Activity Led Learning and Developing Professional Judgement Capacity in Undergraduate Learners.

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Introduction

Activity Led Learning (ALL) is defined within the Faculty of Engineering & Computing at Coventry University as a pedagogic approach in which the activity is the focal point of the learning experience and the tutor acts as a facilitator who creates the learning environment. An activity could be a problem, project, scenario, case study, research question or similar in a classroom, work-based, laboratory-based or other appropriate setting [1]. Within this broad scope the principle is that through carefully constructed and facilitated activity, the learner is presented with a learning experience that not only provides new knowledge but also the purposes by which they can begin to develop and manage networks of knowledge. Koschmann *et al* [2]considered learning to be an active process of mental construction where cognitive initiative and effort are facilitated. This paper reports on ongoing research into current practice in ALL and its effectiveness in developing judgement capacity in learners. It proposes that ALL with strong relevance to real world engineering problems, can provide a learning environment in which the learner can organise and analyse information and exercise the making of judgments to synthesize new knowledge.

1. Current Professional Practice

Modern professional engineering is increasingly recognised as a complex holistic knowledge domain in which real professional practice is comprised of both technical and broader, complex, even fundamentally distinct interactions between a whole range of human, socio-economic, legal, environmental and moral issues which are value ridden and resistant to measurement. Engineering educational practices in higher education however, has traditionally placed emphasis on the teaching of technical domain specific knowledge in a system that may be considered resistant to redevelopment [3]. According to Eraut [4] the technical domain specific knowledge of new professional entrants and professional experts is largely similar, and that the professional performance of experts is largely due to flexible behaviours and the way that judgement is exercised and knowledge is organised. Accepting Eraut's position on this we may hypothesise that where expert performance cannot be distinguished on propositional knowledge alone then expert professional performance can be seen to be characterised by the way the professional organises and uses knowledge in the development of new solutions. Experts are able to do this because they are adept at making

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judgements about propositions that enable them to rationally optimise the number of ways of thinking about a complex problem space to reduce it to manageable proportions [5].

2. The Faculty of Judgement

The faculty of judgement is thought to be synonymous with shrewdness, acuteness, perspicacity, awareness and intelligence. Lipman [6] considered judgement to be a mental accomplishment of immense complexity and Kant [7] placed judgement above all other cognitive functions. Kahnemann and Tversky on the other hand emphasise the heuristic nature of judgements and decision making and the tendency to make serious errors in judgement [5]. The need to develop judgement capacity in learners is however largely understated as a pedagogic objective and is assumed to be implicit by current educational practice. Lipman [6] categorised judgements as mediating and culminating. In the first category there are; judgements of identity, difference, similarity, composition division, inference, membership, analogy, relevance, cause, appropriateness, value, hypotheticality, counterfactuality, practicality, fact, reference, metrology, translation and instrumentality. Culminating judgements are influenced by mediating judgements and culminate as decisions. Judgement capacity is complex and difficult to measure however we know a priori that individuals must exercise judgements given propositions and those judgements precede action. By observation of those actions we can infer that judgements of a particular type have been made.

3. Method

3.1 Undergraduate Research sample

Opportunistic sample groups of 370 undergraduate engineering students at Coventry University took part in the research. The research groups were comprised of learners from the following courses across the faculty of Engineering and Computing. *Table 1.* The undergraduate projects were in the main theoretical problems some with a practical aspect e.g. the use of CATIA, REVIT, MatLAB software, Raspberry Pi hardware. The RC Buggy project involves practical construction skills.

Table 1. Undergraduate Research Groups.

Course	Year	Project	Duration
Mechanical & Electrical	1	Radio Controlled Buggy	10 weeks
Mechanical & Electrical	2	Engine Hoist	10 weeks
Aerospace Engineering	1	Crash Investigation	10 weeks
Aerospace Engineering	1	Hydraulic Actuator Design	10 weeks
Aerospace Engineering	3	Landing Gear Design	33 weeks
Ethical Hacking & Digital Forensics	1	Encryption	10 weeks
Civil Engineering	3	Building Refurbishment & Extension	33 weeks

3.2 Apprenticeship Research sample

In parallel with the undergraduate study at Coventry University, 3 groups of apprentices employed at a precision engineering company in the North East of England were also studied. The main business of the company is the manufacture of subsea oil and gas valves and hydraulic pumps and motors. The apprentices are engaged on a professional development programme that is additional to their usual apprenticeship qualifications. Its purpose is to determine those who might, more exceptionally, have the aptitude to develop into future production engineers. The projects are very practical and demanding in terms of precision and work organisation and are supported by theoretical tutorials on materials, mechanics and production systems. First year apprentices machine and assemble a simple gear pump and second year apprentices design, construct and prove a small pallet work holding system for a component used by the company, *Table 2.*

Table 2. Engineering Apprenticeship Research Groups

Course	Year	Project	Duration
Foundation Cohort 2012-2013	1	Gear Pump machining & assembly	15 weeks
Intermediate Cohort 2013-2014	2	CNC pallet - work holding project	33 weeks
Foundation Cohort 2013-2014	1	Gear Pump machining & assembly	15 weeks

3.3 Data Collection of Learner Experience

All learner groups were observed directly as they worked through the self directed engineering projects listed above. Their activities and dialogues were recorded manually or on video. Also video recordings were taken of project team presentations of their final project submissions. The recording methods sought to capture the way the learners construct, define and negotiate the evolving problem space from the initial concept stages through to the final solution and the issues they felt were important, pertinent and appropriate to the solution. Particular attention is given to the way the learners generate propositions and the rationales on which they discard or develop them further. The transcripts of the observations and videos are analysed in detail for meaning and context and encoded according to the judgment categories proposed by Lipman. Using this method it is possible to infer the kinds of judgments exercised by the learners as they progress through problem space definition, hypothesis and solution. In some instances where the learners thinking needed to be elucidated further, research participants were selected to take part in semi-structured interviews. Interviews lasted typically between 30 and 40 minutes and the line of questioning evolved according to the responses given by the research subject. This is particularly useful in studying how a participant feels about particular issues and developments relating to the project work.

3.4 Data Collection on ALL Environment

One further aspect of the study attempts to examine what the problem space for a particular project looks like from the perspective of the participant. Project scenarios will have a particular emphasis on technical or socio-technical issues according to the specification of curricula, however, how the learner 'intends' that problem space is of particular interest in the judgements they make about it. For example learners will have quite varied perceptions in how important broader holistic issues are and to what extent they shape the solution of the problem or to what extent technical detail should be dominate their deliberations. These heuristic judgements can be captured from the dialogue transcripts where it can be seen readily where the learners discuss technical and holistic issues.

3.5 Definitions

The term 'socio-technical' is used in this paper to define the broader, complex, holistic knowledge domain intended by the learner that impact upon their judgements as distinct from the purely technical or scientific domain. This definition draws further distinction between the holistic issues that the individual problem solver considers relevant and the social constructivist perceptions of the wider population. For any given ALL project, the extent to which either the technical and socio-technical domains appear salient in the learner's problem space can be directly observed from the learner dialogues within the observation transcripts and video footage provide. A plot of the socio-technical domain with the technical domain provides a useful way of comparing the epistemological construct of the engineering projects *Fig 1* refers.

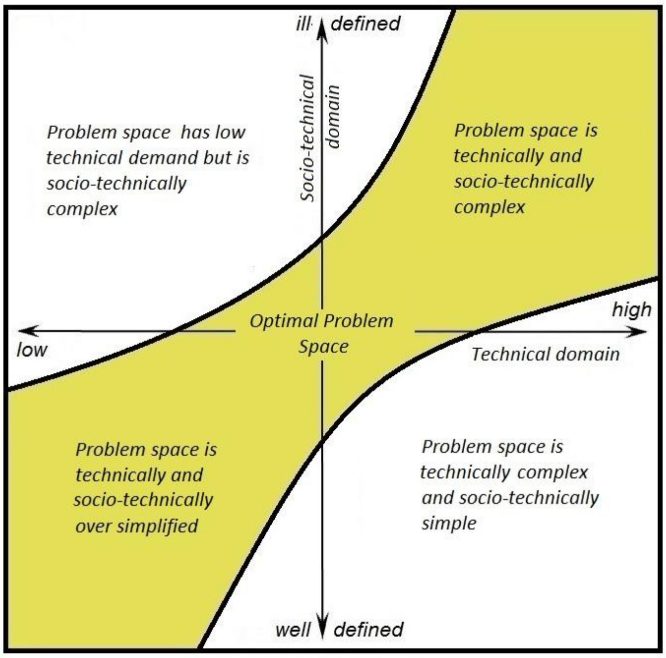

Fig.1 Engineering Problem Space

4. Findings

Within the experiences observed, preliminary findings suggest that ALL experiences can be constructed to provide opportunities that compel learners to exercise complex judgments and make decisions across a diverse range of technical and holistic contexts similar to those of engineering professionals. Projects, which provide problem space demands sufficient to exercise the kind of judgements typical of professional practice, exhibit increasingly, both socio-technical and technical disjunctures. A disjuncture [8] being a point in the flow of learning experience where the unusual or dissonant occurs that compel the learner to consider the proposition and make a judgement from which they can proceed. This can be demonstrated by reference to several of the observed projects.

4.1 Case study 1: First year Apprentices

First year apprentices working in small teams have to complete from drawings the construction and assembly of a small gear pump including the machining of pump body and cover plate, spur gears, shafts and bushes. The drawings provided to them are incomplete, some angular dimensions, tolerances and limits and fits are purposely omitted. Learners also have to calculate the data for machining the spur gears given a gear specification. All necessary information to successfully machine and assemble the gear pump can however be deduced. The resulting disjunctures prompt discussion among the learners and compels them to make judgements about which limits and fits are appropriate, the calculation of speeds and feed rates, gear form, the correct order in which to proceed with machining, which tools are required, the type of finish. This project is technically dominant, there are no socio-technical issues beyond the demands of team working and communication. The learners in this simple example make a whole series of judgements about appropriateness, relevance, fact, practicality and measurement. When they share their ideas in discussion, hypothetical, counterfactual and instrumental judgements are also apparent and become conspicuous when earlier mediating judgements have been erroneous.

4.2 Case study 2: Second year Apprentices

Second year apprentices have a more open ended project to conceive, design and build a pallet CNC work holding solution from first principles in accordance with a broad client specification. The project has continuity from the first year programme in terms of practical skills development but places increasing organisational demands on the learners and the need to exercise appropriate judgements to resolve conflicting demands and achieve an optimal solution. Their proposed solution has to be proven by calculation to be mechanically viable, costed and delivered against agreed deadlines. Teams can negotiate to 'buy in' expert opinion and assistance from their project budget and face 'financial' penalties for over running deadlines or non-delivery. There is a core technical domain with respect to materials selection, mechanics, mathematics, CAD and actually machining the design. Project management and organisation, awareness of financial issues and implementation create socio-technical disjunctures which require additional judgements in conflict resolution.

4.3 Case study 3: First year Aerospace Engineering Students

First year aerospace undergraduate learners consider diverse evidence to investigate the cause of an aircraft crash. This project has both technical and socio-technical domains. Technical data on aircraft position and manoeuvres, air speed, fuel, air traffic control, is made available together with information which is value laden such as eye witness statements, pilot and co-pilot voice recordings, bird flock sightings and weather and visibility reports. The technical data is potentially counterintuitive to the broader socio-technical issues and the disjunctures are compelling. Learners have to exercise judgements about the value and veracity of some of the information in order to define the problem space and make a hypothesis from which they can develop a solution. The problem space is only partly defined by the initial project specification and some learners extend the scope of the problem by hypothesising the need for additional information such as debris field data. Some learners place much greater weight on the value of eye witness reports and anecdotal evidence.

The same group of students engaged in a project to design an improvement to a hydraulic actuator for a landing gear application strive to find a solution that provides rational technical improvement within the context of a viable business case. In this project the solution tended to be technically oversimplified, improvements to material specifications did not take into account machining and manufacturing difficulties and associated costs. Consequently Business cases tended to be exaggerated by the sales communications rather than predicated on actual data.

4.4 Case study 4: Third year Civil Engineering and Built Environment Students

3rd year Civil Engineering and Built Environment students complete an interdisciplinary team project centred on the refurbishment and restructure of an existing campus building that also has to be extended. Teams are self selected and comprised of architects, structural engineers and building services engineers. A number of the students are part time students who are already employed in some capacity in the construction industry. The project is organised into distinct phases involving initial design concepts, structural, building services, BIM and final design proposal. The project management is redolent of projects generally in civil engineering and built environment in that there is a distinct division of work around the team capability. This results in a problem space that is not perceived in its entirety by each team member, they tend to be aware of their own area of expertise and are almost completely reliant on other team members. Judgements about particular issues are not shared and consequently some team members will only have to make technical judgements e.g. structural calculations while others make judgements which are socio-technical and based around the use and value of the building environment. Disjunctures evolve around the need to create innovative, aesthetic and functionally valuable building environments and the necessity to meet budgetary and regulatory constraints within structurally viable constructions.

4.5 Case study 4: Third year Aerospace Engineering Students

Third year Aerospace students engaged in the design of landing gear intend a problem space which is very technical and much of the work is focussed on materials, mechanics and kinematics. However, the requirement of designing against a trade study of existing aircraft systems introduces interesting opportunities to examine and make judgements about current designs, aircraft trim, handling and maximum take-off weight. The different design rationales and a change in client specification create disjunctures that have to be resolved by complex judgements.

5. Conclusions

The research into how ALL can promote judgement capacity is a work in progress and the conclusions given herewith are based upon preliminary examination of research data. The data will be subject to further examination and elucidation after more detailed analysis has been carried out.

ALL environments can create opportunities for disjuncture on which the learner has to exercise judgement. The way that the learner exercises judgement and the difficulty they experience in making a judgement is related to the nature of the disjuncture. Carefully crafted project specifications provide more potential instances of disjuncture where the conflict between socio-technical rational and technical demand is high. In these circumstances the problem space is more difficult to resolve and the judgement capacity of the individuals is exercised most.

The duration of projects is an important aspect in ALL environments. A project of sufficient duration presents opportunities for disjuncture that when resolved by the learners, provides them with a continuity in learning experience as one part of the learning process flows into the next.

Some learners intend problem spaces which are overly influenced by socio-technical rationales even when the project specification invites closer inspection of salient technical detail. As the technical knowledge domain of learners increases, problem spaces with apodictic socio-technical issues are more optimally rationalised. The converse is less apparent however. Learners with strong technical domain knowledge appear less likely to be influenced by the socio-technical. The apprentices for example who are focussed predominantly on habits of action [8] in practical skills of a technical nature, the technical domain is more dominant and socio-technical rationales were much less likely to feature in their judgements. Implementing a work holding solution appeared to them to be technically reduced and socio-technical issues such as work force and union acceptance of a new work practice were not salient in their problem space even though they are employees who would be keenly aware of the imposition of new practices.

For the purposes of developing judgement capacity, the ALL learning environment is sensitive to external unintended influences, particularly in the initial stages of problem space definition. Learners look to means to maximise marks and consider the tutor to be a provider of knowledge. They are keen for confirmation they are on the right track and are susceptible even to subtle psychological clues from their tutor which satisfy this need.

In order to maximise the disjunctures that will exercise judgement capacity, it is important that the problem is not defined in such detail that the learner perceives the problem space as narrowed and pre-defined for them before they can exercise their own judgement in it. If the ALL environment is constructed carefully, there will be useful opportunities in which the learner finds some issue that will exercise their wits. As further disjunctures naturally occur through learner interaction and dialogue the ALL environment can be exploited to exercise the learner's judgement further. Thus ALL permits learners to develop judgement in a community of enquiry

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