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ENHANCING DESIGN LEARNING USING A DIGITAL REPOSITORY

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1 Introduction

The process of design is context dependent and open-ended, and therefore does not revolve around a specific body of information or knowledge. The educational paradigm shift in the area of engineering design from teaching to coaching and the increased use of social constructivist learning ideals requires students to have access to as wide a range of information as possible. Digital resources provide an excellent opportunity for extending the range of information available to design students and to this end, as part of a joint research program with Stanford University, the University of Strathclyde has developed a groupware product called LauLima to provide students with a collaborative environment which allows them to gather, organise, store and share information. This paper describes the improvement to design learning, based on a Design Knowledge Framework, in a 3rd year product design engineering project from session 03/04 to 04/05 which has been facilitated by the implementation of this technology.

2 Background

DMEM (the Department of Design, Manufacture and Engineering Management) at the University of Strathclyde has built expertise in the implementation of digital technologies in the design domain to help aid student learning over a number of years [1]. There is also an emphasis in the department in trying to contextualise the learning students undertake. To this end, there is a series of project-based classes categorised as Integrating Design Project (IDP), the aim of which is to integrate, apply and expand on knowledge gained from theoretical classes in their curriculum. In order to enhance the student learning experience, the department has developed a web–based groupware product called LauLima (http://onlinelearning.dmem.strath.ac.uk/laulima/tiki-index.php), which helps students store, share, structure and apply information when they are working in design teams. The deployment of LauLima has enhanced student learning on a number of levels including design methodology, coaching and teamworking. The class has been restructured in a number of ways to utilise the benefits of the groupware, and student reaction to the changes has been monitored. All improvements are outlined in the context of a Design Knowledge Framework [2].

2.1 Educational aims and objectives

In engineering design, there has been a shift from strongly empirical forms of design theory towards more learner-centered approaches which take account of human and social factors in the design activity [3]. This is concomitant with the general educational movement towards

Vygotskian constructivism [4], where social interaction with the outside world (in this case in the design studio) is thought to be fundamental in developing internal knowledge [5]. While still assuming there is a process of assimilation from the lecturer or coach, this recognises that, "…the learner is much more actively involved in a joint enterprise with the teacher of creating new meanings [6]". In product design engineering in particular, the application of knowledge to creative thoughts and ideas allows the designer to develop new product configurations. DMEM has therefore tried to foster a creative studio environment where students are free to develop and form new ideas. The studio is an informal and social space, whether the student is working individually or in a design team. The key to the Integrating Design series of projects run by DMEM is to then combine the creative design process with the theoretical knowledge garnered in technical classes by working in design teams. Based on constructivist ideas, this contextualisation of knowledge occurs through design practice and interaction with peers, coaches and others. It is during this process that conventionally-delivered chunks of knowledge are used as building blocks to realise a design.

The Centre for Design Research at Stanford developed a 'Design Knowledge Framework' [2, Figure 1] to illustrate the interactions between a design team, coaches and the product development activity. This framework also effectively illustrates the educational issues within collaborative design projects. Whether working alone or in formal design teams, students in the design studio still work in a social context whereby they learn from friends, colleagues, team-mates and coaches in an informal context. A key element of the framework is the distinction between these informal and more formal aspects of practice and knowledge. The instructor, product development history and product development process (the essential structure and core teaching material of the class) are considered to be predominantly formal elements. Coaches, teams and product development practice are considered to be informal elements. The arrows represent the 'acquisition' or 'co-generation' of product development knowledge. The 'learning loops' of the model are therefore associated with different types of design activity and subsequent learning in the design studio- designing, coaching and capturing.

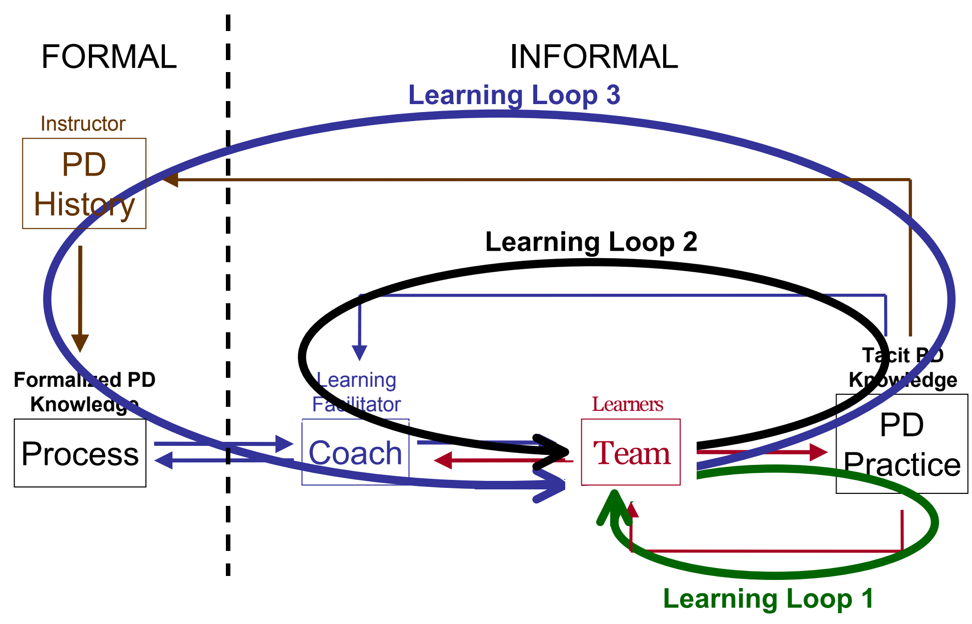

Figure 1. Three opportunities for technological intervention in enhancing design team learning performance.

3 LauLima

Groupware has been shown to provide a supportive environment for collaborative learning. [7]. When groupware is configured as a shared workspace it acts as a central repository for students to store and share resources. This offers great flexibility for students working in groups. They can access and update resources from any location and at any time and can collectively manage their workflow. In addition, constructing resource collections in shared workspaces can benefit learning especially when students are required to reflect on, and interact with, the information and resources they upload into the workspace [8].

The intention was therefore to improve the learning mechanisms in the Design Knowledge Framework through technological intervention. The system designed to support this activity was a customised version of open-source groupware called Tikiwiki (http://TikiWiki.org/TikiWiki). This provides standard document management facilities including file storage, image and web link galleries and Wiki pages (web pages that can be linked together and edited by multiple users). Students were asked to upload content into the file storage areas called file galleries. They were also asked to represent the development of the product using linked Wiki pages. These inter-linked Wiki pages were intended to help students work to develop a shared understanding of their design problem and solution. By the time of the second study the system name had been changed from the original name of TikiWiki to LauLima (Polynesian for 'group of people working together') to distinguish it from the original open-source system.

4 Project year 1

In project Year 1, there was an emphasis on studio-based design activity. It was a short, intensive project where students were asked to design and build a proof-of-concept model for a can crusher while using a digital environment to store, share, organise and record all design ideas and activities.

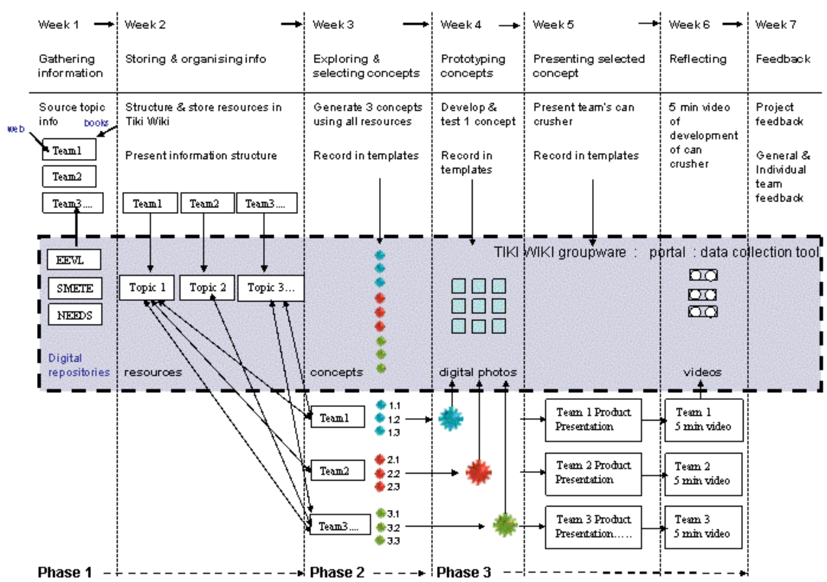

Figure 2. Project format in Year 1

The students were required to undertake a typical early stage design process (Figure 2) but with extra emphasis placed on information gathering and storing at the start of the project: each team created a resource site on a topic relating to a can crusher (recycling, market, user environment, mechanisms, aesthetics, ergonomics or safety) during Weeks 1 and 2. These were then utilised by the entire class in their subsequent design work. Additionally, documentation of design work in the form of scanned images and digital photos were required to be uploaded to the groupware environment to document the design process.

5 Project year 2

In Project Year 2, the design task was comparable to that of the previous year: to create a proof-of-concept model for an ice crusher. The project format was similar, but with less emphasis on broad information searching aspects and more on focussed searches, concept design and proof-of-concept modelling procudres. This was because of the limited time involved in the project. The project was organised and run over 6 weeks using a mixture of short mini-topics (a short lecture) and studio sessions, using LauLima as a digital repository and collaborative tool. Each team created a private domain where they could upload images and files, and create Wiki pages (similar to web pages) where they could build hierarchies and links for this information. This was then used as their means of presenting their work at the end of the project.

The students were learning primarily through the act of designing, and improvement of their learning experience was orientated around ensuring the level of structure and coaching they were given was enough to allow them to achieve all they could without inhibiting their creativity. The class was delivered in 2-hour sessions which were broken into a 30 minute ‘mini-topic’ – essentially a short lecture – and 90 minutes of studio time. The instructor delivered the mini-topic and then the coaching team (typically between 2 and 4 people) would coach the students informally while they were carrying out their design work. There were 70 students in the class and they were all expected to talk with a coach during the course of the session. Five main factors in the class structure which were altered from Year 1 to Year 2 have been related to the Design Knowledge Framework in Table 1. These are explained in more detail below.

Table 1. How class features relate to the Design Knowledge Framework

CLASS FEATURE	LEARNING LOOP
Teamwork & communication	1
Concept maps	2
Logs	2
Coaching	2
Mini-topics	3

5.1 Teamwork and communication

To create well-substantiated concepts, the designer is required to quickly grasp the pertinent subject matter, and research has shown that creating and sharing relevant documents can help in this [9]. A pool of laptops was secured by the department for student use, and these were made available to the teams to use in the studio during each 2-hour class. Students soon developed a habit of using a laptop to store and access information in parallel with their design activities during the class time. All class information and links were also posted on the class site, which was an additional incentive for habitual use of the system. This helped to ensure that their project files were located in one central area which could be accessed or added to by any team member at any time- not just in the studio. Teams could also communicate through this environment to aid synchronous and asynchronous working. Wiki pages could be updated dynamically, rather than having to exchange Word documents which require multiple versions of the same document in existence. These enhanced group communication mechanisms relate to Learning Loop 1 of the Design Knowledge Framework- students are learning from each other as they exchange ideas and information while working to complete the activities required in the project.

5.2 Concept maps

The students were required to do preliminary research on all aspects relating to ice crushing (ergonomics, mechanisms, safety, environment etc.) in order to be able to begin their idea generation work. Jonassen [8] has emphasised the importance of knowledge structuring for design learning, as it gives the students the opportunity to"actively inter-relate concepts, ideas, facts and rules with each other and with prior knowledge, the deeper the understanding and learning". In addition, for effective learning, it is student-generated knowledge structures that are important, not structures provided by instructors or coaches.

It was therefore decided to ask the students to build team concept maps (Figure 3) to help them to create knowledge structures to illustrate their conceptual thinking and to communicate it easily to others outside their team using LauLima. This was led by a learning technologist with a background in librarianship. The result of integrating information literacy within the class, particularly linking information and knowledge concepts to the design process, was that students were better able to understand the design problem and develop a strategy of information searching and retrieval which informed their subsequent idea generation. In many cases, teams identified what they thought were the main issues relating to ice crushing on the concept map, and these issues provided the driving ideas behind their concept generation. This activity was a direct result of lessons learned during Project Year 1 where students displayed a lack of understanding about retrieving, organising and understanding how information related to the design process.

The creation of a visual representation of the design problem that can be shared fits with Loop 2 of the Design Knowledge Framework in terms of externalising and discussing their conceptaulisation of the deisgn problem. The nodes of the concept map were intended to lead directly to information searches and relevant resources. In future, this might be one way of formally linking knowledge structures to resource structures stored in a formal digital library where students are accessing stored information (Loop 3). The interface of a digital repository should be tailored to the needs of the working designer and the design problem, and by crystalising and categorising the pertinent issues early in the process according to their impact on the design of the design output, it may be possible to organise subsequent project material gathered in a way which is responsive to the needs of designers and an alternative to the typical hierarchical structures of digital libraries. Additionally, the Design Knowledge Framework does not distinguish in formality between the discussions which take place with friends and colleagues and those which take place with team-mates and coaches. In future, the model could be refined to take account of this, as well as exploring further what can be regarded as 'tacit' knowledge in a design context.

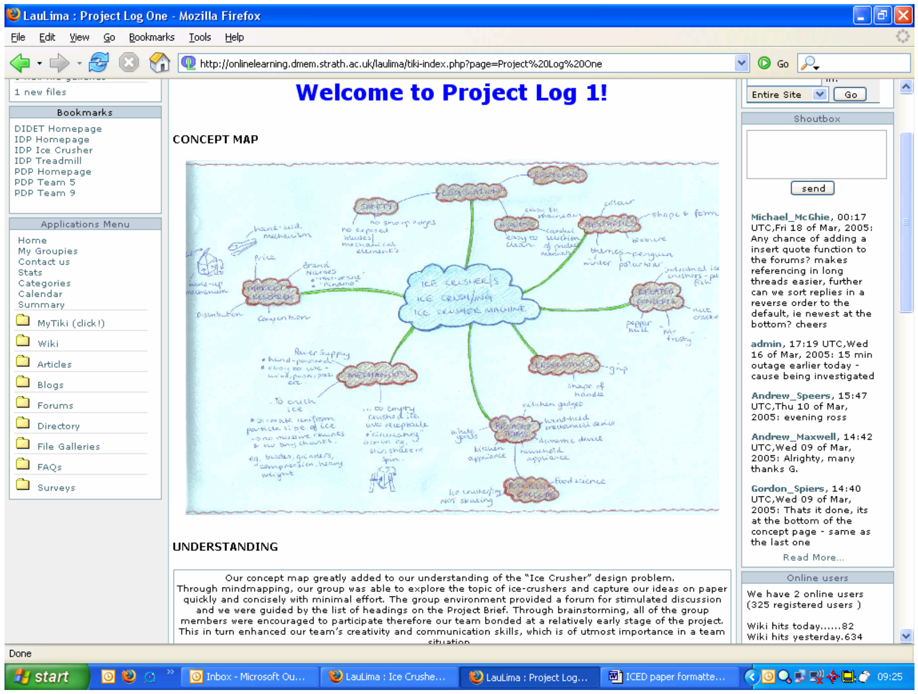

Figure 3. A concept map in the LauLima environment

5.3 Logs

A major problem in teaching design is the allowing students freedom to explore new ideas and to express themselves, while ensuring they meet set academic criteria. The IDP project was intended to emphasise rapid proof-of-concept designing, and therefore the class had a structure which was intended to help provide signposts to move students through the process quickly, while allowing them scope for variation and to develop a distinctive design. To this end, during the course of the project, the teams were asked to keep ‘project logs’. These took the form of on-line Wiki pages which were distributed at the relevant point in the process and required certain key tasks to be completed. In Project Log 1, teams were required to complete a concept map and search for information, in Log 2 generate and evaluate concepts and in Log 3 document concept development and modelmaking.

Because the students had already been storing all their gathered information and generated sketchwork in the shared environment, it was convenient for them to then present the information within this structured log (Figure 4). They were then forced to evaluate where they were in relation to the suggested project progress. The logs were not made compulsory, but students were encouraged to adhere to them with the knowledge that they could use the logs as a means of presenting their work at the end of the project. This equates to Learning Loop 2 on the Design Knowledge Framework, as students had to contextualise the design work they had done with the broader requirements of the class. In Vygotskian terms, the teams could work independently or consult with coaches depending on how they wanted to do it, thus allowing them to set the borders of their own proximal development zone. This attempt to scaffold the learning model allowed better teams to explore their ideas further but still within the class structure- an ideal advocated by Yorke [10].

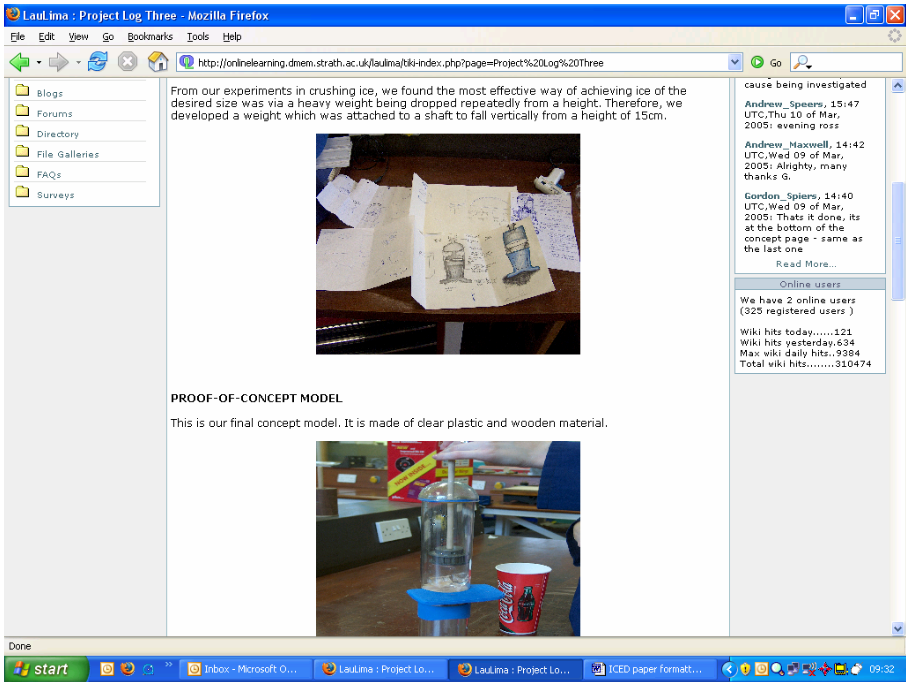

Figure 4. The LauLima environment used to document design work.

5.4 Coaching

The use of LauLima in the project depended on the students having sufficient information technology (IT) and information literacy (IL) skills to engage with the groupware and make effective use of it. They were therefore provided with a tutorial exercise before the project started and given a session discussing IL issues in terms of searching, storing and using design information. The learning technologist was able to provide support for students whenever necessary as the project developed. This is part of Learning Loop 2, although the associated IT skills are necessary for the communication support afforded by LauLima in Loop 1 and capturing of knowledge in Loop 3 to take place. DMEM is examining ways that IL support impinges on the learning loops of the model, and how this can be provided for future projects if a full time learning technologist is not available.

Another change to Project Year 2 was that coaches were allocated to specific teams, rather than floating during the studio time. This allowed the coaches to build a stronger relationship with the teams and their design directions, allowing for deeper engagement. Most teams would have a their own or a pool laptop with the LauLima site active while they were working in the studio. This allowed the coach to quickly check progress by browsing the site and discussing with the students what they had uploaded and the connections they had made between information, ideas and concepts. Dealing with just a few teams ensured that the coaches were more intimate with the decisions and directions each team made.

5.5 Mini-topics

Pugh [11] breaks the design process down into discrete stages, which the designer works through in a typical product development process, in an unaffected way. In all the project work set for the students, an effort was made to return a general development framework to illustrate how their work related to the broader process. The weekly mini-topics consisted of an outline of the types of activities the students should be working on, a discussion of relevant technical issues to that particular stage of the design process, and examples of the type of work they were expected to produce. This class framework informed both students and the tutor team and set the scene for the studio work- relating to Learning Loop 3 of the learning acquisition model.

The LauLima system proved to be of great benefit in helping to illustrate to students the type and quality of work expected of them: the class from the previous year had been through the same process of working, storing and presenting their work in the TikiWiki/LauLima environment. It was therefore extremely easy to select exemplars from last year's class to show students what was expected of them at each stage. This proved valuable, with the students' design activity observed to be more focussed and of better quality than the previous year.

Information gathered on how the students were working in project Year 1 allowed the framework of the class to be tweaked accordingly. For example, the previous year, students used a controlled convergence matrix [11] to choose between their concepts. This was inappropriate, as concepts should be more highly developed before using such a selection tool. In Year 2, it was possible to illustrate this vividly to the students by showing an example of a matrix and why it was not valid, and to suggest alternative methods to choose from their concepts. This means that year on year there is iterative improvement in the formalised knowledge to the left of the Design Knowledge Framework and, with all studentsd being made aware of the issue through mini-topics and coaches fully briefed to reinforce the message.

6 Feedback

In Project Year 1, an evaluator observed and met with teams in focus groups, one minute reaction cards were handed out, and staff observed and discussed with teams the effectiveness of their information structures. At the end of the project, a feedback session for each team with 2 members of staff allowed both staff and students to give feedback on their overall experience and project outcomes. Objective data was provided through weekly analysis of TikiWiki team pages and files. This provided information about how students had interacted with the resources, what metadata they had created etc. It was observed that a digital repository has a positive effect on concept generation, despite the logistical problems with moving information into the digital domain [9]. Overall, TikiWiki was well received and the teams that posted a high level of interaction with the system also produced the better concepts.

In Year 2, teams were asked to give their opinions on the project structure and the use of LauLima at the end of the project in feedback sessions, class use of LauLima was monitored as the project progressed and the Wiki sites were evaluated at the end of the project. This was in addition to on-line forums where students could add comments. Generally, the feedback was very positive. In terms of the class structure, the teams appreciated that the tight time constraints forced them to move quickly through the process- something they were previously not used to doing. LauLima was important in delivering the project logs to achieve this. The LauLima sites the teams created were the team's major deliverable at the end of the project, and doubled as a presentation medium when they were doing a critique to explain their design. This was recognised by the students. Some teams commented that more tuition could have been given in the LauLima system at the project start-up, as it took a while to get used to. It is hoped to address this issue next year. Staff perceived the standard of work produced by the students to have been of a higher standard than the previous year.

7 Summary

The LauLima system is now an integral part of the IDP design project structure. It has enhanced the student learning experience and has been well-received by users. The three learning mechanisms and how they have been improved can be summarised as follows:

Learning Loop 1 (Designing): Teams, typically working in a studio environment, learn by applying the product development process to their project work. This learning at team level can be enhanced by technology that supports and improves peer-to-peer communication such as email, digital messaging, and digital file sharing. LauLima provides all of these features. Mobile phones and text messaging in particular are external forms of communication which were heavily used and future integration of them into the system may be explored. By establishing set forms of interaction, for example in relation to synchronous and asynchronous working for global design teams, the forms of communication could become more formal knowledge structures in themselves.

Learning Loop 2 (Coaching): Coaches observe the practices of design teams and help them to contextualise the product development process for them. Based on the teams' needs, coaches select and extract relevant information and present it in a meaningful way. This can be best enhanced with tools that measure and display the performance of the team in (i.e. have they reached the stage of the project expected at this time). Digital distribution and gathering methods provided by LauLima in the form of project logs and access to teams' Wiki sites improved this process.

Learning Loop 3 (Mini-topics): Lecturers retain a history of the new knowledge which is created and extract elements from it in order to improve the product development process. This is then delivered to the learner in its refined form. Since the learning activity involves the acquisition of formal knowledge, it can be best enhanced with tools that can capture, archive, and index the content that is thought to be of value for future use. Harvesting material from each year becomes easier in the LauLima environment and allows exemplars and illustrations to be obtained for following years. New means of delivery other than lectures and notes, such as the class Wiki homepage and the digital repository, allow students to search and acquire the new knowledge for themselves.

8 Conclusion

Digital groupware has been successfully embedded into an activity-based project, and had a positive effect on the students' design learning activity. The changes made from Year 1 to Year 2 to the class structure included: information literacy sessions early in the project to improve the information searching, organising and storing skills of students; more exemplars, delivered during weekly introductory mini-topics and in the groupware environment to encourage the appropriate use of sketching, concept selection and model-making; a refined set of 'logs' for uploading their design documentation to guide students through the design process without being overly-restrictive; and enhanced digital media facilities to make capturing design work in the digital domain easier. The student feedback was positive, and the standard of work was percieved by staff as being of a higher standard. The LauLima software will therefore continue to be developed in order to improve the learning mechanisms identified by the Design Knowledge Framework.

This project is being evaluated as part of the Digital Libraries for Distributed Innovative Design Education and Teamwork (DIDET) collaboration between the University of Strathclyde and Stanford University. This entails students using digital library resources to aid team based design activity as a first step towards running globally distributed team based design projects, supported by digital libraries and associated technologies.

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