Engineering the Education Industry
to Educate the Industrial Engineer

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Abstract

Not only educational institutions, but also non-educational corporations, recognize the potential of e-learning. To consider the position of learning management systems (LMS) in a non-educational corporation, an analogy is found between learning management systems (LMS) and manufacturing execution systems (MES). The educational issues and concerns related to implementing an LMS at an educational institution (University of Pretoria) are investigated according to a case study in the Industrial Engineering department. It is concluded that the Industrial Engineering educator is in the unique position of understanding and contributing towards the engineering of the education industry whilst educating the industrial engineer.

1. Introduction

Corporate and educational institutions alike recognize the potential of e-learning. Gartner predicts that over 60% of US corporations will have implemented an LMS by the year 2003 and International Data corporation estimates that the corporate spending on e-learning alone will increase from $1bn in 1999 to over $11bn in 2003. It has become a requirement for any large enterprise to have a formal learning program of which the budget is at least 1.5 percent of the total payroll.

The learner is either the external client of an educational institution or the internal client of corporations that wish to develop their own human resources. In both cases, the learning content is the product and the learning, and assessment events are the primary service. In order to manage these products and services, learning management systems (LMS) and learning content management systems (LCMS) have been developed. These systems are not only enablers of paradigm shifts in the educational sector but also often forces behind these changes. Gartner defines LMS as the infrastructure on which e-learning can be built and delivered, whilst LCMSs are used by the learner to customize learning content.

To support the suggestion that Industrial and Systems Engineering skills are equally relevant in the education industry as in the manufacturing industry, an analogy will be drawn between the management of learning systems and the management of manufacturing systems:
2. Manufacturing Execution Systems compared to Learning Management Systems

In the manufacturing industry, three levels of systems are generally accepted:

1. The top planning layer comprises systems such as Enterprise Resource Planning (ERP), and Supply Chain Systems (SCS).
2. The Manufacturing Execution System (MES) acts as middleware between the planning and control layers.
3. Control is established through devices and systems such as programmable logic controllers (PLC), supervisory control and data acquisition (SCADA) and man-machine interfaces (MMI).

The ability to execute learning is one of the two criteria used by Gartner to evaluate current learning management systems. To measure the ability to execute learning, the following are considered:

- Verifiable record-keeping, partnership philosophy, skills management, process for evaluation of customer satisfaction with learning events and integration with enterprise resource-planning systems and other enterprise applications.

Thus, both LMSs and MESs have the functions of executing (manufacturing or learning) and integrating enterprise applications.

Both LMSs and MES’s were developed in the past decade, due to similar paradigm shifts in these industries. In promoting the need for academic middleware to integrate advanced learning systems, Konstantapoulus highlights paradigm shifts in the education industry that necessitate these systems. These changes correspond with paradigm shifts in the manufacturing industry. In both environments, information technology is both a cause and an enabler of change:

1. There is a drive towards modularisation of the study programme in order to offer customised degrees and enhance student autonomy. Similarly, mass production strategy is based on the principle of economies of scale, whilst flexible manufacturing concerns economies of scope and integration.
2. Distance learning programs have been introduced as part of the regular studies in an institution. Markets for all products are becoming global.
3. Inter-institutional programs have been developed and collaborative product development is enabled through information technology.

McClellan distinguishes between core business functions and support functions in the execution layer:

2.1 Core functions

The core functions of an MES are directly associated with the management of production. These functions include the following:

- Planning system interface
- Work order management
- Workstation management
- Inventory tracking and management
- Material movement management
- Data collection and exception management.
The analogical core functions of an LMS are listed by Sinofsky\textsuperscript{10} as follows:

- “Registration capabilities (curriculum, courses, instructional responsibilities)
- Management of curriculum and courses
- Skills and records management
- Student interfaces with courseware
- Administration (e.g., test and assessment capabilities, certification; also, instructor assignment to the courses, any regulatory requirements and history)
- External system application programming interfaces (APIs), including human resources and, optionally, enterprise resource planning (ERP) systems”

If the learning content is considered to be the learning product, it is necessary to add the functions of learning content management systems (LCMS) to this list\textsuperscript{6}:

- Build interactivity, workflow and navigation into the courseware.
- Port the content into the e-learning repository environment.
- Build the network and browser linkages for delivery.

The European patent register\textsuperscript{11} provides interesting examples of how these functions can be practised.

WO 0175840 “A learning-assistance system that uses a computer network and that includes a server computer that can communicate via the Internet, and student computer terminals that can communicate via a computer network, with said system being such that study-materials data is transmitted from the server computer to one or more student terminals.”

GB 2339954 “An interactive education process permits students at remote locations to provide feedback to an instructor in an ordered manner. Inputs are ranked and grouped together. The inquiries and responses are published at an Internet site and are accessible by all the students.”

US 6301462 “The system can also be responsive to an online assessment with remediation and guidance. Lessons, implemented by executable software code can be designed to challenge a learner with ever increasing sophisticated levels of encounter and interaction until the learner reaches their limit of knowledge and is forced to acquire additional skills.”

US 5788504 “Computerized training management system: Each task is linked directly to a performance objective, which, in turn, is linked directly to a learning objective; then, each enabling objective is linked to its respective test items. In addition, tasks, performance objectives, enabling objectives, and test items are linked to their associated reference documents.”

The National Qualifications Framework (NQF)\textsuperscript{12} of South Africa (and other qualifications bodies around the world) prescribes that as part of the design of any course, learning outcomes have to be defined. The exit level outcomes for one course may become the entry level outcomes for other courses. Once an appropriate system is in place, customised learning events can be dispatched according to specific learning outcomes achieved.

Pimentel\textsuperscript{13} In order to give a more comprehensive support for classroom-based courses, discussions occurring inside and outside the classroom have to be integrated into the body of information for each course. Traditionally, the primary data-capturing device during lectures is pen and paper. The limitations of this data capturing are obvious. A system is proposed\textsuperscript{15} that uses ubiquitous computing technology in order to create a classroom that automatically captures much of the rich detail of a lecture experience.
2.2 Support functions

McClellan\textsuperscript{7} lists a number of support functions of MES, including maintenance management, time and attendance, statistical process control, quality assurance, process data/performance analysis, document control/product data management, genealogy/product tractability and supplier management. This list is not a comprehensive list of functions, but rather examples of complementary functions.

Analogically, the following examples of support systems of LMS are given:

In a non-educational corporation, the effects of a specific learning event can be linked to determine the return on investment expected from the particular activity\textsuperscript{14}. In terms of new product development, collaborative – and even inter-institutional – course design and course data management can be established through the appropriate LMS\textsuperscript{15}.

Karapetrovic\textsuperscript{16} shows how statistical quality control (SQC) techniques have been used to measure and improve the quality of education at the Department of Mechanical and Industrial Engineering at the University of Manitoba. The criteria of the Accreditation Board for Engineering and Technology (ABET) are used as “engineering ideal”. In the South African context, this accreditation board will be the Engineering Council of South Africa (ECSA). The accreditation standards of this body are set up in accordance with the guidelines from the South African Qualifications Authority (SAQA)\textsuperscript{12} and are positioned within the National Qualifications Framework (NQF).

The primary functions of assessment are to rectify (formative assessment) and to qualify (summative assessment). However, the diagnostic value of assessment results is often overlooked. Karapetrovic\textsuperscript{16} provides examples of information that can be gathered from assessment data, using statistical process control (SPC) charts:
- Incoming variation in student knowledge
- How much and how well the students have learned the material
- “Before” and “after” knowledge can be compared to roughly estimate the value-added outcome.
- “Unnatural effects”, such as when a student knew the answer before, but not after, are examined.
- Deterioration in the teacher’s presentation of the material.

3. Introducing an LMS to the Industrial Engineering curriculum

As part of its Education Innovation initiative, to keep abreast of changes in the education industry as listed below, the University of Pretoria is in the process of introducing WebCT (World Wide Web Courseware Tools\textsuperscript{17}) as LMS for all its courses\textsuperscript{18}:
- More emphasis is being place on electronic distance education, as well as open and flexible learning environments.
- Education is being commercialized and globalized.
- Education quality and relevance are pursued more rigorously.
In 2001 WebCT was implemented as LMS for the Work-study course presented to undergraduate Industrial Engineering students at the University of Pretoria.

Work-study is a second-semester course in the undergraduate program in Industrial Engineering and was traditionally presented through formal lectures and practical sessions. Brown compiled a matrix according to which the technology content of the learning environment and the learner need can be investigated (Figure 1). The typical Work-study course learning environment fits in quadrant A. (Lecturer-controlled environment with no information technology).

**Figure 1: Learner need compared to technology in environment**

<table>
<thead>
<tr>
<th>Learner need</th>
<th>Tradional delivery mode</th>
<th>New delivery paradigm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dependent (Lecturer control)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Contact Education</td>
<td>Virtual teaching and learning environment</td>
</tr>
<tr>
<td></td>
<td>Learning events initiated by lecturer</td>
<td>The student initiates learning</td>
</tr>
<tr>
<td></td>
<td>Lecturer determines program content and sequence</td>
<td>The student determines program composition and program sequence</td>
</tr>
<tr>
<td></td>
<td>Set timetable</td>
<td>Flexible timetable</td>
</tr>
<tr>
<td></td>
<td>Learning resources are organised on campus</td>
<td>Students acquire access to learning resources through high technology application</td>
</tr>
<tr>
<td>Autonomous (Student control)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Paper-based distance education</td>
<td>Large portion of the course consists of a practical component</td>
</tr>
<tr>
<td></td>
<td>The student initiates learning</td>
<td>Specialized, centralized and limited resources necessitate personal contact between lecturer and student as well as a set program sequence and timetable</td>
</tr>
<tr>
<td></td>
<td>Student determines program composition and program sequence</td>
<td>Flexible timetable</td>
</tr>
<tr>
<td></td>
<td>Flexible timetable</td>
<td></td>
</tr>
</tbody>
</table>

The typical student who chooses to function in an A-quadrant environment needs strong guidance, he relies on tutors and lecturers, prefers a preset timetable and does not want to take responsibility for learning events. These students function according to the old education paradigm, since their ability to realize their own educational efforts is ignored. The average second-year Industrial Engineering student at the University of Pretoria shares the following characteristics with the learner who prefers to function in the A quadrant:

1. Inexperienced as a student in higher education. The need for “student life” social interaction exists: The average student of the Work-study course is 20.5 years old and is enrolled for the second year of their first degree.
2. Residential study: The average Work-study student resides 4.3 km from campus (maximum = 17 km).

However, whilst the typical A quadrant student is unfamiliar with the use of information technology, the second-year Industrial Engineering student has completed the first-year Engineering Computer Competency course. Furthermore, 87% of the students added an e-mail address to their contact details, which implies that they feel comfortable with Internet technology. Thus, as far as the Work-study course is concerned, WebCT can be used to establish a shift from a lecturer-controlled environment (quadrant A of Figure 1) to a flexible, student-controlled learning environment (quadrant C of Figure 1).
In the context of IT-enabled learning environments, Collis\textsuperscript{20} identified five modes of flexibility as priorities for combining principles of good teaching and learning with the needs of increasingly diverse student cohorts:

1. Flexibility of time and location.
2. Flexibility in types of communication and (3) interactions
3. Flexibility in programme and (5) study materials.

### 3.1 Flexibility in interactions

Figure 2 shows how flexibility of time and location was introduced through WebCT.

**Figure 2: Flexibility in time and location through WebCT**

![Figure 2: Flexibility in time and location through WebCT](image_url)

In terms of the policy of the school of engineering, an undergraduate student should spend 50\% of all notional time in the presence of the facilitator, normally at an inflexible lecturer-controlled location. This is called contact time. This traditional situation is represented by Figure 2a. The other 50\% is non-contact time, therefore the student is learning at a location of...
his choice, without the presence of the lecturer. During the first semester of 2001, WebCT was used on an experimental basis for the Work-study course (Figure 2b). One out of four contact sessions per week (12.5% of total notional hours) was spent in the computer laboratory, using WebCT. Students spent 10% of the non-contact time, using WebCT to extract information and complete homework assignments, as indicated by the black line on Figure 2.

A student survey at the end of the first semester revealed that students would prefer to use WebCT even more for non-contact time information extraction and homework assignments, as well as instruction during contact time. These suggestions were implemented during the second semester of 2001 (Figure 2c).

Figure 2d represents the average time allocation reflected by seventeen WebCT facilitators interviewed at the University of Pretoria. Traditional contact time is reduced and flexibility of time and location is increased when a WebCT learning environment is introduced. The skewness of this figure towards non-contact time may be attributed to the fact that postgraduate courses (which consists normally of fewer contact hours) take precedence when WebCT is introduced. Whether contact teaching is considered or whether non-contact teaching is considered, WebCT influences flexibility in terms of communication.

3.2 Flexibility in communications

Collis\textsuperscript{20} solely refers to communication with the facilitator (“instructor”), when she discusses the need for flexibility in forms of communication. The communication between the learner and the facilitator is modeled in Figure 3\textsuperscript{19}.

![Learner responses and feedback](https://example.com/figure3.png)

Both the learner responses and the facilitator’s feedback are subsequently discussed in more detail:

### 3.2.1 Observing, reflecting upon and recognizing learner response

A drawback of communication through WebCT is that valuable no-verbal signs\textsuperscript{19} cannot be transferred. Hence, the decrease in personal interaction is identified as one of the greatest threats of computer-controlled learning environments. Interviews with seventeen WebCT facilitators at the University of Pretoria revealed that although the average contact time had been reduced through WebCT, none of respondents found it feasible to eliminated contact time completely.
On the other hand, some sense of security is provided through electronic communication. Eight percent of Industrial Engineering students surveyed indicated that they prefer to communicate with the lecturer through e-mail, since they can express themselves better and have more confidence to ask questions by means of e-mail. To provide flexibility in communication, students should have the facility to choose a communication mode most appropriate to their specific need. Therefore, whilst the WebCT e-mail and discussion tool could be exploited even more, it should not replace face-to-face communication.

### 3.2.2 Provide feedback on learner response

Due to the lack of non-verbal communication, facilitators' responses through observation, recognition and direct affective encouragement are less efficient. Feedback has both a motivational (reinforcement) and an informative (training and remedial) value. The electronic feedback on quizzes reduces the workload of the facilitator, but the personal motivation (reinforcement) is reduced. However, through WebCT, the lecturer can give personal feedback to quiz answers from individual students. Three quarters (73%) of the Industrial Engineering students surveyed read the individual feedback on quizzes, 38% of these always found the feedback valuable throughout. Of the 27% of students who did not read the feedback, 21% were unaware of this facility. By means of the electronic discussion groups, the facilitator can paraphrase his interpretation or a challenging comment/question by replying to a student’s public posting. The facilitator can even disguise himself as a student to authenticate this challenge. This dialogue is accessible to all students. Guidance to resources can be provided accordingly, without duplicating information. In this way, WebCT contributes towards reflection (paraphrasing), challenging, eliciting and evoking, as well as guidance to resources as feedback.

### 3.3 Flexibility in program and study materials

The undergraduate Industrial Engineering students regarded the opportunity to schedule applicable learning events according to their own flexible timetable as the single greatest advantage of the learning environment. The WebCT version currently used at the University of Pretoria does not enable calendar integration between different courses. If the calendar of all courses can be integrated, the schedules of physical and human resources could be managed accordingly. Additional control measures need to be implemented to enable the tracking of these resources. In each separate course, the scheduling of learning events, the compilation of learning groups according to certain criteria and the allocation of teaching assistants and learning material can be managed through WebCT.

The automatic dispatch of learning, given certain prerequisites, is an enabler of flexible learning and one of the greatest advantages of ICT for learning environments. As with other terminologies in the education sector, the term Just-In-Time (JIT) is borrowed from the manufacturing sector to describe the action of making available the most up-to-date learning event just in time for the learning experience.

Learnframe proposes an LMS that dispatches learning material and learning events as follows: As students progress, information is delivered based on what was learned and how the students performed. For example, a student would log onto the learning server and a customized course would be generated from the content database recognising the courses the learner took, how well he did, what his job description was, what problem was most pressing.
WebCT lacks the sophistication required to execute the dispatch of learning material as explained above. However, for the Work-study course, students were allowed access to additional material according to their performance in previous electronic tests. Interestingly, the principle of dispatching learning material according to unique student data has been patented (US6024577 and KR191329)\textsuperscript{11}.

### 3.3.1 Engineering discipline

Work-study is a component of the undergraduate course for both the Industrial Engineering and Mining Engineering students. The expected course outcomes are the same for all students, although a range differentiation is made as far as the focus industry is concerned. Although, through this programme, flexibility could be provided without using WebCT, parallel themes can be facilitated more efficiently through WebCT. Parallel electronic discussion groups and electronic presentation boards may be created. The facilitator (and any other student) can participate asynchronously in his relevant electronic groups or access the electronic presentation boards relevant to his engineering discipline.

### 3.3.2 Study material

A number of students expressed the need for links to more study material and case studies, related direct or indirect to the course. Wallace\textsuperscript{23} found that the WWW provides new opportunities for students to play a more active role in the acquisition of knowledge. For the Work-study course, students share the responsibility of identifying appropriate additional resources for the course, as recommended by Collis (1998:377). These resources are shared with peer students by means of the presentation tool of WebCT. A wider selection of resources and modalities of study materials can be distributed through WebCT. These include video clips and relevant computer applications. Exploitation of this WebCT facility is identified as one of the opportunities for the WebCT classroom.

### 3.3.3 Language of instruction

From 2002, the Work-study course has to be presented in both Afrikaans and English. If the traditional teaching model is followed, all resources (lecturer and lecturer hall) have to be duplicated. However, through WebCT the student has more flexibility concerning the communication medium. Due to practical constraints, there is less flexibility as far as receptive language skills (read and listen) are concerned. Through e-mail, chat, discussions and presentations students are able to write and speak in the language of their choice (productive language skills), whilst listening and reading (receptive language skills) in their first or second language.

### 4. Introducing workplace design and engineering software as LMS

From 2002, the eM-Human and eM-Workplace modules of the eManufacturing software suite will be used to train Industrial Engineering students in a number of courses, including Work-study. Both these modules form part of the collection of engineering software. Whereas WebCT is designed as learning management system, eM-Human and eM-Workplace have been developed for workplace design and engineering purposes and therefore an unique learning approach is required.
The eManufacturing suite differentiates between planning, execution and engineering modules to tie in with the generally accepted three-layer business architecture. In a manufacturing environment, eM-Human and eM-Workplace should be linked, as shown in Figure 4. However, if these modules are used for education/training purposes, they have to be linked to an LMS (Figure 5), such as WebCT in order to manage the learning process.

**Figure 4: Interface with MES**

<table>
<thead>
<tr>
<th>MES</th>
<th>Humanly feasible work sequence; Execution time; Ergonomic constraints; Layout plan; Logistic analysis; Assembly times</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Work instructions; Work sequences; Resources; Product design information</td>
</tr>
<tr>
<td></td>
<td>eM-Human and e-Workplace</td>
</tr>
</tbody>
</table>

**Figure 5: Interface with LMS**

<table>
<thead>
<tr>
<th>MES</th>
<th>Problem solution; Techniques used; Learning objectives achieved</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Related learning objectives of other courses; Student proficiency profile; Assessment criteria; Learning/assessment event instructions; Formative and summative assessment</td>
</tr>
<tr>
<td></td>
<td>eM-Human and e-Workplace</td>
</tr>
</tbody>
</table>

The interface shown in Figure 5 is currently established only manually. Ideally, these systems should be linked electronically.

5. **Conclusion**

“It has long been known that industrial engineers have the technical training to make improvements in a manufacturing setting. Now it is increasingly being recognized that these
same techniques can be used to evaluate and improve productivity and quality in service industries."

As a result of the information revolution, e-learning, learning management systems and learning content management systems currently receive considerable attention from both systems engineers and educators. In this regard, the Industrial Engineering educator is in the unique position of understanding and contributing towards the engineering of the education industry whilst educating the industrial engineer.

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6 Lundy, J., Harris, H., (2001), E-Learning Suites Emerge: Prices Down, Functionality Up, Gartner Advisory, 18 June 2001,

7 McClellan, M., (1997), Applying MES, St. Lucie Press, USA.


17 WebCT (2002), [http://www.webct.com](http://www.webct.com)


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