TOWARDS THE SYSTEMATIC DEFINITION OF PROJECT-BASED DESIGN MODULES[1]

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Abstract
The need for improved knowledge management practices in higher education has long been acknowledged in the educational literature. This need is nowadays even more pertinent to engineering education because of the continuously changing contexts for educating future engineers. Project-based learning dealing with key aspects of product design and realization has been acknowledged by many academic institutions around the world as an appropriate means in the training of adaptable, reliable and responsive engineering students. It is proposed and maintained in this paper that the establishment of systematic practice in the definition of project-based design modules can have a central role in enhancing knowledge management in engineering education. To this end, Reflection Space–MP is introduced as an approach that can support academic staff to ensure that the content material of their design modules can be demonstrably aligned with a number of academic, industrial and societal needs. The paper details the key six L&T aspects of Reflection Space–MP and gives examples from its application for the planning of a new project-based engineering design module for Level 1 Mechanical Engineering students. Application of Reflection Space–MP has shown that it can serve as framework that can ensure that key planning perspectives of L&T have been considered and evidenced. As a result, actions for the definition, delivery and administration of a module can be determined in a systematic, evidenced and traceable manner.

Keywords: reflection space, action planning, module planning rationale, educational support tools, knowledge management in education

Introduction
The need for improved knowledge management practices in higher education has long been acknowledged in educational literature [1,2,3]. This need is nowadays even more pertinent to engineering education because of the continuously changing contexts for educating future engineers. Changes in engineering education have been originating from a number of factors ranging from a quest of technically advanced trained individuals to serve the evolving societal and industrial needs, to pressures to control the number of credit hours required to earn a degree, to accreditation criteria (e.g. UK-SPEC, QAA and ABET), and to a focus on student-centered learning and teaching approaches. The inclusion and integration of project-based modules into engineering curricula has been one of the most challenging action entailed from such changes.

Knowledge management is such a wide-open area of study that it is difficult to understand its implications for educational settings [2]. According to Kidwell et al [3] higher education institutions have "significant opportunities to apply knowledge management practices to support every part of their mission". Key to this is an understanding of knowledge management practices as applied at a corporate level. For example, Davenport et al [4] conducted a study of 31

[1] In the UK the term *module* is used for what is known in the US as a *course*; typically with a duration of one or two semesters.

knowledge management projects across 24 companies and identified four generic types of objectives (listed below) that corporate knowledge management practices satisfy.

1. *Create knowledge repositories* through a) external knowledge (e.g. competitive intelligence, market data and surveys, b) structured internal knowledge (e.g. reports, marketing materials, techniques and methods), and c) informal internal knowledge (e.g. discussion databases of “know how” or “lessons learned”).
2. *Improve knowledge access* through a) technical expert referral, b) expert networks used for staffing based on individual competencies, and c) exploitation of video conferencing to foster easy access to experts distributed around the globe.
3. *Enhance the knowledge environment* through a) changing organizational norms and values related to knowledge in order to encourage knowledge use and knowledge sharing, and b) asking customers to rate their provider's expertise.
4. *Manage knowledge as an asset* through attempting to measure the contribution of knowledge to bottom line success.

It is proposed and maintained in this paper that the establishment of systematic practice in the definition of project-based design modules can have a central role in enhancing knowledge management in engineering education (see objective 1b in the above list). To this end, the consistency and coherence, in which key perspectives of module planning[2] are considered and evidenced by teaching staff (see objective 1c), need to be both ensured and sustained.

Aim and structure of paper

This paper introduces an approach that enables teaching staff to capture the rationale of their module planning activities carried out during the definition of project-based design modules. To this end, such rationale can provide confidence to staff in their efforts to ensure, for example, that the content material of their design modules is continuously and demonstrably aligned with the needs of the changing contexts.

The paper is structured as follows. Firstly, factors that should be considered during the definition of modules, and specifically project-based modules, are outlined. Then, Reflection Space-MP is introduced as an approach to support the systematic, evidenced and traceable definition of project-based design modules, and key characteristics of it are detailed. Thirdly, an application of the Reflection Space-MP approach is presented and screenshots from a prototype software interface developed to support the implementation of the approach, in the context of improving knowledge management practice, are shown. The paper concludes with a discussion and the conclusions drawn from the development and application of the approach.

Key factors in project-based module planning

Nowadays, engineering students, once the “computer generation” babies, are able to learn very quickly to use CAD systems and are quite proficient in obtaining a near photographic rendering of objects. However, it has been experienced and acknowledged by many engineering teaching staff that, in a number of cases, students know little - if any - about difficulties associated with the manufacturing, assembling, testing and maintaining of mechanical components. For these reasons innovative teaching experiences aiming to make engineering students (especially

[2] The terms *module definition* and *module planning* are used interchangeably for the purposes of this paper.

mechanical engineering) aware of product complexities and challenges of product design and development have been introduced; such experiences are built around projects [5, 6, 7, 8].

Project-based design modules not only allow for the development of the students' design skills but also give opportunities for an improved understanding, and application where appropriate, of engineering science knowledge [8]. The invaluable role that project-based experiences can play to the learning of engineering students has been widely acknowledged in literature. For example, Andersson et al [8] note that understanding of, and abstraction from, real situations are vital skills for engineering design practice. Project-based design modules offer opportunities to the students to learn to develop abstract understanding by confronting concrete details of real problems; and thus, be able to build links between these problems and relevant abstract concepts [8, 9]. Other opportunities offered to the students relate to the development of transferable skills such as teamwork, communication and presentation that are vital for their professional conduct as engineers. It has to be acknowledged at this point that the planning and implementation of project-based experiences formed around is different and more complex than planning and delivery of traditional engineering modules. For example, development of a design-build-text (DBT) experience based on the CDIO standards not only needs to relate to the learning environment or the project task, but to a combination thereof [8].

A number of factors (e.g. students' intellectual demand and generic skills descriptors of outcomes) and activities (e.g. setting aims and objectives) need to typically be considered and carried out, respectively, when designing a module as shown in Figure 1.

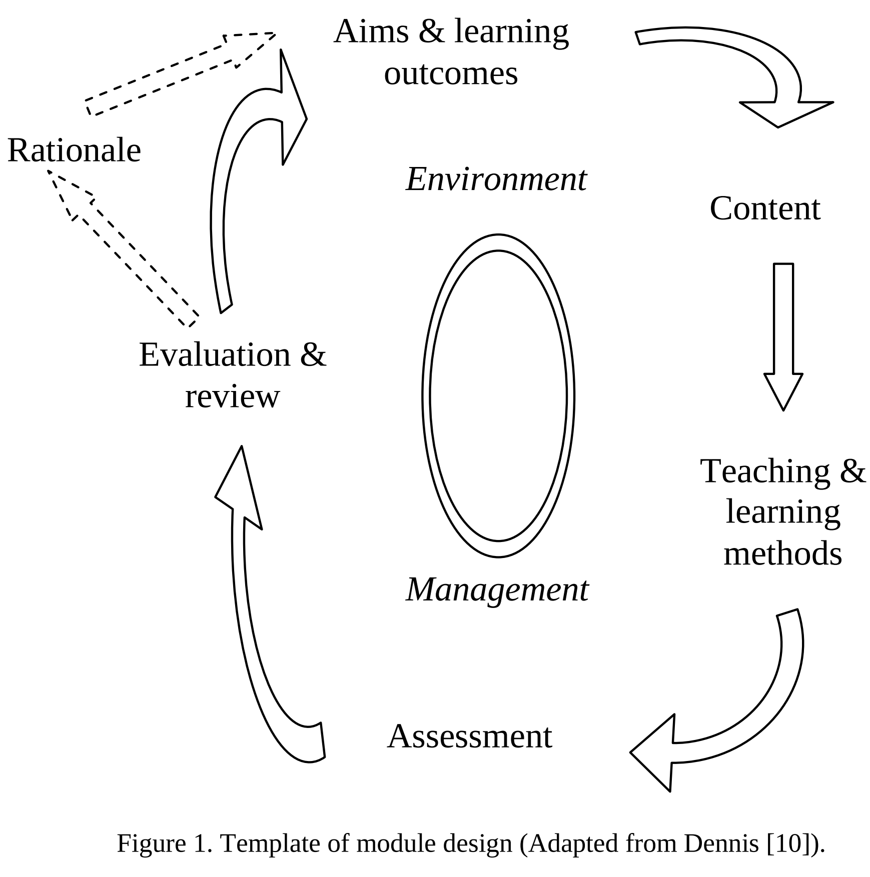

Figure 1. Template of module design (Adapted from Dennis [10]).

Andersson et al [8] highlighted the importance of the following areas to the definition of project-based modules in the context of developing DBT experiences aligned with the CDIO standards.

- Identification and establishment of essential and desired features of a DBT experience
- Statement of learning objectives (including development of content and skills matrices)
- Selection of pertinent learning and teaching methods (characterized through the three-level scale of Introduce-Teach-Utilize).
- Selection of pertinent assessment methods (including identification of key assessment criteria, traits and dimensions that need to be reflected to marking schemes, and definition of scale points to assess different levels of quality).
- Alignment of learning objectives with learning and teaching, and assessment methods.
- Management of DBT modules (including getting the ‘climate’ and ‘environment’ right)

It has been acknowledged that the learning and teaching benefits gained by project-based modules do not come for free; DBT experiences may also be costly, time-consuming, often require new learning environments and varied specialized academic staff competence [8]. Therefore, constraints that arise from such situations may inhibit the effective, efficient and smooth delivery of project-based design modules. Furthermore, finding appropriate balances between opportunities and constraints may result in more complex situations than those encountered when developing and teaching traditional modules. For example, balancing opportunities that arise from learning environments and project tasks, and constraints identified in combining both of them [8].

There is still a lack of systematic tools for the design of design-based learning experiences [6, 7, 8]. For example, Figure 1 shows that although activities associated with the capture of the rationale, which underlies the design of a module, play an important role in the definition and/or update of the aims and learning outcomes of a module these activities may not explicitly be undertaken and/or documented (dotted-line arrows in Figure 1). Considering this, teaching staff who plan and lead such modules could benefit from a systematic way to take into consideration both opportunities and constraints pertinent to the delivery of project-based design modules.

An approach to support systematic, evidenced and traceable module planning

The significant role of careful module planning in sustaining the quality of learning and teaching activities at high levels has been acknowledged by many authors [e.g. 5-12]. A key aspect in module planning relates to the underlying rationale upon which decisions about, for example, learning and teaching outcomes, and assessment methods are made. Central to effective module planning practices is the use of approaches that can ensure consistency in the way in which key perspectives of module planning are considered and documented.

The approach presented in this section is based on an edited version of Reflection Space [13,14]. This is a means of representing the nature, or perspectives, of reflection required on learning and teaching (L&T). Reflection Space has been applied and evaluated to a number of L&T contexts so far as an approach to support the systematic, evidenced and traceable individual reflection practice of teaching staff. For the purposes of this paper, Reflection Space has been edited to include key needs of teaching staff. To this end, *Reflection Space–MP (Module Planning)*, shown in Figure 2, is proposed as an approach to support the establishment of systematic, evidenced and traceable module planning practice.

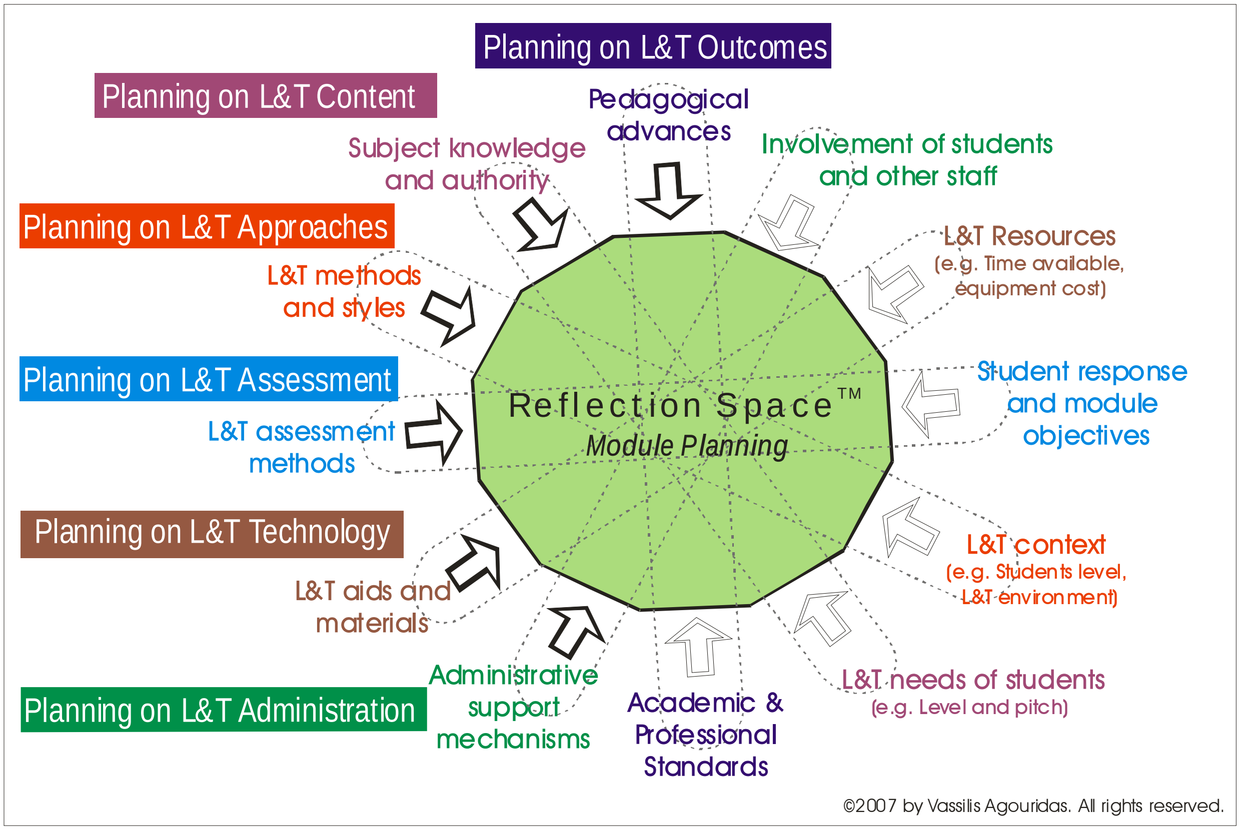

Figure 2. Module Planning version of Reflection Space The characteristics of Reflection Space–MP and its six key learning and teaching (L&T) module planning perspectives.

Reflection Space–MP is a means of representing the nature, or key perspectives, of a module's L&T planning. The represented perspectives are not exhaustive. Figure 2 shows six principal perspectives, which need to be considered during module planning, as they originate from the formation of six pairs. These six pairs provide a framework for planning L&T activities in a holistic and consistent fashion. That is, they firstly bring to the attention of teaching staff key factors that could affect the effectiveness of L&T activities, and they secondly bring such factors together into a unique plane of reference. In this way, the risk of neglecting these factors, which may have previously been overlooked or even unarticulated on their potential effect on the quality of L&T activities, can be minimized.

Opportunities and constraints in Reflection Space–MP

Each of the six pairs consists of two characteristics, or factors, and thus resulting in a total of twelve key factors that support module planning practice. Figure 3 shows that these factors, which at a high-level can be classified either as opportunities or constraints, are topics of module planning practice that teaching staff should be encouraged to explore and integrate.

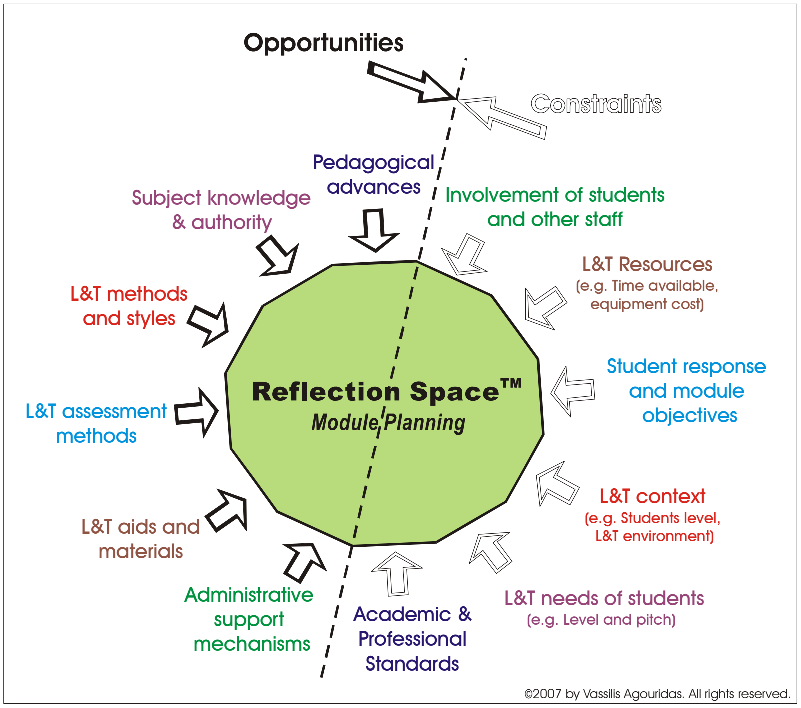

Figure 3. Opportunities and constraints in Reflection Space–MP.

The following list details these opportunities and constraints for each of the six pairs or L&T perspectives:

- *Planning on L&T Outcomes* – The factors of pedagogical advances, and academic and professional standards are classified as opportunities and constraints respectively. This is because although teaching staff may wish to consider and a number of pedagogical advances available to them (e.g. deep learning theories, taxonomies of educational objectives and the CDIO philosophy; i.e. opportunities for improving pedagogy) consideration, and potential implementation of them, should be aligned with the satisfaction of accreditation criteria, or standards, specified by recognized academic and professional organizations (e.g. institutions, societies, agencies, boards and councils such as the Quality Assurance Agency for Higher Education and the Engineering Council in the UK, and ABET in the USA; i.e. constraints on an immediate adoption of pedagogical advances). In the case of CDIO collaborators constraints may arise from meeting CDIO standards. During their module planning practice teaching staff can explore and evidence their rationale with regard to the alignment, and appropriateness, of the considered pedagogical advances (e.g. tools for the definition of L&T objectives) with the standards set by the relevant academic and professional organizations.
- *Planning on L&T Content* – The factors of subject knowledge and authority, and L&T needs of students are classified as opportunities and constraints respectively. This is because although teaching staff may be recognized as experts in their subject area (e.g. internationally reputable and published; i.e. opportunities for disseminating cutting-edge knowledge) decisions on both the depth of the disseminated knowledge and its translation to L&T material should be justified by the identified L&T needs of students (e.g. L&T material pitched at the "right" level and time; i.e. constraints on the dissemination of

cutting-edge knowledge). During their module planning practice teaching staff can explore and evidence their rationale with regard to the degree to which both the disseminated knowledge and the L&T material developed to disseminate this knowledge (e.g. definitions of DBT experiences using CDIO templates) will be satisfying, and aligned with, the L&T needs of the students. This is necessary in order to early discourage the case of knowledge dissemination for the sake of knowledge dissemination; a case that could possibly be the aim of scientific journals but certainly not of L&T material and especially not of DBT experiences.

- *Planning on L&T Approaches* – The factors of L&T methods and styles, and L&T context are classified as opportunities and constraints respectively. This is because although teaching staff may have a number of methods and styles available to them (e.g. invited specialist lectures, design studios and model making sessions; i.e. opportunities for delivery) selection of them should be justified and supported by the context of L&T (e.g. students level, staff expertise and availability as well as availability of suitable learning environments; i.e. constraints on the delivery). During their module planning practice teaching staff can explore and evidence their rationale with regard to the applicability, effectiveness and appropriateness of the selected L&T methods and styles to the given L&T context. For example, in the case of DBT experiences it is important that the chosen learning environments show a large variation in purpose, facilities, equipment and investment [8, 15]. In addition, DBT experiences very often require significant amounts of time devoted to students coaching (opportunity) which may be insufficient because, for example, of the given research pressures that faculty have to cope with in conjunction with a lack of sufficient teaching support staff (constraint).
- *Planning on L&T Assessment* – The factors of L&T assessment methods, and student response and module objectives are classified as opportunities and constraints respectively. This is because although teaching staff may have a number of assessment methods available to them (e.g. portfolio student work, student presentations and design review reports; i.e. opportunities for evaluating students' skills) selection of them not only should it be aligned with the already defined module learning and teaching objectives but also informed by students response/perception on certain methods or formats of assessment (e.g. students unwillingness to be solely assessed based on team-work, and students' lack of appreciation of the importance of design review reports and hence of lack of committed effort; i.e. constraints on evaluating students' skills). During their module planning practice teaching staff can explore and evidence their rationale with regard to the appropriateness and students' 'acceptance' of the selected L&T assessment method. For example, in the case of DBT experiences teaching staff make sure that the chosen assessment methods address, as also highlighted by Andersson et al [8], both the design/development process and the final product. That is, a functionally excellent technical solution does not necessarily imply clear and detailed documentation of its development process. Likewise, systematic work does not necessarily result in a functional prototype or innovative product [8].
- *Planning on L&T Technology* – The factors of L&T aids and materials (technology), and L&T resources are classified as opportunities and constraints respectively. This is because although teaching staff may wish to use certain technology to support their L&T activities (e.g. use of an electronic voting system, and online interactive L&T material and assessment; i.e. opportunities for using L&T aids) decisions on the acquisition and/or use

of such technology should be justified by the available L&T resources (e.g. cost of ownership and/or use, and time required to develop or learn to use certain technologies; i.e. constraints on the use of L&T aids). During their module planning practice teaching staff can explore and evidence their rationale with regard to the degree to which the planned L&T aids and materials can benefit the satisfaction of the defined L&T objectives whilst taking into account the resources involved in satisfying them. This is necessary in order to ensure at an early stage the sustainable use of the selected L&T materials and aids.

- *Planning on L&T Administration* – The factors of administrative support mechanisms, and involvement of students and other staff are classified as opportunities and constraints respectively. This is because although teaching staff may have or develop a number of administrative mechanisms to support their activities (e.g. online student laboratory attendance, module micro-websites, collection of student feedback and tools like Reflection Space-MP; i.e. opportunities for efficient module administration) planning on the use of such mechanisms should be made on the basis of fostering students and other staff participation and involvement (e.g. students availability in giving feedback and staff committed activities; i.e. constraints on obtaining meaningful participation from students and staff). During their module planning practice teaching staff can explore and evidence their rationale with regard to the degree to which the selected administrative mechanisms can be effectively used and exploited whilst taking into account the required involvement of students and other administrative, clerical and technical staff. This is necessary in order to gain early on the commitment of key staff as well as to ensure the sustainable use of the selected administrative support mechanisms. For example, project-based design modules often have increased administrative demands ranging from timetabling a variety of L&T activities (e.g. lectures, workshop/seminar sessions, laboratories and design clinics), to issuing marks and feedback comment to the students, to allocating students to laboratory groups, to forming project-team groups, to making announcements, to contacting sponsors and to carefully reviewing the effectiveness of the delivered project-based design experience (e.g. through collecting feedback from students, other staff and sponsors).

Consideration of the above discussion as well as of Figures 2 and 3 indicates that Reflection space–MP can support continuous monitoring, firstly, of an alignment between L&T objectives and L&T methods and styles, assessment methods and technology, and secondly, of an availability of the administrative support required to enable achievement of the module L&T outcomes defined. Such support can be ensured by the fact that Reflection Space–MP provides a platform upon which meaningful explorations and considerations can be developed and evidenced; and hence it can serve as a means of capturing the rationale behind any module planning decisions.

Action planning informed by Reflection Space–MP

Reflection has been widely defined and perceived as an activity by which one looks back and learns from actions already carried out and/or situations experienced in view of identifying actions to improve, in the case of an educational environment, L&T activities and experiences. Taking this into consideration, Reflection Space [13, 14] was originally developed to support systematic, traceable and evidenced reflection practice. An edited version of it, namely Reflection Space-MP, has been introduced in this paper to support the systematic capture of the planning rationale that underlies the definition of new, or revised, project-based design modules. At this point, it may be noticed a paradox, or etymological contradiction, as reflection relates to looking backwards whereas planning relates to looking forward. The genuine question that may arise from this is ‘how can one look forward by looking backwards?’. It is worth clarifying that the term reflection is used for the purposes of Reflection Space–MP to refer to mental concentration; therefore, Reflection Space–MP is associated with a careful consideration of module planning activities and as such it allows for *forward reflection;* a term used to refer to systematically dealing with, and addressing, key planning aspects of project-based design modules

It can be identified by taking into account the term of forward reflection as well as the illustrations of Figures 2 and 3 that application of Reflection Space–MP to support activities of project-based design modules definition could ensure that key planning perspectives of such activities could be sufficiently explored, considered and evidenced. As a result, both the scope and specific actions for implementing and delivering project-based design experiences (e.g. through a DBT project) could be determined in a systematic, traceable and evidenced manner.

Example application of Reflection Space–MP

This section outlines an application of Reflection Space-MP to support the definition of a new Level 1 project-based design and manufacture module in the School of Mechanical Engineering at the University of Leeds. It should be noted that the reported application refers to ongoing work and thus is not complete. The application has been facilitated by a prototype software interface developed to support the systematic, traceable and efficient documentation of module planning activities.

Background to the example application

The planning of the new module has taken place in the context of changes to the structure of a number of programs of study available from the School of Mechanical Engineering. A major change in the structure has been a transition from semester-based modules to year-based modules (implementation of changes due for the 2007-08 academic session). Based on this, the new Level 1 Design and Manufacture module will be seamlessly running throughout the year from 2007-08 onwards.

Capturing the module planning rationale through Reflection Space–MP

The planning activities have been informed by a number of sources including the documentation of previous design and manufacture modules, the experience of the module leader and other academic staff who lead design and manufacture related modules, informal discussions with a number of other academic, technical and administrative staff, student feedback from currently taught Level 1 design and manufacture modules and consideration of the most up to date professional and academic standards available by the UK Engineering Council and Quality Assurance Agency for Higher Education (QAA). Reflection Space–MP has been used to facilitate the capture of the rationale behind the module planning activities. Specifically, Tables 1 to 6 give examples on structuring and evidencing module planning practice with reference to the systematic definition of project-based design modules through the six L&T perspectives of Reflection Space–MP. The comments/notes found in the tables are informal nature and of relaxed coherence as they represent ‘thinking aloud’ forward reflection personal initial comments rather than a formal documentation of a module’s definition.

Table 1: Example of structuring and evidencing module planning on L&T Outcomes through Reflection Space–MP

Module Planning Perspective: **Planning on L&T Outcomes**	
Pair	Planning (forward reflection) comments/notes
Opportunity: Pedagogical Advances	I have recently come across a number of papers that describe success stories and challenges from the implementation of a problem-based learning (PBL) approach for the delivery engineering, and product, design modules (e.g see papers from ICED'05 and Journal of Engineering Education). I have also been looking at the CDIO initiative. I should explore to what extent the CDIO philosophy supports a PBL approach and can address challenges associated with assessment and explicit links between L&T objectives and project/task characteristics. I have noticed that the CDIO syllabus encourages systems thinking. I need to explore how I could possibly implement CDIO recommendations for incorporating systems thinking within the projects that I will define. The definition of L&T objectives could be informed from the objectives of previous design and manufacture modules whilst considering feedback from other academic staff and from students. Actions: Find CDIO documentation and relevant literature and identify what aspects of the CDIO syllabus can inform, or be associated with, the definition of L&T objectives for the new module. Confirm final list of L&T objectives.
Constraint: Academic & Professional Standards	I need to confirm that that L&T objectives defined based on the objectives of previous design and manufacture modules are aligned with the most up to date benchmark statements published by QAA. In addition, according to the UK-SPEC published by the Engineering Council students should understand the requirement for engineering activities to promote sustainable development. I need to introduce a project that will explicitly deal with sustainable development aspects. Actions: Identify key aspects of sustainable development that should be addressed by the development of a project for the students. Confirm alignment of L&T objectives with QAA standards.

Table 2: Example of structuring and evidencing module planning on L&T Content through Reflection Space–MP

Module Planning Perspective: **Planning on L&T Content**	
Pair	Planning (forward reflection) comments/notes
Opportunity: Subject knowledge and authority	The project context and tasks should be selected through consideration of the module L&T outcomes. The current Design and Make project seems to e appropriate. The new sustainable development project should relate to real world problem situations and could relate to the energy/power sector which would be pertinent to Mechanical Engineering students. Also, some of the existing industrial contacts are from the energy/power sector and could contribute (invited lectures) and sponsor the project. Actions: Use a content material – L&T outcomes matrix not only for the lectures material but also for the project tasks. Contact industrial contacts to explore their interest and commitment to support a sustainable development project.
Constraint: L&T needs of students	It is anticipated that because this is a Level 1 module many students may not demonstrate the required initiative to undertake actions (issues that relate to a transition from a secondary education to a tertiary education (University) environment). Therefore, initial project tasks should focus on promoting team collaboration and communication rather than being intellectually challenging activities. The importance of team working to the realization of engineering projects should be emphasizes during the introduction to the module. The difficulty of the projects tasks need to also be considered. As noted by Andersson et al [8] “a too difficult task may result in students as mere ‘implementers’. A too simple task may on the other hand not promote motivation nor build the self-confidence that result from having met a challenge, which are two of the most significant benefits of DBT projects. The students’ high involvement in the DBT task can also create problems with keeping time-balance to other courses”. An appropriate balance between team work and individual work should be sought through the definitions of the projects tasks. However, because of the nature of the projects it is anticipated that the majority of the work will be team-based. I also need to consider issues associated with changing the formation of team members as well as identifying the optimum number of team members for each project. I could consider the recommendations made by Johnson et al [16] who suggest that student accountability can be improved if the students are assigned to teams of four to five. There is a need for the students to develop systems thinking skills (CDIO syllabus). The sustainable development project seems as an appropriate opportunity not only to introduce systems thinking practices (requirement by CDIO syllabus) but also to promote sustainable engineering practices (UK-SPEC requirement). Actions: Make sure team working is emphasized to the students early on and that the initial tasks of the projects are promoting team work. Establish best practice for forming teams and determine appropriate number of team members for each project. Reconsider difficulty level of the Design and Make project and define level of difficulty for sustainable development project (discuss with Visiting Professor of Sustainable Design). Define project tasks (especially for the sustainable development project) that can develop students’ system thinking skills (seek for CDIO recommendations; e.g. consider a table developed by CDIO that lists essential and desired features of DBT experiences).

Table 3: Example of structuring and evidencing module planning on L&T Approaches through Reflection Space–MP

<table>
<tr><th colspan="2">Module Planning Perspective: Planning on L&T Approaches</th></tr>
<tr><td>Pair</td><td>Planning (forward reflection) comments/notes</td></tr>
<tr><td>Opportunity: L&T methods and styles</td><td>The module L&T methods and styles will initially build on the previously taught design and manufacture modules styles (i.e. less lectures and more time for project work). This is not only acceptable for project-based design modules but rather preferable. As noted by Andersson et al [8] a traditional series of lectures would probably not be the choice but a few selected lectures might be needed “to get started” in the beginning of the module or in order to start a specific phase of the project. That is, the module design would then typically be based on a limited number of lectures, and a high fraction of coaching. To this end, I should consider the introduction of engineering clinics. This is going to be crucial since the students should be enabled to learn through doing rather than learn through being told.

The students should be encouraged to experience the iterative nature of the design process. For example, the project tasks should allow for the preparation of product specifications (derivation of design requirements), the development of initial product concepts (e.g. through functional structures and concept combination/morphological matrices), the justification for any changes or updates, the evaluation and selection of ‘best’ concept (e.g. objectives trees and decision matrices) and the production of physical prototypes as necessary (e.g. by making use of CAD/CAM and model making facilities). The project tasks should play a central role in enabling the students not only to identify engineering knowledge required for the completion of the project tasks knowledge but also to test out the extent to which that knowledge works in practice (e.g. selection of materials and manufacturing processes and trade-offs between them).

<u>Actions:</u> Determine and schedule required lectures, engineering clinics and model making sessions. Determine, and reconsider as appropriate, the projects’ tasks (for both the design and make, and the sustainable projects) – seek advice from the CDIO resources.</td></tr>
<tr><td>Constraint: L&T context</td><td>The introduction of engineering clinics will require extra teaching staff with design and manufacture expertise. Also sufficient model making space and tools should be available to the students.

<u>Actions</u>: Identify CDIO and other resources (e.g. health and safety publications) to discuss requirements for staff and space with other academic staff who are involved in the teaching of design. Communicate these requirements to senior colleagues within the School (Director of L&T and the Head of School). Identify CDIO tools than can support the definition of project tasks that match to the students’ level.</td></tr>
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Table 4: Example of structuring and evidencing module planning on L&T Assessment through Reflection Space–MP

Module Planning Perspective: **Planning on L&T Assessment**	
Pair	Planning (forward reflection) comments/notes
Opportunity: L&T assessment methods	A variety of assessment methods will be used to make sure that achievement of L&T objectives and the development of transferable skills are appropriately evaluated (e.g. design review reports to assess students reflection and technical writing skills, poster presentations to assess their ability to abstract key information, and graphically and orally present it). Marking schemes should be used for all the assessed work and should be communicated at an appropriate time to the students. <u>Actions:</u> Develop a learning outcomes and assessment methods matrix (see also relevant CDIO IRMs and other resources). Develop, or update, marking schemes.
Constraint: Student response and module objectives	Marking schemes should be available to the students early on. When defining marking schemes for the project-based tasks, and to align with CDIO standards, I should make sure that these will be assessing both the design/development process and the final product. As noted by Andersson et al [8], “a functionally excellent technical solution does not necessarily imply clear and detailed documentation of its development process. Likewise, systematic work does not necessarily result in a functional prototype or innovative product”. Think carefully of how the project deadlines are spread. Avoid tight deadlines. Also consider issues associated with the formation of project groups and the number (min. and max.) of team members per group. Feedback to the students should be given within specified time and in accordance to the School’s code of practice of assessment. This code should also be considered for other aspects of assessment. Posters to be digitally prepared by the students and to be presented through projection systems. This could further promote sustainability principles. <u>Actions:</u> Make sure that all assessment methods are aligned with both the School’s code of practice of assessment and the CDIO assessment recommendations. Discuss with module administrator project groups issues. Communicate to IT staff requirements for digital submission of posters by students

Table 5: Example of structuring and evidencing module planning on L&T Technology through Reflection Space–MP

Module Planning Perspective: **Planning on L&T Technology**	
Pair	Planning (forward reflection) comments/notes
Opportunity: L&T aids and materials	A new CAD system will be used for the tasks of design laboratories. A model making area will be used for the purposes of the design and make project. All the necessary tools will be provided to the students. Actions: Ensure that all staff involved in the design laboratories will be receive training for the new CAD system. Contact technicians to confirm availability of model making tools.
Constraint: L&T Resources	The use of a new CAD system will result in the need to update the lecture and the design laboratories materials accordingly. An enhanced model making area will be required to support students' prototype development activities. The following are comments quoted from internal communication between staff responsible for the delivery of design and manufacture modules within the School. "We considered the resources required should we wish to move the first year buggy building exercise into the two week January exam period. If there are 150 students (30 or 32 teams), each team requires 12 to 15 hours of model making time, and we need the buggy building activity to fill no more than half the available time (to allow time for solid and assembly modeling, review and reflection and the buggy race itself), then we need space for 50 students, working 10 teams in teams of five, in three hour shifts over four or five days. We have in mind each team working around a separate workbench. According to the governments guidelines on space for similar sorts of areas in secondary schools, an area of up to 180 square meters is required for this many students … Should we proceed with a plan of this sort, we would need the support (i.e. time) of other members of staff to supervise the model making activity. In particular, we would need staff to provide tutorial-like 'clinics' for the teams to make sure that they are applying some engineering science to their buggy designs. We've not yet thought about time requirements on lab technicians." Actions: Confirm with senior management within the School the availability of an enhanced model making area. Update L&T material to reflect features of the new CAD system (contact CAD technicians as appropriate)

Table 6: Example of structuring and evidencing module planning on L&T Administration through Reflection Space–MP

Module Planning Perspective: **Planning on L&T Administration**	
Pair	Planning comments
Opportunity: Administrative support mechanisms	A module web page will be developed to support the delivery and administration of the entire module. Transition from semester-based to year-based delivery may affect the structure of the module delivery and hence the timetabling of design lab sessions and engineering clinics. Furthermore, the anticipated introduction of engineering will require clinics will require further administration in recording student attendance. Actions: Prepare material for new module web page. Closely collaborate with the module administrator and the student support office. Explore with IT staff and the module administrator the development of an online system to record student attendance at design labs and engineering clinics.
Constraint: Involvement of students and other staff	The module web page should conform to the new standards and formats encouraged the University (templates will be available during summer). Module review, at the end of the academic session, requires feedback from students and staff. Regular feedback should be sought from students (especially for newly introduced projects and activities). It has to be considered that students may be reluctant to give meaningful feedback if asked when their workload is heavy (e.g. periods of tight deadlines for a number of modules) Actions: Contact IT staff to explore requirements for new templates of module web pages. Schedule appropriate times to receive feedback from students (i.e. during a lab session)

Action plan for completing the module planning

Tables 3 to 6 showed how Reflection Space–MP facilitated an exploration and consideration of key aspects of the module design process. Based on this, a number of actions have been identified in the context of implementing, operating and delivering the new project-based module. Table 7 gives a possible format of a table for the documentation of the actions identified from a forward reflection through Reflection Space–MP. It is assumed that before proceeding with the definition of any action plan a draft, at least, list of L&T module objectives has been developed.

Table 7. An example of a possible format of action planning informed by Reflection Space–MP

L&T Module Objective	Relevant CDIO Standard(s)	CDIO Proficiency Level	Aspect of Reflection Space-MP	Action Required	Responsibility *(who's going to accomplish that objective)*	Timeline *(when the implementer is going to be accomplish that objective)*
All	12	n/a	L&T Administration	Schedule appropriate times to receive feedback from students	Module Leader	20th Sept 2007
Model simple components and assemblies for manufacture by common manufacturing processes.	2, 9	4	L&T Technology	Update L&T material to reflect features of the new CAD system	Module Leader and CAD technicians	05th Sept 2007
All	11	n/a	L&T Assessment	Make sure that all assessment methods are aligned with both the School's code of practice of assessment and the CDIO assessment recommendations.	Module Leader	05th Sept 2007
All	5, 7, 8	n/a	L&T Approaches	Determine and schedule required lectures, engineering clinics and model making sessions	Module Leader	20th July 2007
Describe and present sustainable development issues in the realisation of consumer and industrial products	2, 4	3	L&T Content	Contact industrial contacts to explore their interest and commitment to support a sustainable development project	Module Leader	10th Sept 2007
All	2, 12	n/a	L&T Outcomes	Confirm alignment of L&T objectives with QAA standards.	Module Leader	30th July 2007 & 2008

Overview of a prototype software interface for Reflection Space–MP

A prototype software interface has been under development in view of improving the effectiveness and efficiency by which activities involved in the use of Reflection Space–MP are carried out. Figures 4 and 5 give overview screenshot of the prototype. The vision is that the Reflection Space–MP software will be web-based in order to facilitate knowledge access and dissemination between academic staff.

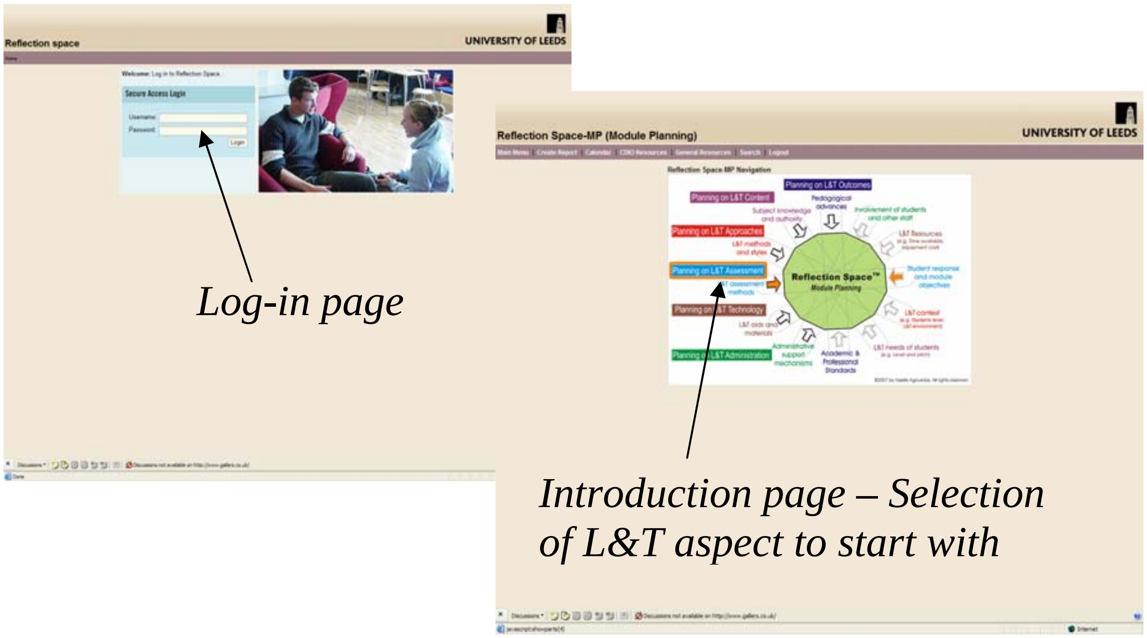

Figure 5. Screenshot log-in and introduction page of the Reflection Space–MP software prototype.

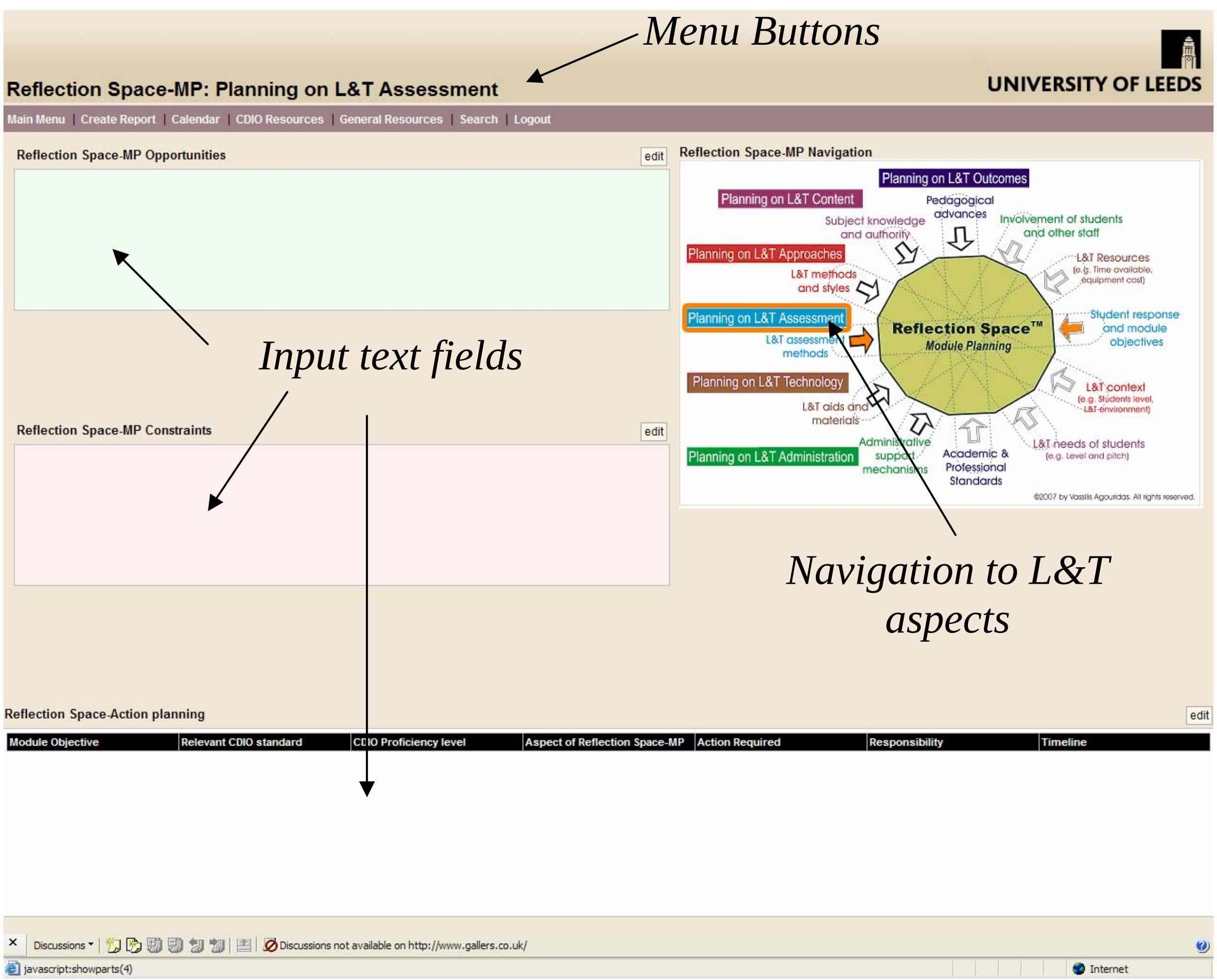

Figure 6. Screenshot from the Reflection Space–MP prototype's main workspace.

Discussion and conclusions

The ever changing needs of engineering education needs include those of more efficient and effective means in linking mainstream engineering advances with engineering practice. For example, a number of European Universities (e.g. in Spain and Italy) have reconsidered their engineering curricula as a response to the Bologna Declaration signed in 1999. The resulted reforms included a transformation from the traditional five-year program to a three-year degree optionally followed by two-year postgraduate (specialization) degree. One of the stated aims of the three-year degree was the preparation of younger engineers having professional skills needed in industry that were not satisfied with the traditional, over-educated, five-year engineering graduates. Project-based learning dealing with key aspects of product design and realization has been acknowledged by many academic institutions around the world as an appropriate means in the training of adaptable, reliable and responsive engineering students.

This situation makes it all the more necessary to have in place effective knowledge management structures to support teaching staff during their module management activities (e.g. definition or update of a module). Such structures should allow for traceability between key L&T aspects so that academic staff can be empowered in dealing with the continuously changing contexts for engineering education and hence keeping design syllabuses aligned with the needs of such contexts. Reflection Space–MP is introduced in this paper as an approach that can support academic staff to ensure that the content material of their design modules can be demonstrably aligned with a number of diverse needs (e.g. academic and industrial), and thus can enable them to tune in better with the dynamics of societal, student and industrial needs.

The paper details the key six L&T aspects of Reflection Space–MP and gives examples from its application for the planning of a new project-based engineering design module for Level 1 Mechanical Engineering students. Screenshots from the development of a prototype software interface aimed to support application of Reflection Space–MP are given. Application of Reflection Space–MP has shown that it can serve as framework that can ensure that key planning perspectives of L&T have been considered and evidenced. As a result, actions for the definition, delivery and administration of a module can be determined in a systematic, evidenced and traceable manner.

It is envisaged that Reflection Space–MP could be used in the context of the CDIO initiative as a tool that could bring together all the different CDIO resources developed to assist academic staff to be more effective and efficient in the definition and delivery of DBT experiences.

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