Development of a Requirement Specification for CDIO Workspaces

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ABSTRACT

A systematic approach for developing the requirement specification, or design brief, of new learning spaces is presented. The process involves the identification of all the learning events and the mapping of these events onto appropriate learning spaces. When combined with class sizes, the result of this exercise can be used to generate the requirement in terms of learning space. The requirement specification is further enhanced through the identification of the physical resources required in each learning space. The overall analysis shows that informal learning events, such as those typical in project-based learning, require a much more diverse range of learning spaces and physical resources than the traditional approach to learning, typified by lectures and tutorials. As there is a general trend towards learning through more informal methods this has obvious resource implications if more progressing learning environments are to be developed and supported.

KEYWORDS

Learning space, workspace, design, specification, requirements

INTRODUCTION

The traditional approach to engineering education has predominately been lecture-based with hands-on activities provided through engineering laboratories. In common with other disciplines, engineering is now moving towards a model of education in which the learning takes place in a more active and collaborative environment. This was summarised well in a JISC publication, which states that, "A learning space should be able to motivate learners and promote learning as an activity, support collaborative as well as formal practice, provide a personalised and inclusive environment, and be flexible in the face of changing needs" [1]. The CDIO initiative is also clear on the importance of the learning environment, with one of its twelve standards indicating the important of providing workspaces to support hands-on learning of conceiving, designing, implementing and operating products, processes and systems [2].

While the need for new types of learning spaces is generally recognised, the process of designing the spaces is less well understood. Much of the published work has focused on the review of existing facilities accompanied by general guidance on the design of spaces [1-4]. Although, some guidance on the design process has been provided by Crawley et al. [5] who describe the development of the first CDIO workspace at MIT and describe a process for designing these spaces. The authors also discuss the concept of learning modes and higher level educational modes, and how these are used to inform the design process.

This paper follows on from the work of Crawley et al. [5] to describe a process for defining the requirement specification both formal and informal learning spaces using the concept of learning events and how these may be mapped onto different types of learning space and physical resource.

ESTABLISHING THE FRAMEWORK

Defining the Learning Events

The first stage in the development of a requirement specification is cataloguing the generic learning events which take place or have been identified as future activities. There will be a range of obvious learning events that all institutions support; such as lectures, laboratory classes, etc. However, it is worth spending some time over this phase of the process to ensure that all learning events are captured and included in the panning process. An example of such an exercise is presented in Figure 1.

	Learning Mode	Learning Event
Formal Learning Modes	Lecture mode	Lecture
		Software demonstration
		Interactive lecture
	Tutorial Mode	Tutorial session
		Computing practical
		Studio session
		Workshop session
	Laboratory Mode	Demonstration laboratory
		Experimental laboratory
		Product testing
		Site visit
Informal Learning Modes	Project Mode	Report / presentation
		Design project
		Research project
		Team project (minor)
		Team project (major)
		Linked project
	Extra-curricular mode	Self-directed learning
		Outreach activity
		Design competition
		Design-build competition

Figure 1: Cataloguing and Categorising Generic Learning Events

It would be difficult to prepare a definitive list of learning events as they will be subject to local terminology and interpretation. Therefore it will often be more appropriate for the designer to construct their own list of learning events, specific to their own environment. Perhaps the more significant aspect of Figure 1 is the higher level grouping of learning events into learning modes and then further grouping into either formal or informal. The learning modes present a more generic description of the learning events, which will have greater relevance across geographical regions. For example, learning events categorised in the lecture mode will predominantly involve the transmission of information by the teacher, with limited or no involvement from the students. Whereas the Laboratory Mode will involve significant hands-on activity by the students will limited intervention by the teacher.

The learning events have been categorised at the highest level into either formal or informal. While the distinction between these is not always clear, it is a convenient way of distinguishing between activities which are either teacher-led (formal) or student-led (informal).

Defining the Learning Spaces

The types of learning space required will be less sensitive to geographical and cultural differences, but nonetheless should be defined with regard to the local situation. Experiences staff should be brought together to construct a list of learning spaces required to support the learning process. It is useful at this stage not be constrained by the list of learning events already developed, as the relationship between the two will become apparent later in the process.

On completion of the learning space list, a second list of physical resources may be compiled. This can often be constructed by reviewing the requirements for each type of learning space, but, again, this should not be a constraint on the list. It is also possible to imagine the resources required without regard for the type of learning space they would be used in.

		Resources											
		White board	Projection screen	Digital projector	Computer	Network connection	Printer	Tools (cardboard)	Tools (electrical)	Assembly area	Photocopying	Access control	Supervision
Learning Spaces	Lecture Room	x	x	x	x	x							
	Tutorial Room	x											
	Studio	x						x				x	
	Computer Lab		x	x	x	x	x					x	
	Teaching Lab	x											
	Workshop								x	x		x	x
	Meeting Room	x			x	x	x					x	
	Social Area											x	
	Library										x		

Figure 2: Mapping Resources onto Learning Spaces

On completion of both lists, they should be mapped onto each other to give a resource requirement for each individual room or room type. An example of this process is presented in Figure 2. A range of learning spaces is presented down the left column and some common physical resources are presented along the top. The physical resources have then been mapped onto the different learning spaces. This is probably a more robust method of specifying the rooms as the designer is encouraged to consider the requirement for each listed physical resources in each room. Whereas, if each type of learning space is considered in isolation, there is a possibility that resources may be missed.

Mapping Learning Spaces onto Learning Events

Following a similar procedure to that shown in Figure 2, it is now possible to map the learning events onto the learning spaces and hence complete the framework required to define the requirement specification. An example of this procedure is shown in Figures 3 and 4.

			Learning Spaces								
			Lecture Room	Tutorial Room	Studio	Computer Lab	Teaching Lab	Workshop	Meeting Room	Social Area	Library
Formal Learning Modes	Lecture Modes	Lecture	x								
		Demonstration Lecture	x								
		Interactive Lecture				x					
	Lab Modes	Demonstration lab					x				
		Experimental lab					x				
		Operate mode									
		Site visit									
	Tutorial Modes	Tutorial session		x							
		Computer session				x					
		Studio session			x						
		Workshop session						x			

Figure 3: Mapping Learning Spaces onto Formal Learning Modes

Figure 3 shows the mapping of the formal learning modes and Figure 4 the informal learning modes onto the learning spaces. When compared, Figures 3 and 4 present an interesting proposition; that the formal learning modes predominantly have a one-to-one mapping of learning event to learning space, while the informal learning modes have a one-to-many mapping. The informal learning modes are more representative of the active and interactive learning that has been shown to be more effective and are therefore an important pointer in the development of learning spaces.

			Learning Spaces								
			Lecture Room	Tutorial Room	Studio	Computer Lab	Teaching Lab	Workshop	Meeting Room	Social Area	Library
Informal Learning Modes	Project Mode	Design project			x	x					x
		Team project (minor)			x	x	x	x			
		Linked project			x	x	x	x			x
		Research project			x	x	x	x			x
		Team project (major)			x	x	x	x	x	x	x
		Report/Presentation				x			x		x
	Extra-curricular	Self-directed learning				x					x
		Outreach			x	x	x	x			
		Design competition			x	x			x	x	x
		Design-build competition			x	x	x	x	x	x	x

Figure 4: Mapping Learning Spaces onto Informal Learning Modes

DEVELOPING THE SCHEDULE OF ROOMS

Cataloguing the Learning Events

The second phase of the process moves away from the theoretical aspects of the specification and onto the realities of the existing or proposed courses. The first task is to list every learning event that will take place. This process can be exhaustive, although with the unknowns inherent in the process it is probably acceptable to construct the list based on a representative sample. For example, it would be possible to list every single class that takes place over a semester or year, however, as most weeks in an academic timetable are similar it may be sufficient to analyse an average week or a worst-case-scenario week. The bulk of this list will be composed of scheduled classes, but it may also contain unscheduled events, such as private study or extra-curricular activities.

Once the list of learning events is constructed, detail, such as class size, demand, etc., should be added. The learning events are then mapped onto the learning spaces to provide a learning space requirement for that particular event. Figure 5 shows an extract from a larger list, to illustrate the point.

Summarising the Requirement Specification

On completion of the cataloguing exercise it will be possible to begin summarising the information into a format suitable for the requirement specification. The output of the learning event catalogue will be a list of classes of a particular size that will require a particular type of learning space. Figure 6 shows such as a list of courses which require a studio for particular elements. The class size is presented in the first column, the load (number of hours required per week) in the second and the cumulative load on the room in the third.

Module Name	**Class Size**	**Weekly Demand (hr)**	**Lecture Room**		**Studio**	
			(%)	(hr)	(%)	(hr)
Creative Design Skills 1	30	3		0	100%	3
Engineering Design 1	150	3	33%	1		0
Engineering Mathematics 1	155	3	67%	2		0
Introduction to Aerospace Engineering 1	40	3	20%	1		0
Introduction to Mechanical Engineering 1	110	3	20%	1		0
Introduction to Product Design 1	30	3	20%	1		0

Figure 5: Cataloguing the Learning Events

Studio		
Class Size	*Load (hr)*	*Cum. Load (hr)*
2	0.9	1
10	3.0	4
10	6.0	10
25	1.5	11
25	3.0	14
25	2.3	17
27	0.9	18
30	3.0	21
30	3.0	24
40	1.1	25
45	0.9	26

Figure 6: Classes requiring a Particular Type of Learning Space

The class size and cumulative load are important to the determination of the capacity and number of rooms required to support the learning events. In terms of the potential of a room, it may be that a room has the capacity to host 36 hours of classes per week, but because of timetabling constraints the timetabled utilisation of a room is unlikely to exceed 80% during a typical week. This then reduces the potential for a room to 29 hours/week, which is the figure against which the cumulative load is compared. In the example shown in Figure 6, the total demand (cumulative load) on the room in a typical week is 26 hours; therefore one room should be sufficient to meet the demand.

The capacity of the room will be determined by the class size of the learning events. It is possible to scale the class size to account for attendance rates, but it may be unwise to scale by anything less that 95%. In addition, as class sizes for future years are largely unknown, it is probably best to err on the side of caution and stay with an attendance rate of 100% or more. On first inspection, the figures presented in Figure 6 would seem to indicate a room capacity of 45, although in this particular case the classes with 40 and 45 are both capstone project groups and are unlikely to all attend at the same time. Therefore in this case a room capacity of 35 may be more appropriate.

If the same process is conducted on each of the other learning space types identified, it will be possible to draw up a comprehensive list of room types, with numbers and capacity of each type (Figure 7). This list may then be combined with the physical resources required to complete the requirement specification necessary to drive the design process.

1 No.	75 seat lecture room
1 No.	110 seat lecture room
1 No.	225 seat lecture room
1 No.	25 seat class room
2 No.	32 seat class room
1 No.	50 seat class room
1 No.	35 seat studio
1 No.	25 seat computer teaching room
2 No.	45 seat computer teaching room

Figure 7: Schedule of Rooms

DISCUSSION

The provision of appropriate learning spaces is an important element in the transformation of engineering education. Learning spaces can be created by either re-tasking existing spaces or building new spaces. Obviously, the first of these options will be more common, although the process of specifying either is remarkable similar.

Regardless of the size of the project, it is unlikely that anyone from outside the immediate learning environment could draw up a specification without substantial input from the faculty. The process of drawing up the specification is quite straightforward, although requires intimate knowledge of the organisation and can be a lengthy process. However, as opportunities to redevelop/create estate are few-and-far-between it is worth spending time on the process to obtain a satisfactory outcome.

When drawing up the specification there will be a natural tendency to develop solutions rather than requirements. This should be avoided as it will impose unnecessary constraints on the design process. Similarly, existing constraints, for example available space and funding, should not be allowed to unduly influence the development of the specification. The specification should be a statement of the needs irrespective of constraints. The design phase will highlight whether or not the specification can be achieved and if necessary compromises can be made during the design phase.

Finally, most development work will include external professional involvement. It may be representatives from the institution's estates division on smaller projects or architects, quantity surveyors, services engineers, etc. on larger projects. No mater who, it is useful if the lead faculty has at least some experience of building works. Fortunately, many engineers are in this position, so this post should not be difficult to fill.

REFERENCES

[1] Designing Spaces for Effective Learning: A guide to 21st century learning space design, JISC, 2006.

[2] Crawley E., Malmqvist J., Ostlund S. and Brodeur D., Rethinking Engineering Education: The CDIO Approach, Springer, 2007.

[3] Fortin, C., Huet, G., Crawley, E.F., Bertozzi, N. and Putman, C., A Description and Analysis of Multimodal Learning Environments in North America for Future CDIO Workspaces Implementation, Proceedings of the 4th International CDIO Conference, Hoogeschool Gent, Gent, Belgium, June 16-19, 2008.

[4] Young P.W., Malmqvist J., Hallström S., Kuttenkeuler J., Svensson T., and Cunningham G.. Design and development of CDIO student workspaces – Lessons learned, Proceedings of the 2005 ASEE Annual Conference, Portland, Oregon, June 12-15, 2005.

[5] Crawley E.F., Hallam C.R.A., and Imrich S., Engineering the Engineering Learning Environment, 2002.

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