff make use of central expertise, good practice shared, depts. become more strategic, staff adopt innovative practice, staff become familiar with pedagogical theory, students have better experience, dissemination.
Long term impact	Raised profile of L&T, holistic view of research and teaching roles, high quality graduates imply university has enhanced external profile.

4. APPLYING THEORY OF CHANGE APPROACH TO ACSE

The reader will have noted that the TOC approach steers one away from a quick fix. Awareness of a problem must be translated into a long term solution. This section shows how the desired long term impact for ACSE is mapped backwards to generate the necessary actions (e.g. tables I, II). The phases are given in reverse chronological order.

The current situation in ACSE

Although this paper focuses on areas needing improvement, it should be emphasised that most of the curriculum is very well received. Based on student feedback and staff observations, more students than desirable were performing poorly in year 1 and there was evidence that for several this was due to a lack of engagement. Of more concern, many students did not see the interdependence of the topics within the year 1 curriculum and this was contributing to poor satisfaction and/or disengagement. There were also ongoing problems with performance in mathematics. The department was motivated to change these perceptions and improve student performance on a long-term.

Desired impact in 3-5 years

For ACSE, the intended impact was better student retention, achieved through improved student satisfaction leading to improved performance. Although not a part of the project, another knock-on effect of improved student satisfaction and progression would be good publicity. This impact could be broken down to smaller items, but for convenience of presentation the facilitating factors, which are also ongoing impact in some sense, are described as outcomes and activities; this includes changes in staff behaviour.

Intermediate outcomes

In order to achieve the desired impact, it was necessary to ask what the year 1 curriculum and delivery should look like. Typical outcomes were for students to: have positive perceptions of the year 1 programme, greater engagement in

the material, greater achievements, improved skills, teamwork ethos and, an increased sense of belonging and being supported. This still sounds a big vague, so the TOC approach goes back a little further to ask: how might these intermediate outcomes might be achieved?

Short term outcomes

A number of rather obvious statements could be made as to what is required to meet the intermediate outcomes, however the TOC approach encourages project leaders to write these down clearly and thus, more importantly, provide a framework to ensure action follows.

Outcomes for students

The list of desirable outcomes for ACSE included items such as students: (i) being aware of the curriculum as a coherent whole and linkages/interdependencies between modules; (ii) feeling assessment is balanced in time and style and appropriate; (iii) feeling supported, for instance through timely quality feedback and pastoral tutoring; (iv) feeling staff communicate effectively; (v) perceiving the curriculum to be both interesting and relevant to the real world context.

Outcomes for staff

In order to meet the outcomes for the students, there are parallel outcomes for the academic staff, for instance the creation of a team of teachers committed to effective communication, flexibility in their individual practice and a common goal. Evidence of the effectiveness of the team could be actions supporting the desired student outcomes such as: (i) engagement with students; (ii) changes to curriculum proposed and implemented; (iii) effective liaison with and influence upon departmental committees.

Processes and activities

Next, one might now ask what processes or activities would enable the outcomes to be met, at all stages of the project. In fact, these are rather obvious, but the TOC framework helps ensure the right questions are asked. From the students perspective some simple activities were needed such as: (i) more group work to encourage peer learning and community; (ii) spreading of assignment deadlines to avoid overload; (iii) links between modules; etc. However, the bigger action lay on the academic staff to ensure these things happened as well as all the other desired outcomes.

1. Staff expected to link their teaching with other modules; this required a good awareness of the content and timing of what was being taught in other modules.
2. Where beneficial, staff were requested to modify their delivery to give better synergy with other modules.
3. Staff should negotiate all deadlines and consider the balance in style (to ensure uniform development of key skills) and magnitude of the entire coursework load.
4. Staff were encouraged to include more real world examples, especially in topics such as mathematics.
5. Staff should provide the year tutor (personal tutors) information to help with pastoring and monitoring.
6. Staff should take joint responsibility for the overall curriculum design. This includes being proactive in proposing changes.

Enabling factors and resources

The next step is to ask what resources and support already exist or are needed to help with the above activities and thus how can we ensure they happen? In ACSE the key enabling factor for effective progress was the establishment of a team approach to teaching where ownership of a module was by the team, not the module leader. Although this is technically already the case, in practice a module leader has a lot of autonomy to modify a module. The net effect of small year on year changes can soon become substantial. By having a team to look after all the modules, module creep would be monitored and directed far more actively and staff would gain a good awareness of the entire curriculum. Thus a team enables or facilitates the effective communication and negotiation which is an essential factor in this project.

The more challenging issue was to convince research active staff to give up valuable research time to attend monthly team meetings and also to take on tasks agreed important by the team. It was decided that an incentive scheme could enable this culture shift; once the benefit was demonstrated, staff should be more willing in the longer term. Therefore, three members of staff put together a bid for internal funds to pay staff an honorarium[1] for contributions to the first year of team activities. This incentive was quite effective in persuading otherwise reluctant staff to contribute and thus was key to the early success. In the longer term, a major enabling factor will be voluntary commitment by staff to the team ethos and thus giving their additional time for free. This will require them to be convinced of the value.

The team leaders also perceived a benefit in giving team members training, for instance in team building and teaching specific skills. However, most members do not see this as central to the project and so take up was not uniform.

5. INTERMEDIATE EVALUATION OF PROJECT

The University carries out formal evaluations of all projects, using the feedback of students and staff involved. For ACSE, the first formative evaluation has been produced [5]. The project will be revisited in 2 years' time to assess the long-term impact of the project. In the interim, the project leaders will be involved in a reflective cycle reviewing the original TOC and progress made with the project. These reflective interviews will assist the project team to make adjustments to the project if required. These interviews will be carried out in 6 to 12-monthly intervals. This section gives an overview of the first evaluation process and results.

Designing the evaluation

The two major stackholders in this project are the staff and students, thus an evaluation is made from each of these perspectives. Qualitative evaluation is more appropriate than quantitative, so most of the evaluation was conducted via interviews based around a well designed questionnaire (Table III). Some of the required activities are simply procedural (e.g. managing coursework deadlines) so the

focus here is on the more fundamental issues which reflect the desired activities, processes and outcomes, for instance:

1. How the First-Year Team approach is perceived by colleagues; is the approach seen as valuable?
2. How effectively the First-Year Team is integrated within the departmental structures for learning and teaching (e.g. integration with the LTC)?
3. What progress the Team has made in addressing student satisfaction, performance and retention?
4. What impact any changes implemented so far have had on student learning and whether the strategies employed by the First-Year Team have been effective?
5. Should the department continue with or extend the Team approach?
6. What the future direction and activities of the First-Year Team should be?

The above questions have been derived from the TOC. The purpose of the formative evaluation was to assess to what extent staff and students felt the objectives have been satisfied and provide the project team with steer towards the future direction of the project.

TABLE III
SAMPLES FROM EVALUATION QUESTIONNAIRE

TOC parameters and issues	Evaluation questions
Resources/enabling factors	
Buy-in from staff on teaching team needed, assumption that staff will make something a priority if they see it as relevant/important to them; Process used: kept meetings as brief and focussed as possible, only engaged them where the issues were directly relevant to them.	Ask staff individually about their commitment, To what level are staff prepared to engage? If they don't engage, why is this?
Buy-in at department & faculty level needed.	Speak to Head of LTC about his perception How do colleagues feel about changing their modules?
Staff time needed. Issue of research commitment over L&T	What has been given? Was it enough? More needed? Hard to do; time constraints?
Desired end-of-project outcomes	
Students perceive the year 1 curriculum as coherent. Is the curriculum taught in a coherent fashion?	Do students know that there is a first-year staff team? Do they perceive it as a coherent group? Are students aware of the assignments working as links between modules?
Students perceive the year 1 curriculum as interesting and relevant.	Feedback on real-world examples, e.g. poster project, BIC and talks from industry.
Having a year 1 staff team that is embedded and exists beyond the funded period	Will the staff team continue having regular meetings once the funding runs out

Summary of evaluation results [4]

This evaluation summarises the achievements to date, provides formative feedback and aims to ascertain whether there is merit in continuing. It is based on ten staff interviews, 22 student questionnaires, eight 3-5 minute student interviews and documentary evidence. An indicative view of the evaluation can be obtained from the selected staff

---

[1] Notionally about 20 pounds per hour to research budgets.

comments in appendix 1. This section gives a summary; some of the more detailed data is given in Appendix 2.

1. The main project objective has been met. The First-Year Team met six times during 2005/6 and has implemented changes, some well beyond original remit.

2. It is too early to judge the impact. Moreover some of the major changes are yet to be implemented. Student feedback is generally positive, with the exception of one new component which subsequently the team have decided to discontinue. There is still some, possibly unavoidable, clustering of assignment deadlines.

3. The team has acted as a catalyst, introducing many positive changes which the department had discussed previously but not progressed. However, some criticism stems from an uncertainty of the role of the Team in relation to other committees and needs clarification.

4. The evidence points towards continuation of the First-Year Team, at least for another year. Indeed, this could be a useful approach for other academic departments.

Quantitative evaluation against specific outcomes

For completeness, this section gives details of outcomes which can be evaluated as yes/no or with numerical data. The summary is very clearly that the project is having a positive impact. However, there remain aspects that could be improved more and some things that are difficult to resolve.

In terms of procedural issues the project has been successful on a number of counts: (i) the programme architecture has been changed substantially. This includes new assignments, substantial modifications to some existing modules and movement of modules to different semesters; (ii) the team argued successfully for replacing the mathematics service modules by in house mathematics modules; (iii) there are now formal mechanisms for ensuring the balancing of workload, the balancing of skills development (including group work), inclusion of sufficient and varied real-world examples, as well as enhancements to personal tutor support and effective communication between module leaders.

In terms of data collected from student interviews and questionnaires: (i) 86% of students recognised the effort put into curriculum design; (ii) 81% felt the links between modules were effective; (iii) the majority were very satisfied with aspects drawing in real world examples; (iv) 82% were happy with the amount of group work; (v) all were very positive about the input of the industrial speakers and (vi) there seemed to be recognition of the wide range of skills developed. However, a minority were still unhappy with the workload distribution, communication with the service departments and, a number of minor individual gripes. In several cases the criticisms relate to the lack of integration of the service module; as there are six very different options each semester, integration of these is infeasible.

Future plans

Although staff found the team based approach beneficial and many support a continuance of this project, a sizable minority wish to return to a traditional model of working. This reflects the ongoing issue of how do we encourage staff

to devote more time to developing their teaching and including more formative assessment [14,16,17] when their main drive is research. Hence, the immediate plans are to seek stronger support from senior management for embedding the project, but in a format that encourages and rewards participation as much as the extra time on research. We hope that once the team has been running for 2-3 years, staff will consider it as normal, get used to and rely on the benefits and no longer consider it an extra burden.

6. CONCLUSIONS

Overall the evaluation is very positive and suggests that the team based approach has facilitated change where previously there was a lot of inertia. It has also encouraged staff to take a broader view of their teaching responsibilities and generally this was appreciated. Nevertheless, there are major concerns over recognition, for instance in terms of workload or how to prioritise teaching and research. These issues reinforce the commonly accepted dichotomy in research led universities and are part of current discussions with the head of department (who is very supportive) about the best way for embedding the key aspects of this project.

APPENDIX 1: QUOTES FROM VARIOUS STAFF

Supportive: Very important to continue in order to talk about problems in an open way, make solid plans and implement them. Good idea. Important to look at coherence due to disjointedness of department. Brings people together. Better than a one person responsibility. Vital but will depend on HoD. Essential - how would you otherwise look after the curriculum and support students? Confident that it will continue after funding has run out. Has made important contributions since it has existed, should continue but not monthly, at strategic times of the year. Will keep it, serves a useful purpose, more issues in first year, small Maths team needed, team looked hard at the curriculum.

Unsupportive: Retention is a serious issue in the department and is taken seriously by staff. Coffee time discussions, informal arrangements have worked successfully before. Up to HoD whether the team will continue to exist, cannot see reason to continue, had arm twisted to go to 1st year team meetings. No, this should be the work of the LTC. Good concept for this type of interaction but is it needed in a formalised way? Is this the right vehicle?

APPENDIX 2: DETAILED FINDINGS

This appendix lists some of the fine detail/comments from the evaluation which were used to build the summary.

- Are student satisfaction, performance and retention at Level 1 a priority for the department? If so, how does this priority related to other priorities, e.g. research? Departmental priorities and formal recognition are important in legitimising investment of substantial amounts of time and effort in curriculum development.
- Structure and role of first year team evolved and seem well understood, even if not formally recognised.

- The team-based approach was viewed as positive and valuable. It is inclusive, bringing together all staff independent of their level of seniority. Enabled focused, in-depth discussion from a cross-section of staff and all contributions were valued by the other team members. The majority enjoyed working in the team and gained a valuable insight into their colleagues' modules.
- There was a view among the interviewees that typically: little or no effort had been made by teaching staff, from within and outside the Department, to make explicit connections between the module(s) they teach and the Level 1 curriculum; it is important for the Department to address these issues; the Team had acted as a catalyst for many issues that had previously been discussed, but had not been acted upon.
- Observations used by the interviewees included 'joined-up', 'coherent', 'integrated', 'co-ordinated', 'strategic' and 'making sense from a student point of view'. Various members indicated that it helped them to know what their colleagues were doing in their modules, at what point which materials were taught or assessed and when and how what they were teaching was built upon by their colleagues on other modules, or vice versa.
- Strategically, the main achievements seem to be that Level 1 is now considered from a holistic perspective. The project has established the First-Year Team, which now has a good profile in the department.
- Several interviewees stated that the project has introduced an effective new approach among colleagues – one which encourages collaboration and strategic curriculum development, rather than individual curriculum development. One interviewee mentioned a stronger drive to QE enhancement rather than QA.
- Overall, despite negative comments from a couple of interviewees, the consensus was that the First-Year Team had met the expectations of those interviewed. There are some issues that have not yet been addressed fully, either by the First-Year Team or the Department and one member of staff queried whether sufficient effort had been made to understand the student needs and the origins of the retention problem. Nevertheless, the First-Year Team has made an impressive start.
- Time constraints have been a significant factor for all members of the First-Year Team, especially as the team's effort was not being formally recognised and could be seen as duplicating work done by the LTC.
- Student feedback indicated that overall, students are fairly satisfied, but there is still work to do to provide students with a greater sense of coherence and satisfaction and to convince them that staff take an interest in them. The timing of some assignments is still problematic. Projects, the 'real-world' examples and group work are appreciated and well received.
- Two-thirds of the interviewees thought that the Team should continue whereas the others felt there are already adequate formal structures and informal opportunities. Significantly, senior staff had positive perceptions of the role and contribution of the Team.
- Some colleagues commented 'a parallel structure to the LTC', 'duplicating efforts' and 'wasting time', 'parallel structures could lead to a lack of accountability' and therefore could not see the point of a First-Year Team. Ironically, the same individuals were quite complimentary about the project, the quality of discussions and the actions and with only one exception, found the team-based approach valuable and even enjoyable.

REFERENCES

[1] Reinventing undergraduate education: Blueprint for America's Research Universities. The Boyer Commission on Educating Undergraduates in the Research University, Available: http://naples.cc.sunysb.edu/Pres/boyer.nsf

[2] Brown, S., Using formative assessment to promote student learning, presented at University of Leeds Learning and Teaching conference, 2006

[3] Connell, J. and A. Kubisch, Applying a theory of change approach to the evaluation of comprehensive community initiatives, In Fulbright Anderson, Kubisch and Connell (Eds.), new approaches to evaluating community initiatives, Vol. 2, Aspen Institute, 1998, pp15-44

[4] Diercks-O'Brien, G. and Powell, A., An Impact evaluation Framework for Learning and Teaching Activity, Sheffield: Learning Development and Media Unit, University of Sheffield, 2006.

[5] Diercks-O'Brien, G. P185 Formative evaluation report, University of Sheffield, 2006.

[6] Engineering Council, Digest of Engineering Statistics 2002, Available: www.engc.org.uk/publications/statsdigest

[7] Gray, L. and J.A. Rossiter, Creating a rich learning environment in a research led university, International Conference on Innovation, Good Practice and Research in Engineering Education, 2006, 6 pages.

[8] Gray, L., Mort, N., Rossiter, J.A. and D. Staniforth, Integrating the student learning experience, Educational Specification for P185, University of Sheffield, 2005.

[9] Higher education academy, www.heacademy.ac.uk

[10] Kent, P. and R. Noss, Mathematics in the University Education of Engineers, Available: http://www.engc.org.uk/publications

[11] Laurillard, D., Rethinking University teaching, Routledge, 2002

[12] Mathcentre (Loughborough, UK), www.mathcentre.ac.uk,

[13] HELM: Available: www.lboro.ac.uk/research/helm/index.html

[14] McDowell, L., K. Sambell, R. Penlington, J. Smailes, M. Gibson, J. Robinson, Putting assessment for learning into practice, presented at Higher Education Academy annual conference, 2006

[15] Oliver, R. and J. Herrington, Exploring technology mediated learning from a pedagogical perspective, Journal of interactive learning environments, 2003, 11,111-126.

[16] Pickford, R. and H. Clothier, The art of teaching, presented at Higher Education Academy annual conference, 2006

[17] Race, P., Scholarship of Learning and Teaching, presented at Leeds Learning and Teaching Conference, 2006.

[18] Race, P, Making Learning Happen: A Guide for Post-Compulsory Education', publisher: Sage (Paul Chapman Publications), 2005.

[19] Ramsden, P, Learning to teach in higher education, 1992, London, Routledge

[20] Roblyer, M.D. and J. Edwards, Integrating educational technology into teaching, Saddlebrook, Prentice Hall, 2000.

[21] UCAS web site, Available: http://secure.ucas.com/figures/index.html

[22] Yorke, M. and B. Longden, The First Year Experience Survey, Available: http://www.heacademy.ac.uk/FYEsurvey.htm