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PHILOSOPHY OF DESIGN: ENABLING REFLECTION WITHIN PBL CONTEXTS IN ENGINEERING DESIGN EDUCATION

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ABSTRACT
During episodes of experiential learning, such as project-based-learning (PBL) in engineering design education, students construct new knowledge (that is they learn) by reflecting on their experience. More accurately, they reflect on their 'perceptions' of that experience, meaning that the prior experience, knowledge, and worldview of the students will have a strong influence on the outcomes of learning from experience. The cognitive structure of engineering design students is heavily influenced by the positivist learning paradigm of engineering science, and so many students may struggle to learn, or not be open to learning, from experiential design projects, because the constructivist paradigm that underpins this type of learning is not in accord with their cognitive structure.
It is proposed here that the teaching of *philosophy of design*, combined with use of reflective learning journals structured using a constructivist inquiry framework, might potentially allow students to access a deeper level of understanding of their own individual approaches to design, by enabling meta-reflection at an ontological level. Philosophy of design serves the purpose of emancipating students from a restrictive worldview by making them aware of multiple paradigms of learning.
This paper presents the progress of an intervention within a second year PBL engineering design course, using the proposed combined approach. Early indications are that it is having a positive impact on reflection and learning.

Keywords: Philosophy, reflection, project-based-learning

1 INTRODUCTION

The positivist learning paradigm of engineering science is well articulated in engineering design education [1], as taught through core engineering science subjects. The kind of knowledge involved in these subjects is explicit i.e. it can be codified into spoken, written, or mathematical language and readily conveyed to others. Methods of teaching in these subjects are therefore generally prescriptive and systematic. Students quickly come to understand not only what they need to know, but how they can come to know it. The constructivist learning paradigm, within which creative design most comfortably sits [2], by contrast, appears not well articulated in engineering design education [1].
In order to acquire design knowledge students typically undertake design projects, or 'project-based-learning' (PBL) design experiences. This is because design knowledge is largely tacit, and must be acquired experientially [2]. Students are invited to jump in and learn design through doing. This is entirely appropriate in the context of creative design. However, these experiences are generally not supported with pedagogical approaches that highlight the different nature of design knowledge and engineering science knowledge. Instead PBL design experiences in engineering design tend to be supported by the teaching of 'design methods', or prescriptive design processes, which only serve to reinforce the positivist learning paradigm of engineering science. There is near silence on the constructivist nature of learning creative design [1].
We need to sufficiently widen the worldview of engineering design students, to encourage openness to learning design experientially, and to reflect on that learning. In other words, the aim is to emancipate engineering design students from a restrictive worldview about the nature of knowledge and its acquisition. Current issues in engineering design education appear to relate to the reduced ability of students to reflect on personal design activity, based on a lack of understanding of the differences between design and science at a philosophical level [3], [4]. Instead, engineering design students tend

to have a superficial view of design as pure rational problem-solving [1]. Current approaches to learning and assessment in engineering design do not reveal the underlying learning paradigms of engineering design education, and therefore limit the ability of students to reflect on their own experiential learning. The students effectively experience an 'epistemological block to reflection'. New pedagogical approaches, which reveal the differing paradigms of design and engineering science, and enable reflection, are required to support these PBL design experiences.

2 BACKGROUND

2.1 Learning and constructivism

In education, the constructivist approach to learning involves using experiential methods, such as hands-on experiments, prototyping, and real-world problem-solving, to create new knowledge and to encourage students to reflect on how this knowledge changes their understanding. PBL design experiences in engineering design education are essentially constructivist in their approach. Constructivism holds that learners are determinants of what is learnt, and their existing ability and knowledge shapes the nature of the learning. In this context teachers operate only as facilitators of that learning. In conceptual terms, this existing knowledge is organised within the mind in a 'cognitive structure', a network of "facts, concepts, propositions, theories, and raw perceptual data that the learner has available to him at any point in time" [5]. The cognitive structure continually changes as new knowledge is constructed, during "processes of mutual accommodation of the cognitive structure and […] new material of learning" [6]. Learning is always linked to existing thoughts and ideas, and is therefore meaningful. Different people display varying degrees of openness to new learning, with some who are naturally receptive to new materials of learning, even if accommodation of this material involves radically altering their cognitive structure, whilst others tend to reject new learning unless it is largely compatible with what they already know. Or as Moon [6] puts it "what we already know, in its guiding and organizing role, can act as a gate-keeper to learning". She goes on to suggest that "the mission of adult education is to emancipate people from a self-imposed restrictive view of the world, to one that is open to new ideas […]".

Learning can also be characterised by a 'deep' or 'surface' approach. The deep approach involves an intention on the part of the learner to understand ideas for themselves, by "relating ideas to previous knowledge and experience; looking for patterns and underlying principles; checking evidence and relating it to conclusions; examining logic and argument cautiously and critically; becoming actively interested in course content" [6]. The surface approach to learning, however, involves an intention to "cope with course requirements, by studying without reflecting on either purpose or strategy; treating the course as unrelated bits of knowledge; memorizing facts and procedures routinely; finding difficulty in making sense of new ideas presented" [6]. It is thought that the deep approach to learning involves more significant changes to the cognitive structure, as it accommodates to new material of learning, and is more strongly linked to relevant existing knowledge. Deep learning is therefore more meaningful.

Another key concept in the learning literature is that of the 'representation' of learning [7]. That is, how learning is expressed. For example, this may be in the form of a written essay, a verbal presentation, or a reflective learning journal (among others). The quality of the representation of learning will be influenced by whether the approach to learning is surface or deep. Representation of learning plays its own role in learning itself, in that "learning occurs in the process of representing the learning [7]. It "gives the learner an opportunity to reflect on the ways in which the bits of knowledge, now expressed, relate together and to previous learning, or how they work in towards the aim of the representation" [6]. This idea of deepening learning is described as 'upgrading' learning. Learning from representation of learning can upgrade surface learning to deep learning, by making further accommodations between the cognitive structure and the materials of learning.

2.2 Reflection and experience

Boyd and Fales [8] define reflection as "the process of internally examining and exploring an issue of concern, triggered by an experience, which creates and clarifies meaning in terms of self and which results in a changed conceptual perspective". Schön [2] has also described reflection, in terms of reflective practice. He introduced the concept of reflection-in-action, a kind of reflection that takes place spontaneously during practical activity, as a kind of improvisation, which in turn guides the development of that activity. He also described a kind of reflection that takes place about reflection-in-

action itself, namely reflection-on-action. Elsewhere Van Manen [9] has proposed a categorisation of reflection, based on four levels of increasingly higher abstraction: 1. Thinking and acting in a common-sense manner on an 'everyday' basis. 2. Reflection that is focused on events or incidents. 3. Reflection on personal experience and that of others. 4. Reflection on the manner of reflection. The second level of reflection roughly matches Schön's [2] reflection-on-action, whereas the third level of reflection is of a higher order, not linked to a specific event, and may involve knowledge developed from previous reflection. The fourth level is meta-reflection, on the very nature of knowing and reflecting i.e. reflecting at an ontological level.

Reflection appears to play a key role in experiential learning [10]. Meaningful experience in this sense in not just limited to pure activity. Additional material for reflection that relates to this activity will be considered, such as understanding from previous experience as well as prior knowledge about theories and ideas. The subsequent production of representations of learning, based on this experiential learning, will involve further reflection and therefore further learning (effectively a second cycle of Kolb's [10] experiential learning cycle: experience, reflect, conceptualise, experiment). Therefore "few situations of learning from experience will be pure activity, or absolutely distinguishable from all aspects of classroom teaching. It seems reasonable to suggest that no learner will come to a situation without any prior knowledge and experience", indeed "the nature of learning itself can be defined as the active construction of meaning by a learner building on and modifying meaning that they have arrived at in prior learning" [6]. Reflection and learning from experience cannot be forced, they are private processes entirely controlled by the learner. They can only be encouraged and guided within a learning environment. Assessment is a powerful tool in this respect, providing a strong incentive to learn, but also shaping the form of that learning, and more crucially, can either encourage or discourage reflection. One of the defining characteristics of surface learning is a lack of reflection; therefore the encouragement of reflection in learning, through assessment and other means, is fundamental in stimulating a deep learning approach.

A key point to make is that learners do not learn directly from experience, rather they learn from their 'perceptions' of that experience. The prior experience, knowledge, and worldview of the learner will have a strong influence on the outcomes of learning from experience. Moon [6] suggests that educators involved in experiential learning "need to pay more attention to the prior experiences of the learner that will affect their initial perceptions of the experience". This has significant implications for engineering design students undertaking PBL experiences, whose perceptions of that experience will be strongly influenced by prior engineering science learning and its related positivistic worldview.

It is hard to evaluate the impact and value of approaches used to encourage reflection in learning, especially in quantitative terms, but many studies reveal a positive emotional response and expression of value in the learners involved. A study by McDonnell, Lloyd, and Valkenburg [11] explored the construction of video-stories to encourage reflection in design education, using small teams of final year industrial design students. The students spoke of "a genuine struggle to make sense of the discrepancies between education and practice, to resolve the objective views of designing products through rational problem-solving and structured process stages with their practical experience as creative individuals cooperating socially in design activity".

The most commonly used (and researched) means of encouraging reflection in formal education, is use of reflective learning journals [12], [13]. The mechanism of reflection is stimulated by the process of representing learning (usually) in written form, and reading this representation back. Learning journals also enable the upgrading of learning, from surface to deep learning "where unconnected areas of meaning cohere and deeper meaning emerge" [6]. Some of the other key purposes of learning journals are [6]: to enable the learner to understand their own learning process, to increase personal ownership of learning, to explore the self, personal constructs of meaning, and understand one's view of the world, and to enhance creativity by making better use of intuitive understanding. Learning journals can be completely unstructured, or structured to varying degrees to guide the process of reflection more specifically. Structured forms can include questions, exercises, or guidance about particular issues to reflect on. This structure is determined by the learning that the journal is intended to accompany. In a study by Chappell [12], reflective learning journals were used to support an experiential problem-based learning module, in the first year of a Geography programme. Chappell describes how the students were seen to undergo a 'grieving process' in the transition from 'teach me' to 'help me to learn' attitudes, and that "the students learning journals demonstrated a critical engagement with their learning environment'.

2.3 Teaching philosophy of design

In addition to learning journals, Moon [6] recommends that students be encouraged to reflect by including teaching of critical thinking and philosophy in formal education… "Following a course in philosophy legitimises and enables practice in the questioning of assumptions that underpin any other learning – the process of reflection." Therefore, a complimentary pedagogical aid to reflection is the teaching of 'philosophy of design', before or alongside PBL design courses. Where 'philosophy of design' can be considered as "the pursuit of insights about design by philosophical means" [14]. In other words, exploring the learning paradigms within which different problem-solving approaches sit, and how creative design activity can be understood in philosophical terms. This would help to make visible the positivist learning paradigm within which schools of engineering operate, and allow students to understand how problem-solving in design is different. Downey and Lucena [1] suggest that "reform in engineering education may have to move beyond expanding and enhancing design education to address the very distinction between science and design". Galle [14] suggests that "[philosophy of design] serves the end of helping, guiding, suggesting how the [designer] comes to understand what he is doing, and not simply how he comes to do what he is doing."

2.4 Complexity and constructivist inquiry

Findeli [15] questions the status quo of design education, suggesting that the prevailing paradigm, with its "materialistic underlying metaphysics; positivistic methods of inquiry; and an agnosticist, dualistic worldview" is an inappropriate basis for design education. He proposes an alternative epistemology of design practice based on complexity theory, and a theoretical model of design for education conceptualising design activity as a complex system. He argues that a new structure of the design process should be: instead of a problem, we have state A of a system; instead of a solution, we have state B of the system; the designer and the user are part of the system. Findeli suggests that "the designer's task is to understand the dynamic morphology of the system, its 'intelligence'. One cannot act *upon* a system, only *within* a system." Because the designer and user are part of the system, they change state too, i.e. they are learning. He suggests that mathematical or formalistic approaches are not appropriate as an educational basis for complexity theory in design education, due to their 'objective' nature. Instead he suggests that "a system, and especially a human or social system, is best understood from within, through a constructivist, phenomenological, approach". In a more recent paper, Wang [16] supports the notion that a design project can be conceived as a complex system and points to the fact that, within complexity theory, "there is no distinct separation between knower and knowledge. A learner does not assimilate objective truth; instead, he or she creates subjective meanings and values from the educational experience." Like Findeli, Wang concludes that learning is research-like and that "under this paradigm research is mainly concerned with constructivist understanding of the relationship among all the parts of the system. In other words, such research is sociocultural instead of scientific".

3 DEVELOPING NOVEL PEDAGOGICAL AIDS TO REFLECTION IN PBL

It is proposed here that the teaching of philosophy of design, combined with the use of reflective learning journals structured using a constructivist inquiry framework, might potentially allow students to access a deeper level of understanding of their own individual approaches to design, by enabling meta-reflection at an ontological level. This section outlines an educational intervention that has been carried out within a second year PBL engineering design unit, using this combined approach.

3.1 Intervention context

The intervention has been taking place within the CAME School of Engineering at the University of Bristol (UK). The educational context of the undergraduate engineering design programme is that of an integrated PBL approach to learning design. As an institution, the University is also a member of the international 'Conceive, Design, Implement, Operate' (CDIO) curriculum initiative.

The focus of the intervention is a second year PBL group design unit, 'Design Project 2'. A mandatory core unit within the programme, spanning 20 weeks. It is the first PBL design experience the students encounter within the degree programme. There are currently 31 students registered on the unit, with a near equal gender balance. The students are required to carry out 3 group design projects, of increasing complexity, with the final project involving both design and make aspects. The unit is taught by three members of academic staff (including the author), each with a minimum of 3 years' experience

teaching on the course. Reflective learning journals have not been used previously in this unit, and none of the three academic staff has experience with using them in a design teaching capacity.

3.2 Aids to reflection

During the first half of the unit the students received a series of 3 lectures on the philosophy of design, alongside their studio-based design work, and were asked to submit a reflective learning journal, structured using a constructivist inquiry framework, as part of their assessed final project report.

The philosophy of design lectures include content on the fundamental nature of designing (paradoxes [17], framing, problem-solution co evolution, fixation), the differing paradigms of engineering design, including positivism and constructivism, and complexity as meta-paradigm, the differing nature of design and science knowledge, and design framed as constructivist inquiry. The purpose was to open-up the worldview of the students, to allow them to place their own learning within the appropriate philosophical context, and to reflect on their experience of designing at an ontological level.

The students have also been asked to submit an individual reflective learning journal, in which they reflect on their experience of designing, written from the perspective of a constructivist inquiry researcher exploring a complex system. They have been asked to structure the journals according to the five core activities of constructivist inquiry; *collecting design data, analysing and interpreting design data, identifying themes and a central paradox, theory-building and testing*, and *writing the design story* [4]. The purpose of the journals is to deepen learning from experience, by encouraging the students to develop meaning about that experience through reflection. The structured learning journal is also a place for each student to exercise reflexivity during design activity, in order to explore the self and personal constructs that influence how they view the world. Assessment of the structured learning journals should provide motivation for the students to engage with, and learn from, the process of reflection. They will be assessed according to the *quality* of reflection, the *engagement* with learning, and the *depth* of insights into designing that result. Worth 10% of the final project mark.

3.3 Data collection and analysis

The submitted reflective learning journals form a dataset with which to evaluate the impact and potential value of the novel combined approach. This qualitative dataset will be analysed fully using thematic analysis, a method for identifying, analysing, and reporting themes within data. Any emerging themes should help shed light on the impacts of teaching philosophy of design and using structured reflective learning journals to enable meta-reflection.

4 PRELIMINARY RESULTS AND DISCUSSION

Early indications are that this combined approach is having a positive impact on reflection and learning. All 31 students submitted a reflective learning journal and successfully completed these according to the constructivist inquiry framework set out in the guidance notes. The general quality of these representations of learning is very high, indicating that for the majority of students deep learning has occurred. Key philosophy of design concepts introduced in the lectures, such as; fixation, framing, problem/solution ‘spaces’, design abductive reasoning, and constructivist/positivist learning were used to support reflection in 23 of the 31 submitted journals, even though these concepts were not explicitly mentioned in the journal guidance notes. Arguably the most challenging element of the constructivist framework was *identifying themes and a central paradox* - a novel experience for these students. 24 of the 31 students were able to identify appropriate themes and a central paradox for the design problem (with the remaining 7 students attempting to, but falling wide of the mark). These preliminary results indicate a critical engagement with the new materials of learning relating to philosophy of design, and therefore imply an accommodation of the cognitive structure, apparently leading (in most cases) to meaningful reflection at a high level of abstraction. Results from a full analysis of the dataset will be published in a future paper.

In general, the value of using philosophy of design as the basis for new pedagogical aids to reflection in PBL design experiences is four-fold. Firstly, there are positive implications for ethics and reflexivity in design education. Constructivist inquiry, within a complexity paradigm, acknowledges the influence of the self, and that the designer is always a part of the system they are studying, and therefore there is a need to be reflexive. The designer has a responsibility to users, the wider population, society, and the environment. Secondly, philosophy of design, complexity, and constructivist inquiry are established areas of intellectual endeavour. There is a wealth of published literature available, and an established core of knowledge. Thirdly, aids to reflection based on

philosophy of design are straight forward and practical to implement, even in a saturated curriculum. Learning journals are a well-established method of encouraging reflection, and philosophy of design may be taught effectively through conventional lecture-based methods. Finally, and perhaps most crucially, philosophy of design has the potential to resolve the meta-paradox at the very heart of engineering design education, the clash of constructivist and positivist paradigms of learning. Complexity as a meta-paradigm is compatible with both constructivism and positivism. Students can become aware of, and comfortable in, multiple paradigms of learning. By emancipating students from a narrow world-view about the nature of learning and knowledge, students should be enabled to reflect at a higher level of abstraction, allowing them to make deeper sense and meaning of their own design experience during PBL units, and gain the necessary tacit skills and knowledge of creative design.

5 CONCLUSIONS

This paper proposes a novel approach to enabling reflection during PBL design experiences, using philosophy of design teaching combined with use of reflective learning journals structured using a constructivist inquiry framework. It also outlines the progress of an educational intervention within a second year PBL engineering design course, using this approach. Early indications are that this combined approach is having a positive impact on reflection and learning.

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