A Blended Learning Approach to Teaching First Year Engineering Degree Students

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***Abstract* – Students at many UK universities tend to under-perform in core engineering analysis subjects. This has been the experience of the teaching team at the University of Hertfordshire in a first year Fluid Mechanics and Thermodynamics module. The introduction of StudyNet, the University's managed learning environment, in 2001 provided an opportunity to rethink our approach to teaching this module. The approach was one of continuous improvement coupled with reflection and evaluation. It involved a gradual introduction of the use of new technologies, managed or "delivered" through StudyNet. The use of technology includes improvements to teaching materials, use of discussion groups, computer aided assessment, worked examples using multi media and podcasting and extension to include the use of virtual classroom technology. The effectiveness of some of the technologies employed are evaluated. Evaluation has included student questionnaires and structured interviews coupled with overall student performance analysis. The evaluation provides an insight into student behaviours and expectations as well as a commentary on the teaching, learning and assessment methods employed. The benefits of the use of these technologies are presented together with recommendations for their deployment and support in the overall context of designing and implementing a Blended Learning Curriculum.**

Index Terms – Blended learning, e-learning, Fluid Mechanics, Thermodynamics.

INTRODUCTION

Fluid Mechanics and Thermodynamics is a core module on the first year of the Mechanical, Automotive, Aerospace and Aerospace Systems BEng and MEng degree programmes at the University of Hertfordshire. The number of students taking this module over the last 5 years has varied between 127 and 190 students. The module attracts 15 credit points 1/8 of the total first year credits and is designed for 150 hours of study for a typical student. Students enter these programmes with above average UK GCE Advanced level qualifications, or equivalents, which include Mathematics and Physics.

Prior to 2001 the students engaged with this module through large group lectures (150 students), small group tutorials (30 students) and smaller group (15 students) laboratory sessions. Tutorial sheets were provided to the students to enable students to practice problem solving within tutorials and in independent study time. Students attended 2 laboratory sessions which were designed to provide fundamental understanding of core Thermodynamics and Fluid Mechanics topics, the steady flow energy equation and fluid flow measurement, respectively. Assessment was based on a final examination plus laboratory reports and a test in the latter part of the module. The overall aim of the module was to introduce fundamental concepts and to apply these to a limited range of engineering processes.

The overall performance of the students was poor with around 50% of the students passing the module at the first attempt, with many borderline passes.

The University introduced a new Managed Learning Environment (MLE) in 2001 providing an ideal opportunity to review and rethink the teaching of this module coupled with a process of continuous improvement that has led to a gradual improvement in the performance of the students over a period from 2001 to 2005. The key features of these improvements are presented with an emphasis on student engagement.

DESIGNING THE CURRICULUM FOR STUDENT ENGAGEMENT

Gamson and Chickering [1] provide seven principles of good practice in undergraduate education. They suggest that good practice:

- Emphasises time-on-task
- Gives prompt feedback
- Encourages active learning
- Communicates high expectations
- Respects diverse talents and ways of learning
- Develops reciprocity and co-operation amongst students
- Encourages contact between students and staff

These principles provide a suitable framework for analysis of the problems experienced with the module as well as a

framework for continuous improvement. Considering these principles the module team (comprising 4 lecturing staff) determined that the reasons for, and issues contributing to, poor performance of the students could be summarised as:

- Increasing student numbers
- Increasing range of abilities of the students (although qualified to a similar level)
- Increasing range of motivation of the students
- A lack of learner focus
- The assessment of the module did not support learning

The key problem revolved around decreasing student engagement as student/staff ratios increased. The challenge was therefore to reverse this trend making use of the opportunities provided by the new MLE, StudyNet and utilising other opportunities to increase cooperation and contact between students and students and students and staff, recognising that:

- Learning is a conversation, [2]
- Learning is not a spectator sport
- The learners have much to offer as well as to gain.

The module team felt that the face-to-face teaching and learning methods of lecture, tutorial, laboratory, used to support the module should be maintained but be supplemented by strategic use of the MLE and by the use of other technologies as appropriate. This was the starting premise but also included recognition that the nature of the face-to-face activities could change as the use of the MLE and other technologies matured. The chronology of developments from 2001 to the present is summarised in Table 1, below:

TABLE 1
CHRONOLOGY OF DEVELOPMENTS

2001, StudyNet – opportunities to provide:
- Improved teaching materials – on-line access
- Additional support material
- Encourage student participation via discussion forums

2002, Weekly Assessed Tutorial Sheets (WATS)
- To encourage student engagement

2004, Peer assessment of laboratory reports
- Learning through assessing
- Sharing good and bad practice

2005, Just-in-time teaching
- Intelligence led teaching

Use of interactive white boards to encourage collaborative learning

2006, Exploration of Virtual Classroom technology.

THE MANAGED LEARNING ENVIRONMENT

The University of Hertfordshire has a locally developed MLE (StudyNet) integrated with a student intranet which was implemented across the whole institution in September 2001. StudyNet provides a suite of tools to enhance teaching and learning by delivering course materials and facilitating on-line communication, group work and assessment through a web browser. StudyNet is integrated with all the major IT systems at the University and existing data from those systems is used to link each student through individual profiles to all appropriate university information and to provide integrated access to information resources, course materials and student services.

StudyNet has module websites for all modules. The front page of the Fluid Mechanics and Thermodynamics web site is illustrated in Figure 1

It was decided that the discussion area could be utilised to improve on the limited contact time and to support the large student group as well as encouraging student to student teaching/learning. It was also decided that additional teaching materials could be provided in the form of 'tutorial sheet tips' and 'how to statements' to support the range of student abilities. In addition lecture notes were improved and preloaded onto StudyNet and additional material was made accessible through appropriate web links within StudyNet. Finally the module front page was made 'topical' and stimulating by regularly loading and changing an image relevant to the subjects under discussion and motivating for the students or including a question in order to stimulate on-line activity. Fig 1 includes an image of streamlines around a racing car predicted from a computational fluid dynamics model.

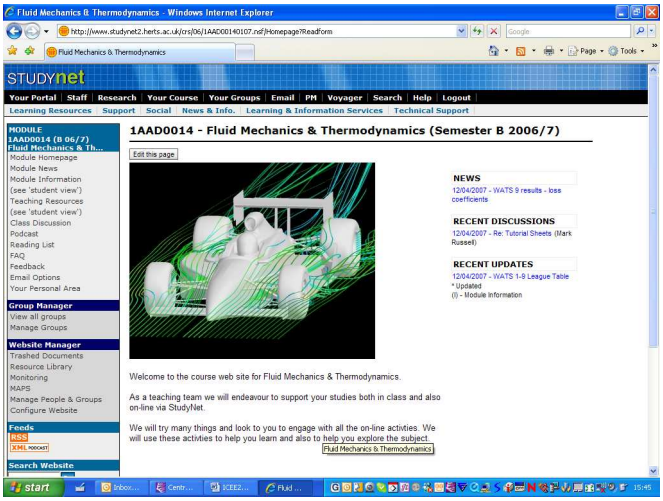

FIGURE 1
STUDYNET FLUID MECHANICS AND THERMODYNAMICS MODULE FRONT PAGE.

Further potential benefits from the use of StudyNet were the 24/7 access, supporting flexibility for students and the efficiency gains for staff, particularly from the communication tools. There was also an impact on the face to face teaching, where lectures included more application examples and referenced supporting materials available within StudyNet. Similarly during the smaller group tutorials individual students could be advised to access the support material as appropriate. The use of 'discussions' within StudyNet is discussed in greater detail in the next section.

THE USE OF DISCUSSIONS WITHIN STUDYNET

In terms of the principles of good practice the aims were to:

- Develop reciprocity and co-operation amongst students
- Encourage contact between students and staff
- Give prompt feedback
- Respect diverse talents and ways of learning

This was achieved by:

- providing additional information promoting specific activities – special lectures, websites
- encouraging interest in and reinforcing the subject though tutor prompts
- supporting tutorial questions through a maximum 48 hour response time, by seeding the discussion and offering timetabled on-line asynchronous 'contact'
- encouraging student feedback to tutor prompts
- supporting assessments, including laboratory work.

Evaluation over 2 years, showed that in 2001/2002, 75 items were posted in the discussion forum, with 23 from students (approximately 10% of students actively participating) and in 2002/2003, 81 items were posted, with 30 from students (approximately 10% of students actively participating).

This appears on first site to be a disappointing result, but further evaluation, through a questionnaire sent to the 2002/2003 cohort revealed that between 50 and 60% of the students responding (about 2/3 of the student group) found the discussion forum useful. Figures 2 and 3 illustrate the responses to two of the questions on the use of discussions within StudyNet. It is estimated that the staff time involved in supporting the discussion area amounted to 1 to 2 hours a week but this was set against the reduction in time spent answering individual student questions outside normal timetabled hours, representing an overall benefit to the students and an improvement in efficiency. In subsequent years the proportion of students actively participating in discussions increased significantly; 20.3% in 2003, 49.1% in 2004 and 37.4% in 2005. This increase is largely related to the introduction of a Weekly Assessed Tutorial Scheme.

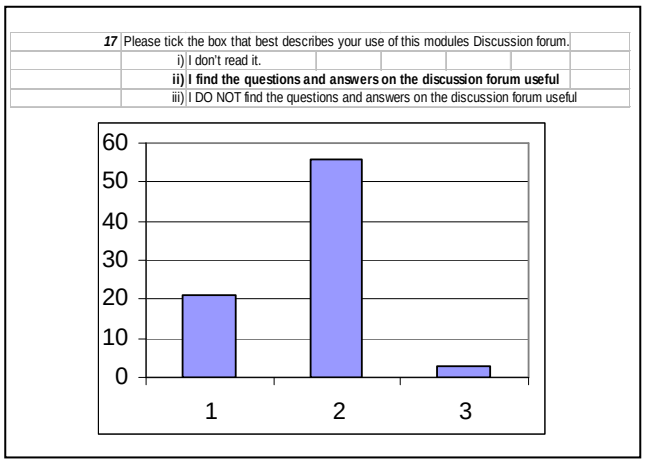

FIGURE 2
USEFULNESS OF THE DISCUSSIONS AREA.

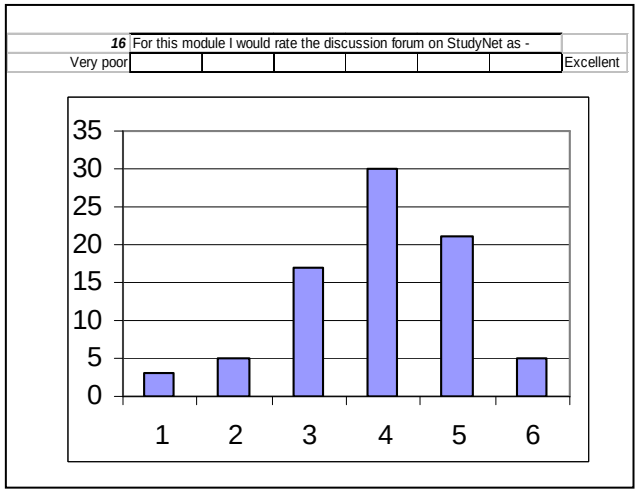

FIGURE 3
DISCUSSIONS AREA RATING.

ASSESSMENT

In terms of the principles of good practice the aims were to:

- Emphasise time-on-task
- Give prompt feedback
- Encourage active learning
- Respect diverse talents and ways of learning
- Communicate high expectations

Prior to 2002 the students obtained quantitative feedback on their progress in the module from the one assessment test and from laboratory reports in the latter part of the module. This proved problematic because both students and staff needed more time to take corrective action if the test results showed a poor understanding of the subject. The assessments were also limited in scope only covering a small fraction of the course content. It was felt that students were not fully engaging in the module. It was decided that there was a need to promote and significantly increase active learning and provide rapid feedback to the students on their progress.. This could not be achieved with the increasing student numbers using traditional methods and therefore an automated, personalised assessment scheme was developed and introduced, known as WATS (Weekly Assessed Tutorial Sheet). The WATS provided the students with weekly tutorial questions, delivered through StudyNet, containing personalised, unique data. The students entered the answers to the tutorial questions into an individual on-line data collection facility, by a prescribed deadline (midnight a week after the issue of the question). The following day each student then received a personal email providing an overall mark and the answers to the questions compared with their answers. In addition a model answer was posted on StudyNet together with other data showing the relative positions of the students (anonymised) within their student group. Further details can be found in [3]. The WATS contributed 5% to the total module assessment mark providing an incentive to students to participate, although the major incentive that was promoted to the students was the need for "active learning" and the positive correlation between active learning and final grades, in this module. From a staff point of view, once the

WATS system had been developed, the resources required to implement the WATS required selection of questions, selection of ranges of data for each question (to achieve personalisation) and production of a model answer. The WATS system utilised spreadsheet and wordprocessor with mail merge technology to completely automate the rest of the process. This is, therefore, a highly efficient and effective way to implement an assessment programme which achieves the aims.

The WATS also illustrates the benefits of a Blended learning approach where opportunities offered by technology are used to enhance learning and allow additional benefit to be gained from the face-to-face tuition. WATS not only provided rapid feedback to students but it also provides rapid feedback to staff on the students understanding of the subject. Teaching staff can then use this knowledge of the student's understanding to adapt their face-to-face teaching to reinforce topics or to correct misunderstandings and thereby further enhance student learning. The opportunity was also taken to add some additional questions to the WATS to attract responses from the students which would provide additional information to the teaching staff on the student's understanding of the module topics. A free text box was added to the WATS data collection facility to capture these responses. Figure 4 illustrates the type of questions asked of students, overlaid on a view of the WATS data collection facility. The concepts of this approach, known as 'Just-in-Time Teaching' are described in detail in [4].

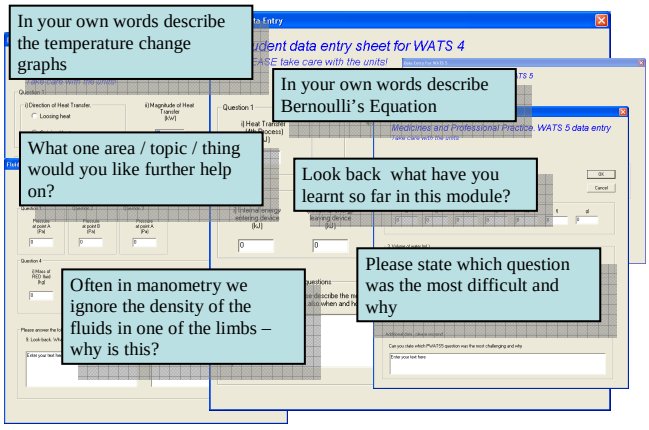

FIGURE 4
GENERATING FEEDBACK FOR STAFF THROUGH THE WATS DATA COLLECTION FACILITY

Whilst the module team took every opportunity to implicitly 'communicate high expectations' to the students the module team became aware that the students did not understand what these expectations involved. This was redressed by the introduction of a peer review activity involving one of the laboratory exercises. Student were asked to produce laboratory reports as part of the laboratory work and on a particular day were then asked to mark each others reports (suitably anonymised) against a marking scheme developed by one of the course team. The students therefore became engaged in the marking progress and had the opportunity to better appreciate the standard expected from them. Interestingly this approach elicited some student anxiety, evidenced from the discussion forum, before the marking exercise and considerable praise after the exercise.

USE OF MULTIMEDIA MATERIALS

In terms of the principles of good practice the aims were to:

- Develop reciprocity and co-operation amongst students
- Respect diverse talents and ways of learning
- Communicate high expectations

Regular assessment brought demands from students for more worked examples. The teaching staff felt that these demands indicated that students were wanting to adopt a more surface approach to learning and resisted publishing worked examples, preferring to concentrate on a 'problem solving approach' aiming to 'communicate high expectations' and support a 'deep' approach to learning [5]. This took the form of introducing a problem solving methodology and applying this to examples during lectures and tutorials. The methodology formed the basis of the Thermodynamics review lecture at the end of the course when supporting power point slides and an accompanying podcast were published through StudyNet. In addition 3 worked examples were developed using SMIRK [6] software. SMIRK produces multimedia presentations integrating slides with audio and captioning. The resultant worked example presentations illustrated the application of the problem solving methodology applied to final examination style questions and was accessible at any time through StudyNet.

The course team took the opportunity to use an experimental teaching room that was developed and commissioned in 2005/2006 by the newly established Blended Learning Unit. The room was designed to support collaborative learning for a maximum of 28 students, equipped with interactive whiteboards installed around clusters of 6 to 7 tables. Further details can be found at [7]. The idea was for groups of students, guided by a lecturer to produce their own solutions to tutorial examples utilising the interactive whiteboards, which could then be captured and republished on StudyNet. Even though the students had worked on group projects in an engineering design module they did not seem able to transfer this group work approach to this module. It became apparent that students quickly reverted to a very individual style of working and this experiment was not a success. Any further use of this facility for the core 'engineering science' modules would require some initial training for the students and staff to develop a more productive collaboration that would lead to useful 'worked example' resources collaboration. This experiment showed the potential of the benefits of collaborative working but highlighted the need for preparation to better support reciprocity and cooperation amongst the students.

STUDENT PERFORMANCE

The overall performance of the students on the module is illustrated by their final examination marks as presented in Table 2. This table shows a significant improvement in student performance from 2001 to 2002 which corresponds to the introduction of WATS in 2002. The next year shows a similar performance with a further significant improvement from 2003 to 2004 where the % of students achieving the minimum examination pass mark, or better has improved from 49% to 77%.

TABLE 2
FINAL EXAMINATION MARKS 2001 TO 2005

Academic Year, start	2001	2002	2003	2004	2005
Mean %	38.7	47.1	42.2	52	33.1
Median %	34.0	48.0	43.0	55	26.5
Standard deviation	24.4	23.7	21.3	22.6	23.3
N > 34%	62	88	83	125	75
% > 34%	49	67	65	77	44
Population	127	128	133	163	174

Figures 5 to 7 show the distribution of examination marks for the 3 academic years 2002 to 2004. The distributions in the first 2 years, Figures 5 and 6, of WATS are similar although 2002 shows a typical normal distribution and 2003 is more of a skewed distribution with fewer students achieving high (>70%) examination marks.

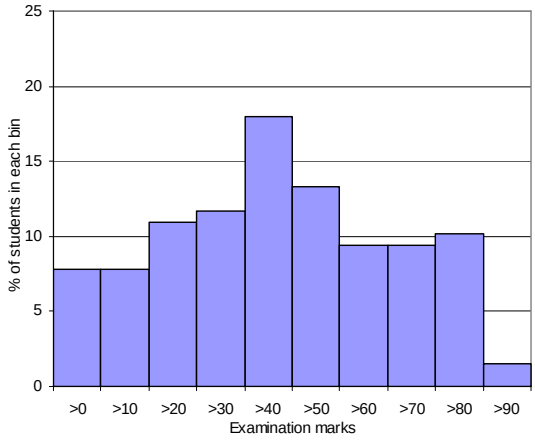

FIGURE 5
EXAMINATION RESULTS 2002

The distribution of examination results for 2004, figure 7 show a negatively skewed distribution. This tends to indicate that the introduction of WATS, just-in-time teaching and multimedia resources have had a positive effect.

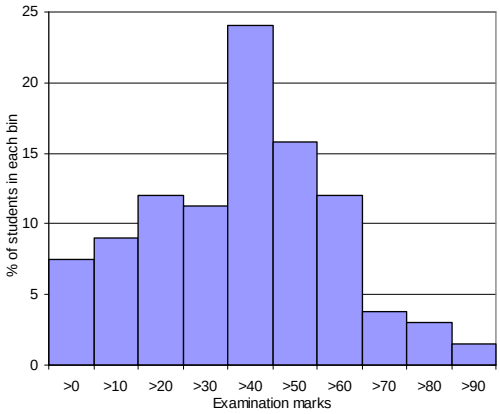

FIGURE 6
EXAMINATION RESULTS 2003

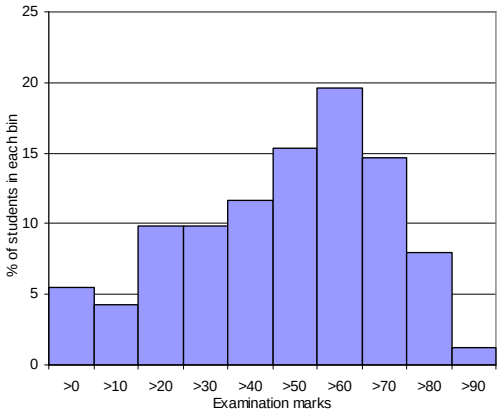

FIGURE 7
EXAMINATION RESULTS 2004

However the results for 2005, figure 8, show a return to the pre-WATS results with a very unusual distribution and a very high failure rate. The distribution of results above 30% appears normal although somewhat flatter than previous years. But the distribution below 30% is clearly distorted and indicative of an unusual occurrence. Table 2 shows that the results for this year were in fact worse than the pre WATS year of 2001 although the number of students had increased by approximately 40%.

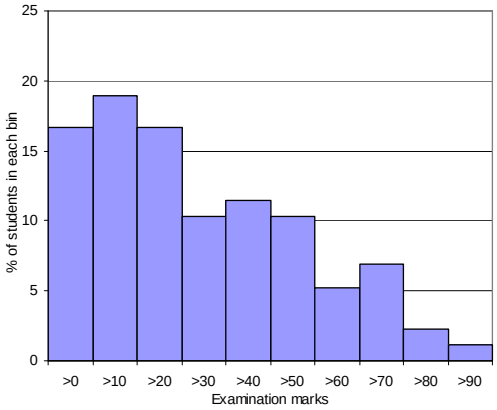

FIGURE 8
EXAMINATION RESULTS 2005

An investigation into this disappointing and unusual result was carried out by conducting individual interviews with students from the 2005 cohort.

EVALUATION THROUGH STUDENT INTERVIEWS

Ten students from the 2005 cohort were interviewed by the Blended Learning Unit Student Consultant. The interviews were structured around a series of questions which focused on the student's approaches to learning, their use of resources provided within the module and their expectations of the module. The students were asked to volunteer for the interview and a group representative of the range of student performance was selected for interview. The interviews were carried out individually and recorded for later analysis by the Student Consultant. The participants remained anonymous to the teaching staff.

The students provided a variety of responses in the interviews from which some common themes emerged. It was apparent that the weaker performing students did not make full use of the resources available to them and generally limited themselves to what they saw as core components of the module, mainly the lectures. The higher performing students appeared to make better use of the resources provided and were appreciative of the range and quality of these resources. The poorer performing students appeared to adopt a surface approach to learning and continually referred to the number of equations that they 'had to learn' whereas the stronger students were more engaged in the problem solving approach and an understanding of the principles of the subject, characteristic of a deeper approach to learning. Most importantly it became apparent that the weaker students had had prior access to the solutions to WATS and were using these to complete the WATS tasks and therefore not properly engaging in the WATS process. This meant that these students were not properly prepared for the final examination and most importantly the teaching staff were not receiving true feedback on the student's understanding of, and progress with, the subject. This result indicates that the WATS, combined with just-in-time teaching, when used properly by the students, are powerful tools to engage and motivate all students.

A number of the students interviewed identified the provision of more worked examples as the way to improve the module – a familiar theme.

The interviews also highlighted that it had become the norm for full time students to undertake paid employment during their studies. It is estimated that at least 70% of the students now work to help support themselves financially during their studies, with one example of the higher performing students working in paid employment, on average 37 hours per week. This supported the need for greater flexibility and led to the exploration of the use of virtual classroom technology.

VIRTUAL CLASSROOM TECHNOLOGY

The Blended Learning Unit had undertaken an exploration of the use of virtual classroom technology providing the opportunity to offer a voluntary evening on-line tutorial to the 2006-07 cohort of students. 14 students signed up for these on-line tutorials which focussed on worked examples. The software Elluminate [8] provides synchronous communications and the ability to record a session and thus provide a resource for all students in the cohort. The overwhelming reason for the students choosing to participate was the reputation of a demanding module and an opportunity to gain additional help. Evidence to date shows that this virtual classroom technology offers enhanced support for student collaboration and provides opportunities for individual help within a mass education environment.

CONCLUSION.

The adoption of a Blended learning approach to teaching first year engineering degree students has resulted in an improved student performance as measured by final examination results. In particular greatest benefit has been achieved through:

- The use of the weekly automated assessment scheme (WATS)
- Adopting a just-in-time teaching approach

Weaker performing students tend to adopt a surface approach to learning and need:

- Greater structure as further on-line resources are developed.
- A more personalised approach to learning

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