An Evaluation in the Use of Internet-Based Instructional Resources and MLE in Support of the Teaching and Learning of CAD/CAM

Dr Tom Page, Department of Design and Technology, Loughborough University

Abstract
This work provides an account and evaluation of the development and integration of internet-based instructional resources and a Managed Learning Environment. They were used to enhance the teaching and learning of computer-aided engineering applications in support of engineering undergraduate courses. They provide detailed instruction in the design of 3-Dimensional engineering part-models. The user is guided through creation, analysis of the structural integrity and subsequent planning of the process operations required to manufacture such part-models. Additional internet-based learning resources, in the form of self-assessment tutorials and quizzes, were developed to enable the students to gauge student understanding at staged points throughout the tutorial and laboratory sessions. Moreover, this work describes strategies used to encourage the use of the Managed Learning Environment along with the internet-based tutorials. It outlines an evaluation of the Managed Learning Environment by the students with a view toward setting this cohort's skills in context via an evaluation over a two year period since its implementation.

Key Words: Managed Learning Environment, Evaluation, Computer-Aided Engineering.

Introduction
The purpose of the work reported here is to provide an insight into the observed outcomes of integrating a Managed Learning Environment with using internet-based learning resources for the delivery of computer-aided engineering modules in undergraduate engineering courses. The objective of this is to find out how this can be used to enhance the learning and teaching experience of the students. The work reported here has taken place over a two-year period where the Managed Learning Environment was prepared with learning and teaching materials in advance of delivery of such modules. The computer-aided engineering software was implemented at the same time because the university changed vendor and adopted SDRC-Ideas® for the support of all computer-aided engineering modules. The internet-based tutorials are accessible from the help menu library within SDRC-Ideas® and contain a sequence of instructional tutorials and detailed guidelines in Acrobat Reader (.pdf) format. Furthermore, a series of assessment tutorials, accessible from the Managed Learning Environment, provided the students with self-assessment of the theoretical foundations of design, analysis and manufacturing.

The observations were made with respect to how things were done before and comparing this to what is being done now. Through discussions with students, feedback through assessment and course evaluation, such comparative observations led the course development team to expand the scope of such modules to encompass more advanced features within the computer-aided engineering environment. The MLE was intended to supplement and enhance the existing learning and teaching experience and not merely replace lectures, tutorials and laboratories. Students could elect not to use the Managed Learning Environment and still participate in learning on these modules as paper-based handouts and copies of slides were also distributed to the students.

Evaluation of Managed Learning and Web-based Instruction
Managed Learning Environments implemented using hypermedia and instructional-based systems have been developed and used extensively in support of modules and courses in Higher Education, (Narum & Conover, 2002) and (Wilson & Kennedy, 1992). The work reported here attempts to perform a learner-centred evaluation of the Managed Learning Environment with the development of web-based instruction (McLoughlin & Luca, 2002). Web-based instruction is defined as:

> a hypermedia-based instructional program which utilises the attributes and resources of the world wide web to create a meaningful learning environment where learning is fostered and supported. (Khan, 1997).

Jones and Liu define web-based instruction as:

> the application of a repertoire of cognitively oriented instructional strategies within a constructivist and collaborative learning environment, utilising the attributes and resources of the world wide web. (Jones & Liu 2001).

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Web-based instruction, also called web-based training, is defined by Boger as:

> individualised instruction delivered over public or private computer networks and displayed by a Web browser (Boger, 2001).

Web-based training is not downloaded computer-based training, but rather on-demand training stored in a server and accessed across a network. Web-based training can be updated very rapidly, and access to training controlled by the training provider (Neilson, Mayes & King, 1994). Consequently, in design education there has been significant development of instructional based teaching and learning technologies for the delivery of distance learning courses specifically in computer-aided design and manufacturing (Chang, 2001 & 2003). The managed learning resources as described and implemented in this work have been designed in accordance with effective teaching and learning practice (Lee & Paulis, 2001), (Schaffer, 2000). Furthermore, much of the development and testing of such resources have been aligned with current research aimed at the evaluation of learning technologies for the support of distance learning. Lockwood and Gooley predict that:

> the potential benefit from formulating evaluation methodologies for the Web [for instructional materials] depends on whether or not the Web will become a permanent medium or a passing fad.
> (Lockwood & Gooley, 2001).

In fact, the Web will likely soon become the most popular medium for the delivery of distance education type materials (MacDonald and Breithaupt, 2002). The literature supports the assertion that web-based instruction is a growing trend. The literature also indicates that a critical factor to the success of web-based instruction is the incorporation of usability design into the development process (Verbeeten, 2001). The design issues gleaned from the literature review include:

- transfer of existing course material, as is, to WBI, without considering using the medium's capabilities, such as graphics or communications, like listservers (Weston & Barker, 2001);
- ignore the forms and styles required by the medium, such as using the structure of a traditional lecture course as the structure for a WBI course (Wilson & Meij, 1997);
- use existing course material and while ignoring features without restructuring existing material to fit the features, which can lead to the student learning less (Weston & Barker, 2001).

Moreover, research into evaluation of such implementations has focused on methodologies for evaluation rather than the processes and techniques for the evaluation of such learning technologies from a user perspective (Scanlon & Tosunoglu, 1998). The work reported here is an attempt to conduct a evaluation by from the learner's perspective with respect to eliciting the degree of confidence the learner has in the fulfilment of the learning objectives of these modules and report on the outcomes of such evaluation. The Managed Learning Environment utilises hypermedia-based instructional resources along with self-assessment quizzes and tutorials (Willis & McNaught, 1996). It was designed initially to facilitate distance learning and provide teaching learning materials that were accessible from outside the timetabled teaching sessions.

Learning Resources Used in this Study

The learning resources used in this work comprised tutor-generated resources, student-generated resources and a strategy for assessment. The tutor-generated resources consisted of lecture notes and slideshows, supplementary notes, links to relevant websites and scanned versions of articles (with copyright permission). Such student-generated resources comprised:

- computer-aided design (CAD) part-model files;
- results of Finite Element Analysis (FEA);
- analysis of the assembly of such parts through kinematic animation;
- respective process plans and machine tool-path verification programs, containing cutter-location data for subsequent post-processing and part machining.

The assessment strategy was such that the parts designed using the CAD system were analysed structurally with the aid of the FEA

system and must be fully planned and specified for subsequent machining using the computer-aided manufacturing (CAM) system. Such assessment was reinforced with self-assessment tutorials and quizzes.

The Managed Learning Environment (MLE)
The MLE is a virtual space where learning, assessment and interaction can take place in a structured and managed way fully integrated into and linking all university processes and systems. It provides student level information comprising university-wide information on university procedures and regulations and support services. More importantly, the MLE provides links to modules, tutors, lecture materials and course related news alerts. Course and module information is provided through portal news and bulletins. Each module has its own dedicated website which is structured such that staff can provide news; create, upload and link to teaching materials; host on-line discussions; set and receive assignments; upload reading lists; obtain class lists and organise, as well as set, online group work (see Figure 1).

Figure 1: *Teaching materials index page in the Managed Learning Environment*

The MLE provides a mechanism toward joined up systems or systems integration by creating links "seamlessly" to other systems such as web servers (departmental and central), "QuestionMark" and the university library resources system "Voyager". The MLE enables the use of data existing in other systems such as the university-wide management information system "Genesis" and the rooms and timetabling system.

The Internet-Based Tutorials
The internet-based tutorials accessible from the computer-aided engineering package provide a valuable learning resource in as much as they clearly instruct the student in the use of the CAE system. The class learning time was split between a lecture and laboratory upon the use of the tutorials in the design of part models and subsequent analysis and CNC part-program generation of such models. The students were given lectures in the theoretical aspects of geometric modelling, finite element modelling and analysis as well as kinematic simulation. They were taught process planning of CNC machining operations on 3-axis machining centres with the aid of the MLE as the primary mode of delivery. These internet-based tutorials enabled students to draw upon the theoretical foundations in computer-aided engineering and apply such theory into practice. Moreover, by tiling the tutorials and the CAE system together on the screen, the students follow and refer to the tutorial instructions whilst using the package.

The tutorials themselves were amply illustrated and highly detailed instructions in the use of the CAE system. In essence, they enable the student to learn through geometric construction of part models in CAD, analysis of integrity of models using FEA and the detailed planning of the machining operations required to make such part models in CAM. The output of the CAM system provides for tool-path verification and the CAM system produces cutter-location data files in APT (Automatic Program Tool) language. This cutter-location data file is subsequently post-processed for the Machining and Turning Centres within the department machine tool laboratory (see Figures 2 and 3).

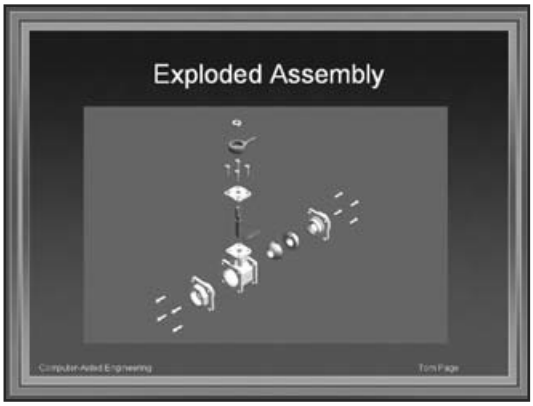

Figure 2: *Screen shot from internet-based tutorials*

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Figure 3: *Detailed screen-shot from internet-based tutorials*

The Self-Assessment Tutorials

The self-assessment tutorials, developed by the author, provided the students with the ability of performing a series of staged checks within the teaching and learning of CAE. This enabled the students to assess themselves with respect to the theoretical background to the subject. These self-assessment tutorials were essentially a series of quizzes that were accessible from the MLE. These quizzes sought to assist the students with their understanding and knowledge drawing together the theory of manufacturing process planning with the practical aspects of such. The solutions to which were administered via email through the MLE to each student after the timetabled tutorial session.

Method of Teaching and Learning

The lecture sessions were delivered in computer laboratories where the students could follow the lecturer through Microsoft PowerPoint slideshows via the MLE. The laboratory time was used to support the lecture in as much as the students worked through the on-line tutorials within the CAD package. The time spent between lecture and laboratory was one-hour lecture for two-hours supervised laboratory time.

The modules taught were computer-aided design and computer-aided manufacturing which include the design and analysis of engineering components and assemblies as well as specifying the means by which these components are machined. These modules are integrated in as much as the computer-aided design module is a prerequisite for the computer-aided manufacturing module. The content of these modules encompass geometric modelling techniques, concurrent engineering through team-based design, machine tool algorithms for interpolation of NURBS and CNC part-programming techniques. The successful student is required to demonstrate both theoretical understanding and practical competence in the design, planning and part-programming of machined parts (see Figure 4).

Figure 4: *Self-Assessment Tutorials in Managed Learning Environment*

Teaching and Learning Prior to MLE

Up until two years ago before using the software (SDRC-Ideas®) and the Managed Learning Environment, the department used Matra-Datavision Prelude®. This CAE system did not support internet-based tutorials for instruction. Therefore delivery of the course involved much preparation and considerable tutoring by the academic staff on small group and individual basis. The preparation involved numerous instructional guides to using such engineering software coupled with detailed assessment strategies for individual and group-based work. Moreover, the students tended to learn the software from the teacher's perspective and only undertook tasks with such software that the teacher condoned as being able to use him or herself. In other words, prior to using the MLE and the learning tutorials for the delivery of these modules, the learning process was unduly constrained by the teacher.

The advent of using the MLE and internet-based tutorials freed both the student and teacher to explore further the subject area of computer-aided design and manufacturing and beyond what had been done previously. This included assembly modelling and more advanced surface creation within the CAE software.

The advantage of the engineering software system adopted is that it supported group-based design environments and such made a very useful resource for facilitating not only individual but for group-based learning on problems in component design and manufacturing. This obviously emulates industrial situations where design is conducted in groups, with each member exercising some decision making over the functional design and manufacturing of the engineering components or part-models.

Evaluation

An evaluation of the effectiveness of this approach to learning and teaching was achieved by administering structured questionnaires to each year group of students undertaking this module. This questionnaire aimed to assess each student's confidence, perceptions and usage of the MLE, internet-based and self-assessment tutorials. Furthermore, this evaluation sought to estimate the amount of discussion "traffic" in terms of the number of discussions, the initiators of these discussions and the nature of the discussion content. This evaluation was conducted prior to the advent of the managed learning resources and the subsequent two years after.

The questionnaire itself was designed to evaluate the degree of confidence that each student had with respect to the learning outcomes of these modules. The questionnaire was distributed to the students one week in advance of the formal examinations on these modules. The questionnaire used a four point Likert scale to indicate the degree of confidence that the students had in attainment of the learning outcomes of these modules. As can be seen from Tables 1 to 6 that the Likert scale was dimensioned as very confident, moderately confident, not very confident and not confident.

The rationale behind this evaluation was essentially to determine whether the MLE, internet-based tutorials and self-assessment materials would provide the basis for a strategy of further development of these module and widening of the scope of its existing learning outcomes and content. As stated earlier, this course was unduly constrained in its scope by the teacher's own knowledge and practical use of the CAE system. The combined resources proffer a significant benefit in providing a deeper learning approach in the use of such systems yet enabling students to work through such internet-based tutorials at their own pace within the boundaries of the module milestones and assessment criteria. Table 1 shows the breakdown of questionnaire responses in terms of the confidence that students has in the knowledge and understanding of surface modelling in CAD. The data shown in Table 1 indicates the levels of confidence of those students that have studied these modules over the last three academic years.

	Prior	%	Y1	%	Y2	%
Very confident	30	46	46	71	46	87
Moderately confident	23	35	18	28	7	13
Not very confident	10	15	1	1	-	-
Not confident	3	4	-	-	-	-
	66	100	65	100	53	100

Table 1: *Confidence levels among students regarding Surface Modelling*

Table 1 shows the year prior to and two years since the implementation of the MLE and internet-based tutorials. It illustrates that in the second year of implementation, the students had higher a degree of confidence as compared to the first year. It is clearly seen that prior to the implementation of the MLE and internet-based tutorials, that overall confidence was even significantly lower.

It is of interest to note from Table 1 that no students indicated 'not very confident' two years after the implementation of the managed learning resources. Moreover, owing to general trends in recruitment of engineering undergraduates it can be seen that the total number of students on these modules has decreased significantly by 20% over a one-year period. Nevertheless, proportionally with respect to the total numbers of students undertaking these modules that there has been a notable increase in confidence regarding surface modelling in CAD.

Table 2 illustrates the questionnaire responses in terms of the confidence that each student has in the knowledge and understanding of solid modelling. Similarly, as with Table 1, it indicates the levels of confidence of students that have studied these modules over the last three academic years. It illustrates that in the second year of implementation that the students had a higher degree of confidence as compared to the first year. It is clearly seen that prior to the implementation of the MLE and internet-based tutorials, that overall confidence in the module was even significantly lower.

	Prior	%	Y1	%	Y2	%
Very confident	25	39	43	66	40	75
Moderately confident	23	35	12	18	10	19
Not very confident	12	17	8	13	2	4
Not confident	6	9	2	3	1	2
	66	100	65	100	53	100

Table 2: *Confidence Levels Among Students Regarding Solid Modelling*

It can be seen from Table 2 that for the combined "very confident" and "moderately confident" responses there is a twenty percent increase between prior to the advent of the managed learning resources and two years after its implementation. In fact this is a linear increase as it has risen by ten percent one year after the implementation of the MLE.

Table 3 illustrates the questionnaire responses in terms of the confidence that each student has in the knowledge and understanding of FEA. It illustrates that in the second year of implementation the students had higher degree of confidence as compared to the first year. It is clearly seen that prior to the implementation of the MLE and internet-based tutorials, overall confidence in the module was even significantly lower.

	Prior	%	Y1	%	Y2	%
Very confident	16	24	27	41	35	66
Moderately confident	18	27	22	34	12	23
Not very confident	18	27	11	17	6	11
Not confident	14	22	5	8	-	-
	66	100	65	100	53	100

Table 3: *Confidence Levels Among Students Regarding FEA*

It can be seen from Table 3 that for the combined "very confident" and "moderately confident" responses there is a seventy five percent increase between prior to the advent of the managed learning resources and two years after its implementation. It is also noted that no student response indicated 'not confident' in Year Two.

Table 4 illustrates the questionnaire responses in terms of the confidence that each student has in the knowledge and understanding of kinematic animation. Again this profile follows a similar characteristic to the other responses in Tables 1 to 3.

	Prior	%	Y1	%	Y2	%
Very confident	21	32	30	46	33	62
Moderately confident	26	39	28	43	15	28
Not very confident	14	21	6	9	8	10
Not confident	5	8	1	2	-	-
	66	100	65	100	53	100

Table 4: Confidence Levels Among Students Regarding Kinematic Animation

It can be seen from Table 4 that for the combined 'very confident' and 'moderately confident' responses there is a twenty seven percent increase between prior to the advent of the managed learning resources and two years after its implementation. It is also noted that no student response indicated 'not confident' in Year Two and one such response after Year One.

Table 5 illustrates the questionnaire responses in terms of the confidence that each student has in the knowledge and understanding of process planning. Again this profile follows a similar characteristic to the other responses in Tables 1 to 4.

	Prior	%	Y1	%	Y2	%
Very confident	21	32	43	66	42	79
Moderately confident	27	41	18	28	11	21
Not very confident	11	17	3	5	-	-
Not confident	7	10	1	1	-	-
	66	100	65	100	53	100

Table 5: *Confidence Levels Among Students Regarding Process Planning*

It can be seen from Table 5 that for the combined "very confident" and "moderately confident" responses there is a thirty seven percent increase between prior to the advent of the managed learning resources and two years after its implementation. It is also noted that no student response indicated "not confident" and "not very confident" in Year Two.

Finally, Table 6 illustrates the questionnaire responses in terms of the confidence that each student has in the knowledge and understanding of CNC part-programming. Again this profile follows a similar characteristic to the other responses in Tables 1 to 5.

	Prior	%	Y1	%	Y2	%
Very confident	24	36	38	58	43	81
Moderately confident	21	32	24	37	9	17
Not very confident	13	20	3	3	1	2
Not confident	8	12	-	-	-	-
	66	100	65	100	53	100

Table 6: *Confidence Levels Among Students Regarding CNC Part-Programming*

It can be seen from Table 6 that for the combined "very confident" and "moderately confident" responses there is a forty four percent increase between prior to the advent of the managed learning resources and two years after its implementation. It is also noted that no student response indicated "not confident" and "not very confident" in Years One and Two after implementation of the managed learning resources.

It seems evident that the confidence level of students in the learning outcomes of these modules has increased since the advent of implementing the managed learning resources. In some cases the MLE has been proven to significantly increase the confidence level of the students. For example, the confidence levels of students on the FEA learning outcomes demonstrated a seventy five percent increase over the two year period since its implementation.

A further questionnaire was devised and distributed to those students in Year One and Year Two after the MLE implementation so as to determine the degree to which the students used the managed learning resources. This attempted to elicit the frequency of MLE use, the ease of access the students felt that had to the MLE and to attempt to define those managed learning resources the students felt where more useful than others. Table 7 illustrates the responses from the students to the frequency of use of the managed learning resources.

	Prior	%	Y1	%
Used very frequently	30	46	38	72
Used frequently	29	45	12	23
Used infrequently	6	9	3	5
Not used	-	-	-	-
	65	100	53	100

Table 7: *Frequency of usage among students use of managed learning resources*

It can be seen from Table 7 that usage of the managed learning resources in Year Two was more frequent than in Year One. Scrutiny of all for both years found that 142 items were posted to students in Year One and 229 items were posted to students in Year Two. This is somewhat a blunt measure of usage, nevertheless, it indicates increased activity in the usage of the MLE. Access from home was 51% in Year One and 73% in Year Two after the implementation of the managed learning resources from home this level of access is not unusual, it is comparable with that reported by others.

Table 8 illustrates the responses from the students to the ease of access to the managed learning resources. It is evident from Table 8 that the students in Year Two found it generally easier to access. This is compounded by the fact that all students in Year Two had access to the managed learning resources from home whereas in Year One, seven students indicated that they didn't have access to the managed learning resources from home. Nevertheless, the learning resources centre on campus provides for 24 hour access to the managed learning resources.

	Prior	%	Y1	%		
Very confident	28	43	41	82		
Moderately confident	32	47	12	18		
Not very confident	5	10	-	-		
Not confident	-	-	-	-		
	65	100	53	100		

Table 8: *Ease of access levels among students regarding managed learning resources*

Tables 9 and 10 illustrate the percentage responses from the students to the usefulness of the managed learning resources since the implementation of the MLE one and two years respectively. The tutor generated resources such as lecture notes and slideshows were the most well received aspect of the managed learning resources. Moreover, the hyperlinks to other learning and information resources were favoured by the students. The student generated resources consisted of part model files, animations of kinematic motion of assemblies, graphical results of analyses on part-models and CNC part programs for subsequent machining of parts. The Managed Learning Environment for the basis of an integrated product data management environment. Regular news bulletins and discussion topics were posted by the teaching staff as well as the students.

	Year One (%)			
	Lecturer Material	Lecturer Material	News	Discussion
Very useful	82	58	22	29
Quite useful	16	38	44	51
Limited use	2	4	20	12
No use	-	-	14	8

Table 9: *Degree of usefulness of items within managed learning environment for Year One*

	Year Two (%)			
	Lecturer Material	Lecturer Material	News	Discussion
Very useful	91	68	48	40
Quite useful	9	30	40	34
Limited use	-	-	12	26
No use	-	-	-	-

Table 10*: Degree of usefulness of items within managed learning environment for Year Two*

The discussion forum comprised of twelve discussion topics of which four were initiated by the tutor and eight by the students with 42 contributions. This discussion forum traffic related mainly to giving information, asking for help, offering help and arranging to meet face-to-face (22 out of the 42 messages). Such traffic was not primarily concerned with knowledge construction this perhaps happened on face-to-face basis.

Discussion of Observations

Through observation and module evaluation it was found that these resources enabled students to work at their own pace through such tutorials without the fear that they may be falling behind the scheduled milestones and learning outcomes each week within the modules. This was also enabled by the implementation of the computer-aided engineering software within the Learning Resources Centre where the students have 24-hour access. This provided for differences in learning rates and styles among the group of students. This approach enables the students to manage their learning in an organised and structured manner, the internet-based approach tends to appeal to students as they have become quite accustomed with using the internet as a research and learning resource. The tutorials indicate to the students "what happens if?" scenarios and prompt the students with information and data input so that they have to think for themselves about what they are doing and how that is consequentially related to the underpinning theoretical knowledge of computer-aided engineering.

The Managed Learning Environment contains all the lecture slides and notes for the students to relate the theoretical foundations of computer-aided design and manufacturing with the pragmatic emphasis of using computer-aided engineering software to assist in the design and planning of machine-parts. It must be stated that the CAM software does not actually plan the sequence of operations for machining part-models such planning needs to be decided upon by the students. The CAM package facilitates the implementation of the process plan into operations suitable for machine tool-path verification and the respective generation of cutter-location data files.

It was also found that students tended to explore the subject further than was done before the implementation of this approach to teaching and learning. More sophisticated engineering designs have been created with more detailed and extensive technical analysis and specification of manufacturing data. One drawback of this was that the students tended to over-specify and elaborately present their process plans for their assignments.

There have been advantages in utilising these approaches to the delivery of modules. The self-assessment problems enabled students to find their own level of skill and efficiency in undertaking the learning tasks. Nevertheless,

there were some problems encountered in issuing assignment-based problems too early during the module. For example, many students attempting the assignment before completing the internet-based tutorials found difficulty in the modelling of parts and specifying their respective machining parameters in the CAM system.

On a strategic level there were structural modifications made to the degree course in that much of the third-year module content was brought forward to the second year. In essence, the overall approach enabled a widening of the scope of the degree course permitting advanced surface creation and assembly modelling to be taught as complete second-year modules. Such topics were merely explored prior to the advent of using the MLE in conjunction with the internet based tutorials. In summary, this appears to have been a successful implementation in as much as it provided a focus for the teaching team in module and course development.

Conclusion

This case study provided an insight into the observed outcomes of using a Managed Learning Environment in tandem with using internet-based learning resources for the delivery of computer-aided design and manufacturing modules in undergraduate engineering courses. The work reported here took place over a two-year period where the Managed Learning Environment was prepared with learning and teaching materials in advance of delivery of such modules. A series of assessment tutorials, accessible from the Managed Learning Environment, provided the students with self-assessment of the theoretical foundations of design, analysis and manufacturing. The observations were made with respect to how things were done before and comparing this to what is being done now. Through discussions with students, feedback through assessment, and course evaluation such comparative observations led the course development to expand the scope of such modules to encompass more advanced features within the computer-aided engineering environment.

It has been found, since its introduction, that the MLE has been greatly appreciated and widely used by students in general. It almost seems that when given a task their first point of reference is the internet and by utilising the MLE in the teaching of such modules it has become proven and useful tool for the teacher and student alike. Nevertheless, it is appreciated that clear guidelines are needed which need to be reiterated to the students concerning referencing of materials found via the internet as much of what is published can be and is often un-refereed.

The future role of the MLE in tandem with the internet-based learning tutorials is to expand the scope further to include analysis of engineering components using finite element methods. These resources are currently being developed as the CAE software also supports detailed instruction in finite element modelling and analysis.

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