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ACHIEVING COST-EFFECTIVE DESIGN EDUCATION: HIGHEST QUALITY GRADUATES FOR LEAST RESOURCES AND COST

R. Cowdroy and A. Williams

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1. Introduction

1.1 The thrust of this paper

The primary purpose of this paper is to show how results of recent original basic empirical research into the mental processes of various types of creativity apply to design education. The intent of the paper is to help overcome entrenched suspicion about creativity as too imprecise for pragmatic design such as in engineering. The paper makes no claim to contributing anything new to recent literature about best practices in education in general. Instead, the paper makes an original contribution to understanding relationships between the mental processes of creativity and design processes (particularly engineering and related "pragmatic" design fields) and how recognition and development of the underlying creative processes can contribute to greatly improved best-practices and cost benefits in design education. The paper shows how the various combinations of creative thinking processes are directly relevant in varying ways to *all* design, then goes on to show how these creative thinking processes can be assessed transparently and can make innovative and significant contributions to increasing design ability in students and graduates, and to meeting educational objectives of best practice, and institutional objectives of accountability and efficiency.

1.2 What do we mean by design?

Common usage of the word "design" (in English) gives it several conflicting meanings (adding to the confusion) and it is therefore necessary for us (the authors) to say what *we* mean when *we* use the word and its derivatives in this paper, ie:

- designing (or to design) refers to a combination of primarily intellectual activity and subsequent crafting activity which result in a design;
- a design refers to an iterative artifact (a design for…) which is a sketch, drawing, model or other that expresses the design intent for a nominated purpose or product.
- Both designing and a design are precursors to a nominated end product (that was intended to be designed).

Design takes many and varied forms across a wide range of disciplines including graphic design, textile design, fashion design, engineering design, industrial design, architectural design, civic design and landscape design (among others). These range from very "pragmatic" to very "aesthetic" design types.

1.3 What do we mean by design education?

Design education takes many and varied forms across the range of design disciplines For present purposes we use the term design education to mean development of ability to design, through processes of structured formal learning and, through processes of formal assessment, verification of ability to design at graduation across the whole range from very pragmatic to very aesthetic design types.

1.4 What do we mean by cost-effective?

It is unfortunate that the term "cost-effective" puts cost ahead of effectiveness; in this paper our focus is on achieving educational effectiveness (first and foremost) at cost efficiency. In this paper educational effectiveness refers to achieving highly effective graduate designers, and cost refers not only to monetary cost, but also to resources and teacher and student workload. Cost-effectiveness in design education therefore refers to a balance between two realities: the reality of need to achieve effective graduate designers and the reality of having to justify the resource costs of doing so.

1.5 A brief historical introduction to current practices in design education

Broadly, the educational approaches for various design disciplines fall into three groups: those evolving from a fine-arts background and generally conforming to a studio-based Beaux Artes educational model; those evolving from a technology background and generally conforming to an applied science educational model; and alternative combinations of studio-based and scientific models often referred to as Bauhaus educational models.

Interest in alternative educational approaches to design education has been gradually increasing since the Bauhaus experiments of the 1930s in Germany and their "migration" to America in the post-war years and then to design education institutions throughout the developed world. The "Reflective Practitioner" philosophy of Donald Schön [1983] focused particularly on architectural and engineering education, was developed from Bauhaus principles and led initially to the introduction of "Problem-Based Learning" by Donald Woods [1985] for undergraduate engineering design education.

Howard Barrows [1986] developed a "cognitive apprentice" model (also called "Problem-Based Learning") combining Schön's and Woods' themes for medical education. Barrows' model was then adapted to architectural and other design education domains, including particularly an "Integrated Learning" model and (later) a "Research-Based Learning" model in Architecture at the University of Newcastle, Australia [Maitland & Cowdroy, 2001] and a "Block" model in Architecture and related design programmes at TUDelft, Netherlands [de Graff & Westrik, 1994]. The outstanding success and acceptance of Woods', Schön's, Barrows', Newcastle's and Delft's models led to further adaptations across a wide range of design education.

Many design educators reacted against these innovations and entrenched themselves in either Beaux Artes "free expression" approaches or "scientific" design education approaches based on rigorous analytical design routines. A majority, however, adopted various combinations of studio-based and scientific approaches, with studio-based tutorials and master classes for some parts of their programmes, and analytical, procedural approaches for the other parts.

Most assessment in design, however, is of the product, not the student. In the absence of specific criteria for assessing the mental processes of creativity in the student's mind, drawings, models, prototypes, etc are assessed for their observable imaginative, innovative, inventive or creative qualities on the grossly erroneous assumption that this is a measure of the student's creative ability [Cowdroy & DeGraaff, 2005]. The research findings outlined here, however, provide a reliable means of directly-assessing the student's "hidden" creative abilities and processes.

2. Special challenges for design education

2.1 The accreditation anomaly

A major challenge for design education arises from conflicting expectations of three external authorities: the accreditation authority, the employer profession, and the educational institution [after

Harman & Meeks, 2000]. A design education programme can be given consistently high professional accreditation but at the same time be subject to consistent calls from the same profession for reform, and consistent complaints from the institution for poor teaching practices. Why does this anomaly occur? A major part of the problem is that design education programmes do not entirely fit either the “real science” or the “real humanities” educational stereotypes. Added to this, professional accreditation does not care whether it is science or humanities; it is only concerned with minimum curriculum content components of knowledge and procedures and whether they have been delivered. The profession who employ graduates, however, are more concerned with “real-world” complexity of knowledge, procedures and personal development. At the same time, the institution is primarily concerned with best educational practices at least resource cost, for meeting both the accreditation and employer expectations. The results of research outlined in this paper promise to give all three external authorities common ground for more precise definition and alignment of graduate attributes (design ability), curriculum content, and educational strategies.

2.2 Contradictory educational objectives = alignment problems

These conflicting external requirements result in ambiguous teaching and assessment practices, particularly when the institution pressures faculty to adopt least-cost teaching and most-transparent assessment. Faculty respond by trying to restrict teaching and assessment to entirely “objective” science methods, or entirely “subjective” humanities methods, but attempt to adopt both “prescriptive” science teaching methods (didactic lectures and apprenticeship laboratory sessions) and “interpretive” humanities teaching methods (group discussions, essays and studio sessions). The prescriptive science approach will work for the technical and rational/procedural components of the curriculum but not for the interpretive (creative) design components, while the interpretive humanities approach will work for the interpretive design components but not for the technical and rational/procedural components. The most significant consequence of these contradictory educational objectives is faculty’s inability to defend themselves against calls for reform and funding cuts, because they have been unable to satisfy the basic requirement of quality assurance: alignment between programme objectives (ie attributes) stated in the handbook, with curriculum content and assessment protocols, as indicated in Table 1 below:

Table 1. Test for alignment

<table>
<tr><td>Handbook</td><td>Curriculum</td><td>Assessment</td></tr>
<tr><td>Exactly what graduate designer attributes are stated or implied here as objectives of the programme?</td><td>Exactly what graduate designer attributes are being developed by the curriculum at any point and over the whole programme?</td><td>Exactly what graduate designer attributes are being measured by the assessment protocols at any point and over the whole programme?</td></tr>
<tr><td colspan="3">Are these graduate designer attributes all exactly the same for objectives, curriculum and assessment? That is: are the graduate designer attributes in alignment?</td></tr>
<tr><td colspan="3">If the answer to these last two questions is “YES”, then the attribute objectives are in alignment and the basic requirement for quality assurance has been met; if the answer to these two questions is NO, then the basic requirement for quality assurance cannot be met.</td></tr>
</table>

The more precise definitions of creative thinking provided by the research outlined in this paper offers a solution to the alignment problem by allowing creative/interpretive thinking to be assessed reliably in conjunction with rational/prescriptive procedural skills.

3. RELEVANT RESEARCH OUTCOMES

3.1 Defining creativity

A series of recent empirical research projects into the mental processes of creativity and complex decision-making has showed (amongst other things) that creativity at a fundamental level is a combination of particular sets of thinking processes and particular types of memory to generate ideas, which are then transformed from “just an idea” into a “creative idea” through some form of iteration.

These research projects also showed that subsequent development of the creative idea into a creative work involved two less fundamental (and less creative) sets of combined thinking, memory, iterative processes and/or crafting. These studies add to the literature on neuroscience, thinking and memory by showing how neurological functions, memory and iteration combine in various ways to generate what we loosely refer to as creativity [Cowdroy & DeGraaff, 2005].

The research projects showed that high-level creativity starts as embryonic (ie, formless), but nevertheless complex ideas [after Deleuze & Guittari, 1987] generated by combinations of intuitive thinking and "romantic" memory processes [Goldberg, 2001; Eichenbaum, 2003]. These embrionic ideas are translated by iterative processes (eg, doodles, scribbles) [Crick & Cowdroy, 1999] into a conceptual idea. Creative thinking at this fundamental level is referred to as "Conceptualisation" [Cowdroy & DeGraaff, 2005] and is particularly associated with recognised experts in the field.

The creative process may then proceed into (or lower-level creativity may commence in) a second type of creativity referred to as "Schematisation" using a second type of thinking (lateral/rational) combined with a second type of memory (declarative) to generate *schemata* that are "possibilities" for creative works, and iterative skills (outline sketches, initial models, etc) that allow retention and communication of the developed schema [Cowdroy & DeGraaff, 2005]. This type of design process is particularly associated with the "excellent" professional practitioner.

In order to proceed towards a creative work, the creative process must then move on into (or perhaps begin and end with) a third, reflective type of creativity referred to as "actualisation" [after Deleuze & Guittari, 1987] which is entirely a mental processes of reflection and decision on the pros and cons of various schemata generated in the previous stage and decision on whether to proceed into further development and, if so, which schema is to survive (for present purposes we can consider actualisation as engaging the same mental processes as in schematisation).

A fourth type of creativity referred to as "Realisation" engages a fourth type of thinking (procedural) with a third type of memory (processional) and iterative and crafting skills (working drawings, prototype models, etc) that further develop the schemata into "creative works".

In summary, highly creative work requires initial engagement of *conceptualisation* to generate a concept; further development of the concept (or initiation of a lower level of creativity) commences with *schematisation*; a reflection + decision process called *actualisation* is required for further development; and final development of schemata (or commencement of a lowest level of creativity) commences and ends in *realisation*. Thus, this research defines creativity as abilities that reside in the creative person, not in the creative product [Cowdroy & DeGraaff, 2005]. That is, the person is creative but the idea or product are created *but not creative* in their own right. This research also identifies (for present purposes) three levels of creativity depending on which level of creative thinking was the starting point, and a gatekeeping process (actualisation) which plays an essential part in regulating development of creative work.

3.2 Defining creativity in relation to design

A related set of current research and development projects is addressing the ways in which the various types of creativity relate to design processes [Cowdroy & Williams, 2006]. That research, together with other literature on creativity and thinking show that all fields of design use various combinations from the range of four types of creative thinking outlined above, as follows:

1. *Conceptualisation* (or conceptual thinking) takes a form of complex prognostication that is used to generate initial complete holistic design ideas that generally fit the intended purpose.
2. *Schematisation* (or schematic thinking) takes a form of analytic, diagnostic and extrapolative thinking used for testing the fit of the original design idea to the intended purpose, and progressively modifying it until a "best fit" is achieved;
3. *Actualisation* - a reflection/decision-making process that compares alternative schemata and "finalises" (or "decides") the form the final design will take;
4. *Realisation* - a procedural thinking process that manages the production of the design artifact.

Each type of design thinking is accompanied by a particular type of crafting ability: conceptual thinking is almost invariably accompanied by doodles and rough diagrams (that could not properly be called sketches); schematic thinking by initial "schematic diagrams" and sketches that show initial broad general arrangements; and (for present discussion we pass over actualisation) realisation thinking by more formal "presentation" drawings, prototypes and detailed production drawings. While this research concludes that all design processes are creative to various extents, some use all four types of creativity while others use only three and some only two. This research [Cowdroy & Williams, 2005] also shows, however, that regardless of how many design thinking types are engaged in the development of a design, they are always engaged in a set sequence as indicated in Table 2:

Table 2. Relation between Design Process & Thinking Sequence

Design process:	Thinking Sequence
Where all four thinking-types are engaged	*Conceptualization- schematization - actualisation - realisation.*
Where three thinking types are engaged	*(eg) conceptualisation - schematisation - actualisation* *OR schematisation – actualization - realisation*
Where only two thinking types are engaged	*(eg) schematisation - actualisation* *OR actualisation - realisation*

3.3 Basic design, moderately complex design and highly-complex design.

Three types of creativity, conceptualisation, schematisation and realisation referred to above can now be considered in terms of three differing levels of design complexity [Cowdroy & Williams, 2006], as follows:

1. **Basic design:** In many designs the design process requires only minimal analysis of alternative design types. For instance, for renovating a building, designing a new conventional bridge, or designing a new electric appliance are relatively simple adaptive or repetitive designs with few new constraints, and a design decision (actualisation) can be reached relatively easily. The design process in these cases will only require *actualisation* thinking (decision on design type) and *realisation* thinking (production of drawings, models and prototype), with a primary focus on realisation through development of production drawings and models, etc. For present discussion we refer to this as a basic design process.
2. **Moderately complex design:** Other designs (perhaps a majority of professional and commercial designs) involve a combination of three thinking types (and associated crafting types): schematisation thinking to develop the initial overall design idea within a set of conventions, actualisation thinking to decide on the final form of the design, and realisation thinking to control the articulation of the design idea into production drawings, models and working prototypes. The dominant thinking type here is schematisation, which involves extensive reference to (past) experience and data, consideration of alternative design possibilities (through various schematic drawings and diagrams), and extrapolation to a new application, such as design of the new Wembley stadium, design of a new generation Maserati car, or design of next year's fashions (with progressive advance to presentation and then production drawings, prototypes, etc). Design in these examples does not involve radical departure from previous designs for each of these products. For present discussion we refer to this as a moderately complex design process.
3. **Highly complex design:** Some design processes, however, involve radical departure from previous designs, in order to make a "break-through" innovation to a new design type or benchmark, that addresses multiply complex constraints in a new way. For instance a radically new type of building such as the Pompidou Exhibition Centre in Paris (which is an "inside-out" building), a new type of ship such as the wave-piercing catamaran ferry, or a new type of product such as the iPod were all radical departures from the norm for the respective product-type. Design involving this level of innovation and inventiveness and departure from conventional design rules require all four types of design thinking (and related crafting) to be engaged. For present discussion we refer to this as a highly complex design process.

At this point we can note that while conceptual design (ie design generated by conceptualisation) is generally associated only with "aesthetic" design such as in architectural design and disassociated with "pragmatic" design such as in engineering design, conceptualisation can now be seen to be a part of any highly-complex design, including inventions (which are widely associated with engineering), and conceptualisation is therefore an essential part of the design process at the highest levels of design in both architecture and engineering (and all other design fields). Similarly, schematisation can be seen to be part of any moderately complex design, and is therefore an essential part of the design process in the majority of all professional design practice in all design fields, while realisation is seen as an essential part of the basic design level of design production (working drawings, mock-ups, prototypes) in all design fields. Thus, while engineering (for example) is generally considered to be pragmatic and requiring only analytic/diagnostic approaches to design, the discussion above indicates that some engineering design (at the highest levels of complexity and inventiveness) depends on conceptualisation design thinking as its starting point; that the majority of professional design practice is moderately complexand depends on schematisation as its starting point, while basic engineering design (at the least complex, least innovative level) depends only on realisation.

4. DESIGN EDUCATION IMPLICATIONS

4.1 Reflection on the alignment issue

From the literature we can see that best practice in design education, as in all effective higher education, requires alignment of three operative components: outcome objectives, curricula and assessment [after Biggs, 2003], as follows:

1. outcome-objectives of the programme must be defined in terms of explicit graduate attributes (eg, ability to…..) and not in broad mission-statement terms (eg, world class graduates)
2. curricula include detailed syllabi (content) and teaching protocols (methods of delivery) which together form strategies for achieving the outcome-objectives defined in #1 above. In order to achieve alignment, the syllabi and teaching protocols must directly and comprehensively develop the specific graduate attributes defined in the outcome objectives.
3. assessment protocols are not only tests of individual students' achievement in terms of syllabus, but must be seen as monitoring the effectiveness of teaching strategies, in #2 above, in order to achieve the outcome-objectives set, in #1 above.

4.2 Re-casting the outcome-objectives in terms of creative design ability

In practice, in nearly all design fields, individual designers rarely work through all stages of design development. In cases of highly complex design processes, the initial (overall concept) designer will often "hand over" at some stage in the design process for further schematic development of the design through to actualisation (decision). The design process will then be handed over again to other designers for realisation in terms of final drawings, models and specifications. In practice, however, graduates are expected to undertake design activity at all levels of complexity and innovativeness within their design discipline and to take their place at any stage in the overall design process in complex break-through designs. In practice, too, a graduate is expected to base design thinking at all levels of complexity on theoretical frameworks, technical knowledge and experience. That is, various theoretical frameworks, technical knowledge and experience from various sources must be integrated through the design process. From and educational perspective, therefore, graduates must have acquired all four types of design thinking and their sequence, as well as respective crafting abilities, and relevant theoretical frameworks, technical knowledge and experience, and be able to integrate them into various types of design process, by the end of the design education process. Graduate attributes can now, therefore, be more explicitly defined in terms of

1. Ability to design at the three levels of design complexity,
2. Ability to design by means of the four design thinking abilities in sequence
3. Ability to integrate particular theoretical frameworks, technical knowledge and experience at each level of design complexity and sequentially.

4.3 Re-casting the curriculum

The curriculum content (syllabus) can now be re-cast to directly and explicitly address development of the three attributes (abilities) outlined above, and teaching/learning methods selected to develop the specific abilities. Without going into specific teaching/learning methods and their pros and cons in this paper, the emphasis on integration and composite thinking, iteration and crafting abilities in the graduate attributes outlined above imply that project-based, problem-based, research-based or cognitive apprenticeship approaches to teaching and learning are likely to be more appropriate than didactic and elemental approaches. It is also most likely that a uniform one-size-fits-all approach to teaching and learning will not be effective for development of design ability at all levels of complexity, nor is a uniform approach likely to be appropriate for development of these abilities at all stages of a student's development. A multiple approach to teaching/learning is therefore indicated [after Biggs, 2003] for instance:

1. Development of basic design abilities (actualisation + realisation) requires lower-order skills including linear thinking and particular iteration and crafting abilities (eg, production drawings, prototypes). Appropriate learning methods for lower-order task ability include conventional rote, recognition and repetition (RRR) methods.
2. Development of moderately-complex design abilities (schematisation, actualisation) involves lateral and diagnostic thinking and particular iteration and crafting abilities (prototype model-making, presentation graphics) and implies a significant shift towards student-centred heuristic learning by individual searching and experimenting. Case-study based cognitive apprenticeship learning strategies including domain specific diagnosis, debate and dialectic, (DDD) have been very successful in developing mid-level task abilities.
3. Development of highly-complex design ability involves significantly more complex conceptualisation design thinking and iteration abilities (but little or no crafting). Effective learning strategies for developing design abilities at this level are characteristically heuristic and increasingly research-and-development (R&D) oriented (i.e. closely related to the way an expert practices) with extensive praxis, often in simulated practice environments

4.4 Re-casting assessment

Assessment of such variable composites of abilities suggests that multiple assessment methods will be required [after Biggs, 2003]. Assessment of basic design ability (realisation) is largely concerned with lower-order abilities, suggesting that conventional analogue (numerical) assessment methods (eg right/wrong demonstration or multiple choice examination) may be sufficient and appropriate.

Assessing mid-level "professional" design abilities, however, involves composites of various types and levels of ability, including ability to integrate theoretical frameworks, technical knowledge and experience. To be effective, assessment of this type of composite of abilities is likely to require holistic/hermeneutic approaches (interpretation of work/evidence in terms of "accepted" quality/ranking value systems) that can simultaneously accommodate multiple types of knowledge and skills. [Cowdroy & Williams, 2005]. Recent developments of variable-criteria and transitional criteria assessment methods provide for reliable assessment at this moderate level of complexity.

Assessing highest-level "expert" design ability requires a more radical assessment method such as the Authenticative Assessment approach based on research evaluation methods [Cowdroy & Mauffette, 2003] and involving "expert" assessor panels addressing the individual student's rationale (presentation and defense). This type of assessment method simultaneously addresses composites of widely differing abilities. It closely reflects assessment protocols used in the evaluation of design proposals in industry, commerce and the professions and has established credibility for both educational and accreditation purposes.

5. Conclusion

The results of this research allow re-casting the outcome objectives in terms of explicit graduate attributes defined as design abilites related to creative abilities and various levels of design complexity and provides a much more explicit set of attributes than usually found in handbooks.

Teaching/learning strategies such as those outlined above can then be chosen (and perhaps adapted) to specifically develop these explicit attributes, and recently developed assessment protocols can then be adopted to specifically test and demonstrate achievement of the complexity implicit in the graduate attributes prescribed in the outcome objectives. Thus, the alignment problem common to most design education programmes can be overcome. Alignment of the attributes, teaching/learning and assessment then allows students and teachers to monitor progress much more closely against the intended graduate attributes. Further, inclusion of explicitly defined highest-level design abilities (as well as lower level design abilities) in the outcome objectives provides agreed measures of achievement towards which all students can strive and excel. Provided the graduate attributes are set at the highest level (rather than the customary minimum level for accreditation), brilliant students'work (beyond mere excellence) can be measured. Cost effectiveness can then be achieved by demonstrating the alignment between graduate attributes (based on both accreditation and employer expectations), the most effective teaching/learning methods for developing those graduate attributes, and assessment protocols that properly measure and demonstrate achievement of the outcome expectations in each student at each stage of development.

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Professor Anthony Williams
University of Newcastle, School of Architecture and Built Environment
2308 Callaghan, Australia
Email: tony.williams@newcastle.edu.au