P029

Activity Led Learning within Aerospace at Coventry University

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Abstract: *It is widely thought that, due to the nature of the subject, engineering education should be vocationally orientated. This paper explores the application of activity led learning that already exists in the Aerospace Systems degree at Coventry University. It was developed to be an educational experience that provides industry with graduates that are prepared for the workplace. The main assessment in the final year takes the form of a group exercise. The staff present themselves as a company requiring a complete design solution to a problem e.g., a new landing gear for a fighter aircraft and its related systems. The students are provided with a basic specification and draw on the knowledge they have acquired over the previous years to begin the exercise. They have to appreciate what it is they still do not know and interact with the academic staff as their 'customer' to fully solve the problem and provide a feasible solution. This not only expands their engineering knowledge but also encourages the development of inter-personal skills, communication skills and a more professional approach. How effective this style of teaching has been in improve the employability of the graduates is shown in our student exit statistics, feedback received from employers and the feedback from the students themselves. Developments into other modules and activities throughout the aerospace courses have included airport management exercises, glider design and build and participation in the first national Unmanned Air Vehicles (UAV) competition.*

Introduction – Pedagogical and Employability Rationale

Teaching is sometimes described as the ability to impart information to the students, as delivering content (Theory 1, Ramsden (2003:108)). He describes this as the transmission of authoritative content or the demonstration of procedures. This way of teaching focuses on what the teacher does to students and that teacher has to be an expert in the field. The application of this theory has indicated a surface approach to learning and seems to assume that learning is going to occur as long as the right quantity of information is imparted to the students. Ramsden (2003:108-115) goes on to explain two further theories of teaching in Higher Education. A summary of the main points of the three theories is shown in Table 1.

Ramsden (2003:18) does not say that the first two theories are necessarily wrong but they are narrow. Imparting facts to students is not in itself wrong but it is only one part of teaching and not necessarily the most important part. The point is that these theories represent a continuum and they are not definitive explanations of separate approaches but do provide a useful classification.

	Theory 1 Teaching as telling	**Theory 2** Teaching as organising	**Theory 3** Teaching as making learning possible
FOCUS	Teacher and content	Teaching techniques that will result in learning	Relation between students and subject matter
STRATEGY	Transmit information	Manage teaching process; transmit concepts	Engage; challenge; imagine oneself as a student
ACTIONS	Chiefly presentation	'Active' learning; organising activity	Systematically adapted to suit student understanding
REFLECTION	Unreflective; taken for granted	Apply skills to improve teaching	Teaching as a research-like scholarly process

Table 1: Theories of university teaching (Ramsden 2003:115)

The Faculty of Engineering and Computing (EC) at Coventry University is currently housed in six buildings on a city centre campus (with some laboratory areas located in another two). The whole faculty is being moved to a two new purpose built buildings by 2011 and EC is using this opportunity to design the learning spaces within the building around a new pedagogical ethos. The educational idea that is the main basis for development is the concept of Activity Led Learning (ALL), an approach that, looking at Table 1, can be seen to really embrace the continuum teaching idea and involve all three theories. Theory 2 starts to include the active learning concept but Theory 3 involves the idea of reflection, looking at what is needed for this student group, even the individual student, to help facilitate their learning. It explores further the idea of active learning and the student's own personal exploration of the subject matter.

Activity Led Learning (as defined by EC) is a pedagogic approach in which the activity is the focal point of the learning experience and the tutor acts as a facilitator. An activity is a problem, project, scenario, case-study, research question or similar in a classroom, work-based, laboratory-based or other appropriate setting and for which a range of solutions or responses are appropriate. Activities may cross subject boundaries, as activities within professional practice often do. Activity Led Learning requires a self-directed inquiry or research-like process in which the individual learner, or team of learners, seek and apply relevant knowledge, skilful practices, understanding and resources (personal and physical) relevant to the activity domain to achieve appropriate learning outcome(s) or intention(s). To be appropriate, the learning outcomes or intentions must be consistent with the aims, outcomes and intentions of the programme of study with which the student is engaged.

The learning environment development proposed in EC will support this activity further. It is currently being designed but is looking towards project-based work. Example ideas so far include allowing the students to have a project room, bookable only by students, that remains theirs, a bookcase/secure space for them to leave their project work and access outside of 'normal working hours'.

Through various discussions during the idea development stage of the new build project, it became clear that in some areas of the Faculty, ALL was already being delivered to an extent, in particular the use of problem-based learning (PBL).

The School of Engineering course documentation for chartered engineering courses details how the courses were structured with PBL and active learning in mind (School of Engineering 2000:14). The 8 modules were divided into 'core' and 'discrete' modules. The 'core' module was designed to:

- Be problem-based
- Provide product/service focus and an industrial context
- Integrate cognate topics to provide an holistic view
- Develop key skills
- Foster creativity and commercial awareness
- Foster student independence
- Be continuously assessed

It would be taught by a team of academic members of staff whose collective knowledge could be drawn upon to aid the students undertaking the PBL activity.

Discrete modules were designed to:

- Provide a rigorous base of knowledge, techniques and skills
- Feed and match the demands of the core

PBL is a form of education that uses real life industrial examples and issues to help encourage students' deep learning of the subject matter. It is still common to confuse the problem-based with the problem solving approach. Savin-Baden (2000) acknowledges the confusion and clearly explains the difference. Problem solving is essentially a teacher driven problem and it is the application of traditionally/conventionally taught data. PBL is a learner driven problem that has to be contextualised. The starting point in PBL has to be the problem that needs solving in the first place. The learner then seeks out the necessary knowledge to answer the question. Overton (2003) summarises the difference as in PBL the problems are encountered before the relevant knowledge has been acquired and solving the problem comes from that acquisition of knowledge. In problem solving, the knowledge acquisition has taken place and the problem is delivered to explore and enhance that knowledge. During this process the students should not only acquire knowledge but also content related skills, self-management skills, attitudes, know-how, basically what Biggs (2003:233) calls professional wisdom.

One of the areas where ALL was already being delivered was Aerospace Systems Engineering. The approach taken for the second and third year design problems is similar to the concept of PBL but what is being delivered within ASE does still involve a planned lecture series that is determined by staff and not by student needs so in context is partly a problem solving process as well. It is therefore better described by the all-encompassing definition of ALL given earlier. The way in which the course, in its current form, has been developed is around this idea of creating projects and scenarios in which the students have to use and develop on their 'soft' skills as well as technical knowledge. The course was designed by an academic member of staff who had joined from industry and had an insight into what was actually required by the aerospace industry (locally in particular) from graduates.

Making graduates employable is essential in today's climate hence the needs for the employability criteria provided by the Higher Education Academy for all disciplines. The Employability Guide for Engineering produced in October 2004 (Appendix D.1) was put together by the HEA, ESECT (Enhancing Student Employability Coordination Team) and CIHE (Council for Industry and Higher Education). It is a thorough handbook for us as individuals and institutions to refer to regarding what is required of our graduates in addition to their subject knowledge e.g., cognitive, written and oral skills.

Coventry University's own teaching and learning strategy states the following:

> "[to help enhance the learning environment we need to] develop enterprising and entrepreneurial graduates who contribute to innovation, creativity and productivity in organisational life, through the use of inquiry-and work-based curricula"
>
> (Blackmore 2006)

The development of the Add-Vantage suite of modules at Coventry is a response to this employability need

> "Employability is a set of competencies that make graduates more likely to gain employment and be successful in their chosen occupation(s), which benefits themselves, the workforce, the community and the economy."
>
> (Coventry University 2008a)

Felder (2006) details a hypothetical interview for an engineering job. It highlights how narrow and potentially unemployable traditionally taught undergraduates can be. He talks about the need for the undergraduates to be able to show other skills (creative, self-direction, language) which are in line with the ideology behind ASE.

Biggs (2003:233) backs this up from an educational point of view and describes how this approach to higher education teaching leads to a rich learning context by emphasising context, active learning, interaction, building, elaboration and consolidation of knowledge, application, self-management and self-monitoring.

Development and Impact of Aerospace Systems Engineering at Coventry University

When the course designer joined the staff at Coventry University in 1993, he taught on an aerospace propulsion and aerodynamics module in the final year, the first dedicated aerospace module that the aerospace students studied in their whole degree. He had come in from an industrial background and could identify fundamental gaps in the students' knowledge and skill sets. The design aspect of the aerospace course, for example, was being delivered by the Design Department. The basic ideas of design were therefore taught very well but the essence of 'aerospace design' was an alien concept. The aerospace students were not required to do many calculations and not given an understanding of material stressing and weight optimisation, both of which are vital in the aerospace industry. The examples that were used and the projects set were not aerospace applications.

The ethos of the engineering at Coventry at that time was 'preparing you for employment' and it was felt this is was not being achieved within the aerospace course. There were aerospace companies (predominantly the local ones) saying that they required graduates with knowledge of reliability and redundancy within aircraft systems, knowledge of airworthiness targets, subjects that were not being covered within the existing aerospace degree. The industry required graduates with a background understanding of the systems involved on the aircraft and the regulations that govern the industry as a whole. The university needed to provide graduates that can design aerospace systems (or at least the components of the systems) and how all the different systems had to integrate together. They needed to be people with team skills to be able to facilitate that integration. Around this same time British Aerospace changed its name to BAE SYSTEMS. This name change indicated the industrial shift to a systems approach and confirmed the need for change with aerospace engineering at undergraduate level.

It took around three years to change but eventually the Aerospace Systems Engineering degree, in its current form, was created. The structure of the course now includes two dedicated aerospace modules in the first year (Aeronautical Engineering and Aircraft Principles and Practice), so that aerospace students are immediately exposed to the basics of the subject area. The modules taught over the three years are, on the whole, discrete subject matters e.g., Mechanical Engineering, Engineering Mathematics, Flight Dynamics and Control, Avionics (a subject area that had to be started from scratch for this new course approach). However, in the second and third year all these various subjects are brought together in the form of a project (individual and team projects respectively).

The graduates that this new course has been delivering to the industry have been well received. Some companies come back to Coventry time again for graduates as they have been so impressed with the immediate competency they display in the work place. Coventry also offers a sandwich course (two years at university, one in industry and then a return to university for the final year) and there are a number of aerospace companies who approach Coventry in the first instance for industrial placement students.

The member of staff that led the redesign of the course has returned into industry as a chief mechanical engineer for Meggitt Aircraft Braking Systems in Coventry. He is now a potential employer and still maintains that the Aerospace Systems graduates leave the university with the knowledge base and skill set required within the industry in the UK. This is clearly evidenced in the amount of alumni that work there e.g., Chief Engineer, Senior Stress Engineer, Brake Performance Engineer, Design Engineer. In addition, Coventry University has graduates in most of the major aerospace companies within the UK (and some further afield) e.g., BAE SYSTEMS, Lockheed Martin, AgustaWestland (Helicopters), Marshall Aerospace, Goodrich Actuation Systems, EADS, General Electric, Rolls Royce, QinetiQ, DSTL.

In 2006, 100% of the graduating class contacted the ASE Course Tutor to let him know where they were and what they were doing. All of them had either found graduate employment or undertook postgraduate study, all within the subject discipline. Statistics do not necessarily display the whole picture though, how this structure has helped our graduates within those jobs is great testament to the effectiveness of an activity led approach. Through an email questionnaire sent out to ASE graduates many positive comments were received, along with some areas of development required to improve on the good practice.

One ASE graduate from 2007, working for AgustaWestland, explains

"My current job involves putting together a systems definition for entire aircraft, this means that I have had to have an understanding of every single system aboard the aircraft. I'm in a core team of three, one is a comms specialist, and the other is a DAS [Defensive Aid Suite] specialist, and they know little beyond their core sections. What my degree has provided is a grounding in everything, I have an understanding of the entire aircraft from rotor blades and transmissions to EGI [Embedded GPS/Inertial Navigation] and DME [Distance Measuring Equipment]. This

I believe is the strength of the Coventry course, it provides an overview of most aspects of the aircraft, and this is one of the reasons behind my uni choice."

Another from the same cohort, working for Marshall Aerospace says

"My university degree course has prepared me well for starting in full time employment, ……on day one of the job I was put into a team of people who are working with Airbus Military to carry out risk reduction flight trials for the powerful new Europrop International TP400-D6 Turboprop engine, FADEC [Full Authority Digital Engine Control] and propeller, which will be fitted eventually to the Airbus A400M Military Transporter.

My role within this team is to carry out a liaison role whereby I bridge the gap between the shop floor and the design office. Although a different task to the one given to me during my last year of university in the group project the problem solving and communication skills I learnt have allowed me to stand out amongst fellow employees. In several instances some of the people in my team who like me have come straight from university have turned to me for advice on a range of different problems and so I feel very fortunate to have been given a complex problem during the last year of university which has allowed me to stand out in such a diverse and competitive crowd."

A mature student, who graduated in 2001, had different motivation for working hard in his degree. He is now working for EADS in Munich.

"It was clear during my studies at Coventry University that the people running the aerospace systems course were preparing you for life in the industry. On reflection, my early observations were spot-on; I have lost count of the occasions where I have draw directly from my experiences on the aero systems course. In particular, the 2nd year provides the student with the opportunity to design an actuator given a wide range of speciation requirements, this was great at bringing all the other modules together and applying what you had learned to a real scenario. The 3rd year went a number of steps further; splitting the group into 4 or 5 subgroups and inviting the subgroups to submit design proposals for an horizontal stabiliser actuator. Two of the groups, who submitted the worst of the proposals, would then be merged with the other groups. The remaining proposals were then subjected to PDR's and CDR's [explained later]. It was a nightmare, the process stretched for the entire academic year pushing everyone to their limits and causing the most outrageous conflicts, both amongst and within the groups. I can honestly say, that the pressure I experienced during my final year has been rarely repeated within the industry. I never saw the light of day during my final year, I remember I went out twice over the Christmas period, the rest of the time I was studying; I can barely remember that 9 months apart from the studying. That said, I entered the aerospace industry as prepared as I could have been. I have fond memories of my time at Coventry University and will be forever in the debt to the people who gave me the opportunity to reach my potential."

Structure, Content and Delivery of ASE

Since the Aerospace Systems Engineering (ASE) course was developed there have been some small adjustments (mainly to the third year module weighting) but the overall structure and content has been fairly constant. The courses at Coventry University did run on a structure that had eight modules a year, each worth 15 CATS points.

Year	Modules	Size
1	**Design, Experimentation and Application** Engineering Mathematics I Mechanical Engineering Materials and Manufacturing Technology Aeronautical Engineering Computing in Engineering Introduction to Problem Solving using MATLAB	2 1 1 1 1 0.5 0.5
2	**Aerospace Systems Engineering I** Avionic Systems 1 Flight Dynamics and Control Solid Mechanics Thermofluid Mechanics Engineering Mathematics II Aerospace Industry Studies	2 1 1 1 1 1 1
3	**Aerospace Systems Engineering II** Individual Project Avionic Systems 2 Propulsion Systems and Aerodynamics Aerospace Structures and Materials Industrial Project Management OR Aerospace Industry Studies II	2.5 1.5 1 1 1 1 1

Table 2: Aerospace Systems Engineering course structure before 2006

From a module perspective, it was found that final year students were spending a lot of time on the group design project, time that was not shown in the weighting of the module mark towards the degree. The individual research project started to suffer (in terms of hours of effort) from the enthusiasm the students had for their group project. This was in no small part due to the peer pressure that group working puts onto the individual. The final format made Aerospace Systems Engineering II being worth 37.5 CATS points and the individual project was 22.5 CATS points, to fully account for the effort and importance industry (and the undergraduates themselves) saw in the group project work.

After the initial development of the Aerospace Systems course, the university brought in the idea of ‘discrete’ and ‘core’ modules. This was a setup whereby students are taught in subjects with one central module that integrates all the other information together. Although they did not have those official names, this was essentially what ASE was delivering anyway. The ‘core’ modules are highlighted in **bold** in Table 2 i.e., the modules in which the course team endeavour to pull together all the knowledge delivered into a project based environment.

The first years are exposed to the principles of ALL in a small part of the first year core module, Design, Experimentation and Application. The second year then focuses on individual work in two coursework projects in Aerospace Systems Engineering I. It is in the third year (Aerospace System Engineering II) that they bring all these skills together and really begin to work in a group. They have to rely on each other, develop team skills and acknowledge individual strengths and weaknesses to create a workable system, not just one component of that system.

In the first year, the group work they have had to undertake has varied over the years. One good example is the wing build. The first years are put into groups and set the task of building an aircraft wing. They are given a specification (with limits and targets) and within the academic modules they are given the background knowledge needed to make their design a success e.g., aerodynamics, aircraft structure(s), material choice (weight and stressing), drafting. In their groups they are given lab time, equipment and technical support to actually fabricate their designs. These wings are then tested to see if they comply with the spec. The major part of the specification is the amount of the loading the wing has to withstand. They are given the amount in Newtons but not necessarily told where that load is going to be applied. It is through further investigation and application of their technical knowledge that most groups being to understand that the wing will be weakest at the tip as the root is securely attached to the body of the aircraft. Therefore, as long as the wing tip can withhold the loading in the specification then the design is OK.

In the second year they have to apply knowledge of many fundamental engineering principles e.g., fluid mechanics, material properties, stress/strain, mechanical linkage. Taking the design of the hydraulic actuator as an example, it is here that the concept of 'working for a customer' is first introduced. The problem is presented as if an aerospace manufacturer is looking for a design to replace an existing mechanically-signalled hydraulic servo actuator, currently used to control the ailerons of a small military fighter aircraft. The students are required to tender for the replacement job, by using the data provided in the specification. to design and justify their alternative product.

At this stage the students are still given a very detailed specification to work to which helps to point them in the right direction. They also follow a lecture series within the same module that loosely plots the same design pathway that they are likely to have to take to answer the question and draws the different designs aspects together.

The third year core module is structured in a way where there is time for group work but a lecture series runs parallel with the design development. The 'customer' (the staff) gives a skeleton specification with some vital information missing. It is therefore the students' responsibility to look at the information they have, look at the problem they have been given and work out what more they need to find out to solve it.

The design activity behind the third year group project has varied over the years and has included: designing a high lift flap system for a large aircraft, helicopter landing gear, V22 tilt rotor. One thing that has stayed constant is the overall plan. The submission timetable for this project was created to follow the timeline usually adopted within the industry but adapted for an academic year. The ideas, options, reliability issues and basic architectures are reported on at the end of the first term (Preliminary Design Review - PDR). The decision as to which system is going to be developed is made at this point and essentially the final design and 'manufacturing' phase is the second term. The Critical Design Review (CDR) takes place before the Easter break.

The students are encouraged to ask questions of the 'customers' to fill in the gaps in the initial specification, the relevant information therefore gets 'drip-fed'. So that no one group has an advantage of that information over others a report from the customer is issued to everyone just after Christmas, which details all questions and answers to them. Those groups that were more pro-active will benefit from having had this information in advance of this release.

Recent and Future Development

In 2004, a large investment was made in the aerospace facilities at Coventry. There is now a bespoke aerospace laboratory with the following available for students to work on (first year labs to final year projects):

- Harrier Jump Jet (complete with engine)
- Westland Scout Helicopter
- Merlin Flight Simulator
    - This was updated in 2007 to two state-of-the-art simulators (one hydraulically and the other electrically actuated) plus a simulator within the Harrier, all able to fly in formation
- Small scale fully operational jet engine
- Primary Flight Controls hydraulic test rig
- Drop test rig e.g., for landing gear shock absorbers
- Police infra red camera system
- Hydraulically operated engine nozzle

All of these allow the teaching team to continue the development of a active learning environment. The first years now, not only have the design and build exercise, but also have to physically undertake a maintenance check over the Harrier, take bits off and put bits back on (with none left over!). All students have physical brakes, shock absorbers, landing gear, transmission systems (for example) to go and look at, touch and investigate whilst undertaking the design activities.

The more active learning has started to expand from just the designated 'core' modules. Under collaboration with Coventry Airport, a Disaster Management Exercise is being developed to be delivered within the third year Aerospace Industry Studies II module, to expose our students to the reality of testing airport operations in an emergency situation. Coventry University is also involved in the Unmanned Aerial Vehicles (UAV) competition that is running for the first time this year. A collection of final year students have been given a specification and a budget to design and build a semi-autonomous UAV. Each one has a specific task which is then their own individual project but they will have to work together to produce a solution that will be tested against those from other institutions at the end of the academic year.

A challenge for the team in being able to maintain this approach was that in 2006, Coventry University moved to a 6 module system, each one being worth 20 CATS points.

Year	Modules	Size
1	Aeronautical Engineering	1
	Aircraft Principles and Practice	1
	Electrical Engineering	1
	Engineering Mathematics	1
	Mechanical Engineering	1
	Environmentally Sustainable Manufacturing	0.5
	ACU*	0.5
2	**Aerospace Systems Engineering**	1
	Flight Dynamics, Control and Modelling	1
	Avionic Systems	1
	Engineering Mathematics	1
	Mechanics and Thermodynamics	1
	Engineering Management	0.5
	ACU*	0.5
3	**Aerospace Systems Engineering II**	1

	Propulsion Systems and Aerodynamics	1
	Avionic Systems II	1
	Vehicle Structures and Advanced Materials	1
	Individual Project	1
	Professional Development	0.5
	ACU*	0.5

Table 3: Aerospace Systems Engineering course structure after 2006

* is a half module from the Add-vantage suite of modules at the university. These cover a wide range of skills outside of the mandatory syllabi across all faculties (Coventry University 2008b).

As ASE is a chartered engineering degree course that is accredited by Royal Aeronautical Society and Institution of Mechanical Engineers, there are fundamental subjects that have to be covered to maintain this status. The new structure allows for that but it is clear to see that the size of the Aerospace Systems Engineering II module has been reduced. The first time this will run is 2008/9 and it is going to have to be radically redesigned, whilst trying to keep the same strength in ALL, as the amount of work the team can ask of the students is going to be reduced. Many of the graduates (from the 8 module structure) that provided feedback already felt that the workload and complexity of the task was too high for the reward.

A graduate from 1999 states:

“With respect to the final year group project, [the lecturer] worked extremely hard in creating a scenario which matched reality which helped to make everything feel more real. The specification and product development process very closely mirrors that found in the majority of aerospace engineering companies which provides great experience. [the lecturer] arranged Preliminary Design Reviews (PDR’s), Critical Design Reviews (CDR’s) some of which were attended by engineers from local aerospace companies. The project was demanding on time but gave good experience in working as a team to get the design developed with each person in the team taking on a specific role. The only issue is that it did take up so much time and this did conflict with our personal project which was worth a double module. “

Another student from 8 years later (2007) did not feel as comfortable with the process and felt more support was necessary, highlighting the need to look at the individual student and what is needed for a particular student group (Ramsden’s Theory 3) and the need to maintain consistency in delivery when there are personnel changes. He says:

“At the time my gripe was that we were essentially short of knowledge, we knew that we needed information but that we wouldn't get taught it for another few months. The problem wasn't that we didn't know something, we could find that out, it was that we weren't aware that we didn't know.

……Looking back now, I believe that more emphasis should have been made on the admin side. Here in industry we're always working towards goals, PDRs, CDRs, cost reviews and workshops (with the customers). …….Although this does increase the workload, I believe that it is worthwhile if the goal is to prepare the student for industry (perhaps this could be offset by actually making the goal a little less demanding technically).”

Conclusions

Aerospace Systems Engineering at Coventry University already embraces the concept of activity led learning and endeavours to instil in our graduates a good working practice, useful ‘softer’ skills as well as relevant technical understanding of the problem at hand. The course has developed and evolved into an experience that prepares our graduates for the reality in industry and provides industry with valuable assets. This assertion is supported by our employability rates, feedback received from employers and feedback given by the graduates themselves. The challenge to the teaching team for the future is to ensure that this is maintained and expanded upon within the new degree structure and eventually the new building. It is hoped that the provision of project-orientated learning spaces and a Faculty-wide ALL approach to teaching will help support us to maintain what has already begun and improve on the existing good practice.

Acknowledgement

The authors would like to thank visiting Professor Mark Maydew from Meggitt Aircraft Braking Systems in Coventry for his contribution to this paper. They would also like to recognise the feedback and input from the ASE graduates.

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