Visual Creativity and the Threshold of Uncertainty in Product and Automotive Design

Karen Bull CEPAD, Coventry University, UK

Michael Tovey CEPAD, Coventry University, UK

Abstract

An investigation into the development of visual and spatial creative capabilities in industrial design students is described. It focuses on establishing whether or not spatial intelligence represents a threshold concept in studying industrial design and evaluating whether or not visuo-spatial intelligence can be a measure of a student's cognitive ability to design. A four year longitudinal study highlighted a number of threshold concepts the most significant of which was the toleration of design uncertainty. A separate range of tests and studies covered spatial comprehension, drawing exercises, and pattern-solutioning capability, and they demonstrated that spatial capability represents a baseline requirement and is not a key threshold concept. Further reflection on the uncertainty threshold located it within the concepts of the designerly way of knowing, as a key ingredient in a 'conversation' between two modes of thought in a dual processing model. This was seen as key to facilitating the development of visual creativity in a holistic approach to Coventry University's design curriculum. A range of teaching interventions can be mapped onto this approach. This has informed the basis for an enhanced industrial design study programme which is being introduced.

Keywords

Creativity, Technology, Education, Industrial Design, Spatial Design Intelligence.

Introduction

The Centre of Excellence for Product and Automotive Design (CEPAD) is one of Coventry University's three HEFCE-funded centres for teaching and learning. It has implemented a five-year plan to reinforce existing teaching excellence within the Industrial Design Department of Coventry School of Art and Design (CSAD) and reflect upon its practices to inform future design education. The project pursued a number of themes such as the exploration of design education in the context of the design community of practice; the internationalisation of design education, threshold concepts in design education and the exploration of visual and spatial creativity through digital technologies.

This paper discusses visuo-spatial design intelligence and its relationship to the industrial design curriculum in CSAD. It focuses upon three questions:

1) Is spatial intelligence, pertaining to industrial design, a threshold concept for students?

2) Can visuo-spatial intelligence actually be a measure of a student's cognitive ability to design?

3) How do we engage with 'design uncertainty' in the industrial design curriculum?

Methodology

The first question was addressed through a four year longitudinal study of student experience involving interviews, observation and focus groups to investigate the identification of threshold concepts within industrial design in CSAD. Staff interviews were also conducted.

Question two included three interrelated activities. The first two involved implementing the The Purdue Visualization of Rotations Test (Bodner and Guay, 1997) in parallel to an internally developed test with a cohort of first level undergraduate transport and product design students (Osmond and Turner, 2008) The aim of these two tests was to identify whether it was possible to measure student conceptions of spatial awareness on entry to the industrial design courses and correlate this with their end of year assessment results. The third activity involved conducting a pattern solutioning exercise to establish whether it is possible to recognise visual solutioning capability that could reliably indicate design capability.

Question three is centred upon the results of the first two and leads to the exploration of curriculum interventions that can promote confidence to engage with solutioning processes at the early stages of industrial design study.

Is spatial intelligence a threshold concept for students?

Staff and student understanding of spatial awareness was addressed through interviews with staff and ten first year transport students in 2007. The question explored whether spatial awareness, considered by staff as being at the heart of the Transport and Product Design course was a Threshold Concept (Osmond, Turner, 2008). Meyer and Land describe threshold concepts as “akin to passing through a portal” or “conceptual gateway” that opens up “previously inaccessible way[s] of thinking about something”. Cousin (2009) also provides a practical description of exploring threshold concepts in education.

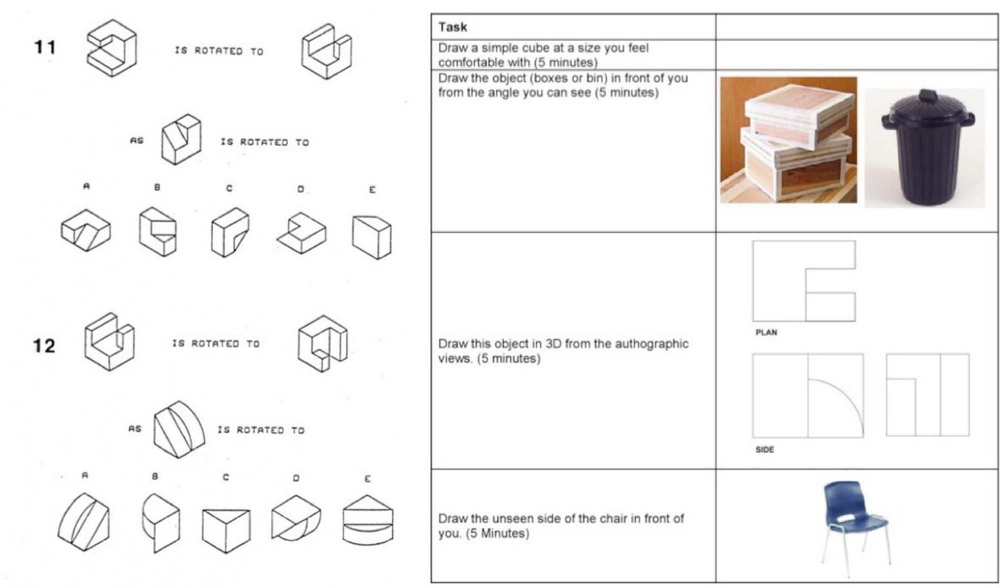
Threshold concepts provide a useful framework for exploring design learning because for the design student, design learning is highly focused on aspiring to become a practitioner and aligning with the design community of practice (Tovey and Owen, 2006, Wenger, 1998). From the beginning of this study design learning was recognised as a transformative process that required a range of cognitive shifts based on engaging with practical design experiences and professional communities along with the acquisition of design knowledge. The research team endeavoured to define the thresholds associated with design learning and findings led to a focus specifically on the toleration of design uncertainty.

A literature search demonstrated that the examination of spatial awareness was well established. Gardner (1983) for example provided useful definitions of spatial intelligence. However sources were more difficult to locate when CEPAD identified that spatial intelligence in the context of industrial design moved beyond the bounds of ‘transformation’ and ‘modification’ to the creative interpretation and progression of form-based ideas. The study became even more challenging when it was identified that even design experts differed in their interpretation of what spatial awareness meant. However interviews led to some themed categories associated with: all-around awareness; co-ordination; design sensitivity; space; intuitive/6th Sense; looking at an object from the outside; mental rotation; positioning system; time; visualisation; and, volume (Osmond, Turner, Land, 2007).

The student interviews, which took place in their first term of study showed a relatively untheorised appreciation of the concept of spatial awareness – some students said that they had not heard of the term, others offered approximate guesses such as ‘Like distance from things and if something will fit into a certain space or if it doesn’t?’. It was evident that spatial awareness is not a threshold concept and that after a few months students developed a more sophisticated spatial understanding. This seemed to indicate that design teaching is effective in the development of spatial ability. While students may arrive with a ‘baseline’ capability in spatial intelligence e.g. show the potential to sketch in three-dimensions, it needs to be nurtured through teaching practice both in terms of skill and articulation.

This phase of the research highlighted that within the field of industrial design education, skills and knowledge practices that staff share with the students in relation to developing visuo-spatial understanding are also relatively untheorised and tacit. However design teaching is recognised by the researchers in CEPAD as being part of a characteristic ‘episteme’ (a system of ideas or way of understanding) of design education practices. The interviews reinforced the perception of spatial intelligence as a fundamental component of the ‘designerly way of knowing’ as defined by Cross (2006). In the context of industrial design this ‘knowing’ is concerned with integrating spatial understanding with solutioning capability along with the application of cultural, technological and empathetic appreciation. The processing involved in this holistic and solution focused approach seems to be centred on matching linear and holistic modes of thinking.

Measuring spatial intelligence



The Purdue Visualization Test

The Transport and Product Design Test

Figure 1: Spatial Intelligence Tests

In parallel with the threshold investigation, two spatial intelligence tests were organised to ascertain if there was a correlation between student scores on the measurement tool on entry to the course and in relation to end-of year assessment results. If a significant correlation existed pedagogic interventions could then be targeted at students on entry to the courses. No clear correlation would require further exploration to understand the centrality of spatial awareness to the first year of study.

The first test was The Purdue Visualization of Rotation Test (PVRT) (See fig. 1 - left) which was developed by Bodney and Guay (1997). It was specifically designed to evaluate courses developed to enhance the spatial skills of students. It focuses on Gestalt processing and the transformation of visual images as a whole, rather than breaking down the whole and re-mapping relationships. The time constrained test involved asking students to recognise a rotation pattern and then select from a range of alternatives a form that represented a similar rotation. This test acted as a benchmark for an internally piloted tool that required students to complete a series of drawing tasks within a limited timeframe to demonstrate skills in spatial awareness (Osmond and Turner, 2008a) (See fig. 1 - right).

The testing showed a lack of correlation between the performance in the PVRT and the internal tests. Performance on the course suggested that the elements of spatial intelligence measured through the tests are not explicitly assessed in the first year of the programme. It was recognised that students already possessed baseline level of skills and creativity sufficient to underpin work for their assessments. Those who scored poorly in their PVRT test did not score poorly in the course assessments. It was concluded that spatial awareness was not a threshold concept, but a required capability that may underpin other potential threshold concepts.

Can visuo-spatial intelligence actually be a measure of a student's cognitive ability to design?

The third test designed by CEPAD centred on the measurement of pattern-solutioning capability at the early levels of study. A small exercise was implemented with a sample of students from both visual and non-visual disciplines at Coventry University. It included students from all levels of industrial design study and a group of non-visual students. The exercise required participants to organise shapes into a harmonious and orderly arrangement (See fig. 2).

The results emerging from visual analysis of the arrangements highlighted that in many instances patterns of solutioning correlated with assessment marks where they were available. However it did highlight differences between sample units in terms of constructing narrative, layout, and accuracy of arrangement, as well as having the confidence to challenge the brief. Non-visual students for example paid less attention to narrative and characteristics such as juxtaposition, use of grids and proportion. It was evident that as students progressed through their study they showed a greater ability to challenge the brief and stretch boundaries in solutioning. However, at the early levels of study the results were less distinct. Students with no visual training were generally able to produce results showing similar capabilities to first level designers.

The exercise highlighted that a student's articulation of their solutioning efforts seemed to be only a coarse measure of solutioning capability. Non-visual students were often more experimental than first year industrial design students, who were often more concerned with geometry and layout. There were also cultural differences in the way the results were organised.

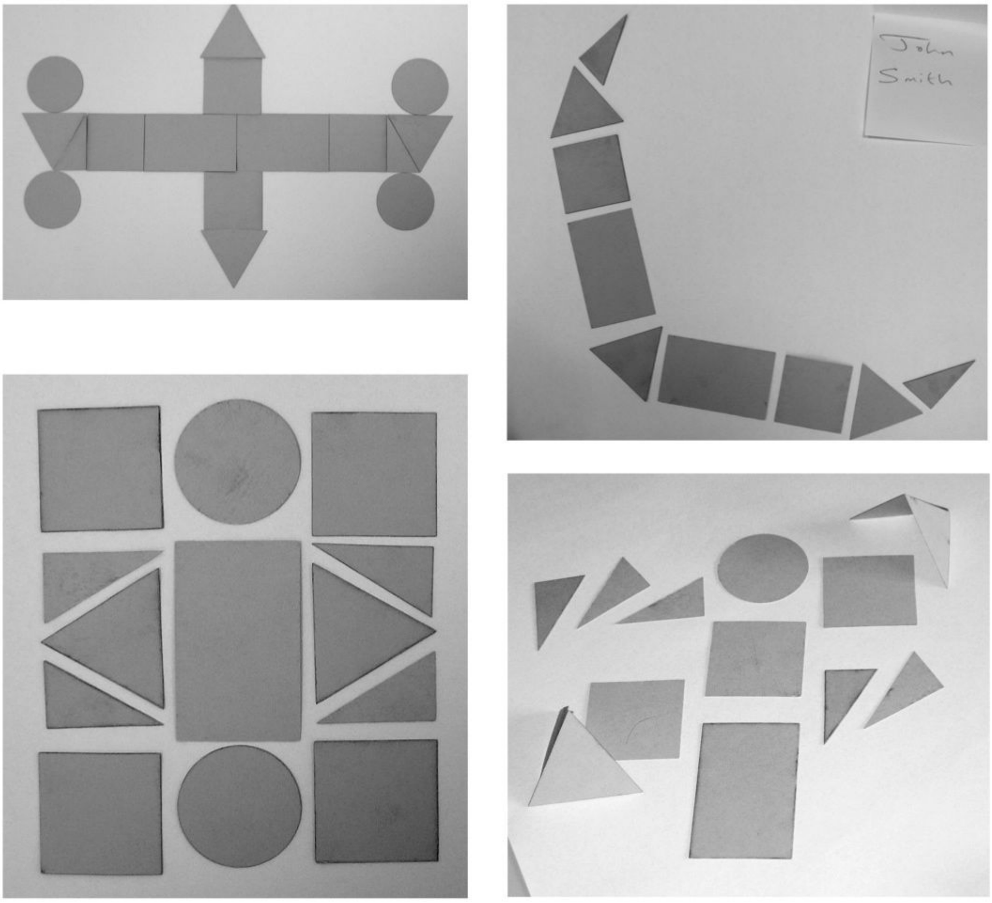


Figure 2: Examples of the visual creativity exercise

Initial Conclusions

From these investigations we came to the slightly unexpected conclusions that we had not demonstrated that spatial intelligence was a threshold concept, and we could not say that visuo-spatial intelligence was a measure of students' cognitive ability to design.

We came to a somewhat more obvious articulation of the importance of spatial ability as a baseline requirement which we perceived as underlying the development of design capability.

'Design uncertainty' in the industrial design curriculum

The results of the evaluation of spatial awareness showed no distinct correlation but did reinforce the view that spatial awareness is a baseline capability that underpins the potential to be a successful industrial design student. What appeared to be more significant was that students needed to gain confidence in design processing activities in order to progress their visuo-spatial capabilities. This 'confidence' relates to the identified threshold concept the 'toleration of design uncertainty'.

CEPAD researchers propose that this threshold manifests itself strongly because it sits between two modes of thinking which range from the analytical (linear and logical) to synthetic (holistic and simultaneous) modes. The ability to integrate these two cognitive modes is core to developing design thinking capability. Experience of new Industrial Design students arriving at Coventry (especially where they have not received a broad, art and design foundation like experience) is that they often have a highly analytical approach to design thinking and have followed a strongly procedural approach to problem solving and project management. The ‘free-thinking’ engagement with synthetic approaches appears to be predominant to the early years of school education and it could be argued that it is somewhat ‘unlearned’ during higher levels of study. This means students can often arrive with a lack of confidence to engage with open briefs which require from them the ability to engage with problem and opportunity definition, and a strong solution focus. They are not equipped for ‘risk-taking’ and conceptual thinking, and often get stuck in the ‘conversation’ that enables them to engage effectively with the solutioning process.

Designerly thinking

The importance of the design ‘conversation’ and its relationship to the threshold of design uncertainty became evident in this research. Our investigation into how it might sit within a design process framework suggested two fundamental characteristics of designing that locate the toleration of design uncertainty within the design process as something familiar and routine. They were:

- ‘Wicked problems’ that commonly present within the ‘designerly way of knowing’
- The analysis –synthesis dialogue that sits at the core of the design process

In the 'Designerly Way of Knowing' Cross (2006) characterises design as an activity involving tackling ‘ill-defined’ problems through a ‘solution-led’ problem-solving approach. Designers employ constructive thinking by using codes to move from the abstract to the concrete and deploying these codes as an object language. Cross makes a number of useful and relevant observations about the design cognition process, noting that designers are solution-focused not problem focused. The designer’s attention oscillates between the problem and its solution, in an appositional search for a matching problem-solution pair, rather than a propositional argument from problem to solution.

Designers are pro-active in problem framing, actively imposing their view of the problem and directing the search for solution conjectures. Problem framing, co-evolution and conceptual bridging between problem and solution seem to characterise design behaviour. Effective design teaching supports and encourages visual creativity within a solutioning framework. However, observations of our curriculum and the longitudinal study have suggested that solutioning needs to be more clearly ‘labelled’ and consciously supported in the curriculum to reduce apprehension surrounding ‘uncertainty’ and reinforce familiarity, especially at the early stages of design learning where the threshold issues are most visible.

These factors are relevant to and support CEPAD’s view that design education should reinforce activities that strengthen the way students engage with the ‘conversation’ that is at the heart of design cognition. This conversation begins with a ‘concept design’ which involves the designer’s attempt to provide a sketchy representation of what the finished design might be or look like. If the designer or design manager sees the concept as providing a basis for proceeding then the structure of the rest of the process falls into place. This is the solution-led approach.

At its core is the process of moving from an abstract statement to a visual object. The designer learns to think in a sketch-like form, in which the abstract patterns of user requirements are turned into the concrete patterns of an actual object, using the code to effect this translation from individual, organisational and social needs to physical artefacts. This is the use of the visual language of designing, employing its translation codes. It is the match of the analytical (left hemisphere) statement to the holistic (right hemisphere) solution. The manifestation of this outcome will be as a visual representation, a drawing or a 3D or virtual model.

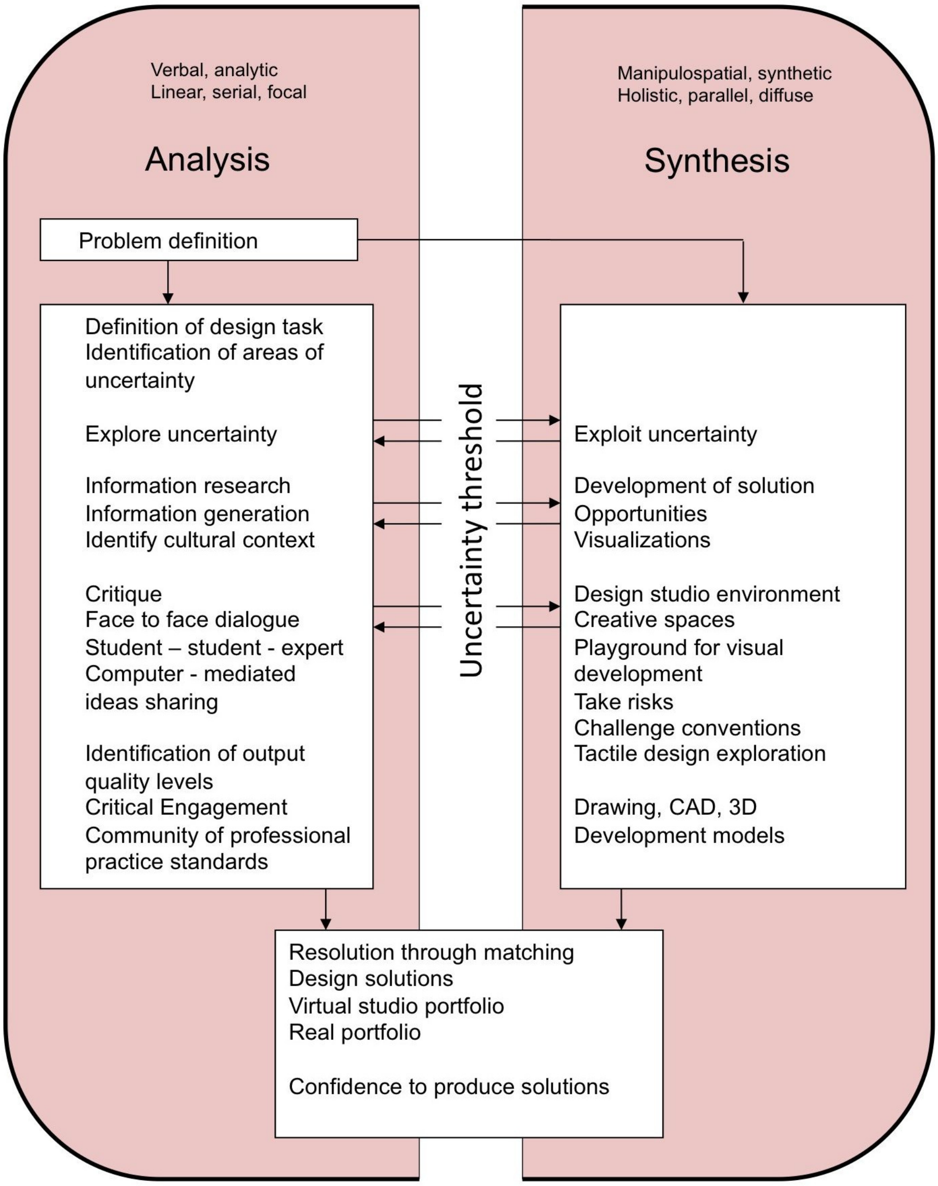


Figure 3: Dual-Processing Model for Industrial Design Education at Coventry

The analysis synthesis dual-processing model

Based on the identification of the preferred processing modes of the two halves of the brain, the essence of the dual processing model (See fig. 3) (Tovey, 1984) is the interaction of the two modes of thought, each stimulating and modifying the other. The evidence for such difference is based on long established research into cerebral laterality. The left hemisphere preference is for local, linear, narrowly focused attention. As figure 3, 4 and 5 demonstrate, the right's preference is for simultaneous, broad, global and flexible attention (McGilchrist 2009). Bruce and Bessant also reinforce this notion, suggesting that creativity is not an entirely rational or conscious activity but rather that "It involves the interplay between conscious and rational thought and unconscious and apparently random or dream-like association and activity".

Serial and simultaneous thinking

Both types of cognition are crucially involved in the evolution and resolution of a fully detailed design proposal. Although the application of such a model to design is of course speculative, it does provide a framework within which different design approaches can be accommodated. The relative emphasis given to serial-analytical and to simultaneous-holistic thinking varies both between designers and between types of design problem. For example engineering designers may give first priority to analysis and the derivation of a specification, whereas product designers may concentrate more on the holistic processes used to derive a design concept presented as a drawing or a 3D model. Nonetheless it is assumed that the design process will always involve both modes of thinking (see fig. 5), in the approach identified as appositional matching (Cross, 2006) and that it is their relative proportions which will vary.

CEPAD and curriculum innovation

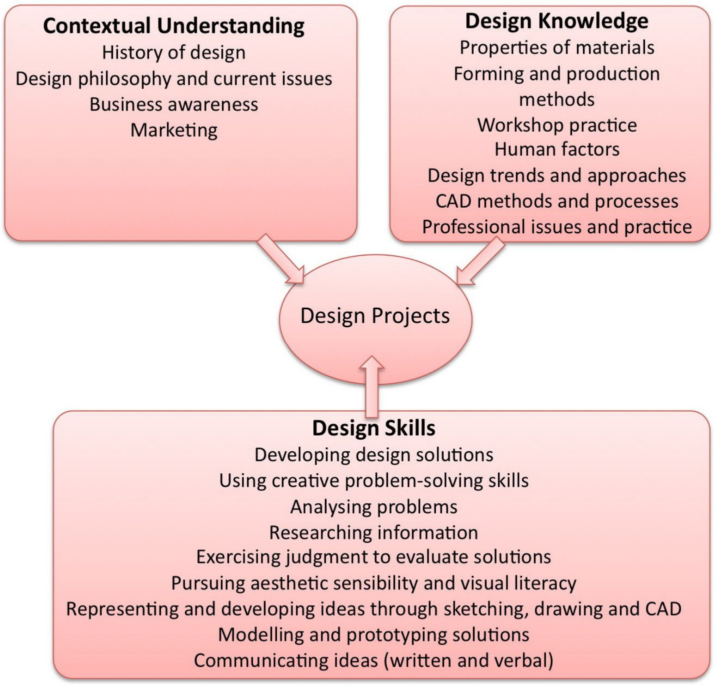


Figure 4: Design education (Adapted from Cooper and Press, 1995)

Cooper and Press (1995) highlight the distinctive nature of design education, explaining that it is based on a ‘traditional learning by doing’ approach. Design students conduct projects (see fig. 6) that help to integrate knowledge and skill through practice, essentially engaging in a dual-processing approach. They stress that industrial design education encourages students to gain and experienced-based knowledge that involves experimentation and risk of failure. Industrial design education has therefore always supported more novel and participative forms of teaching, however this has often been difficult to embed in a strict modular structure (familiar in the UK HE environment) that works well with linear and highly structured models of teaching. It is more challenging, within a modular structure to incorporate more flexible and holistic practices that are required if both analytical and synthetic modes of design exploration are to be engaged with simultaneously. However in CSAD we have explored a number of activities that have helped us to move from the ‘standard’ and established practices of teaching that are fairly straightforward to implement within a modular framework, to exploration of a set of activities built around the ‘Dual-Processing Model for Industrial Design Education’ as defined in this paper (see fig. 7).

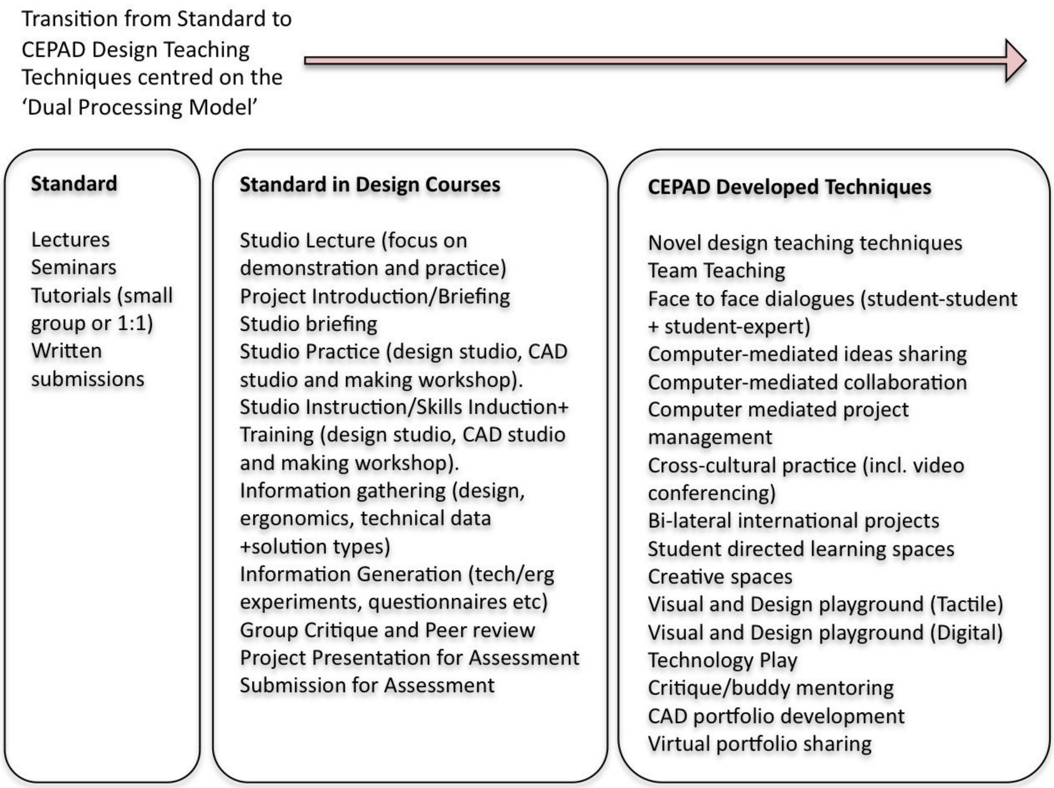


Figure 5: Types of Teaching

Based on this understanding the intention in CEPAD has been to explore teaching interventions that would focus around developing student engagement with the toleration of design uncertainty threshold. This is recognised as sitting at the centre of the two modes of thinking, analytical and synthetic, and across both linear and holistic design approaches. The aim is to encourage a ‘conversation’ or engagement with design problems and opportunities by drawing a student through a set of activities, modes of thinking and design approaches that support a more exploratory and playful approach without too much systematic constraint (See fig. 3).

As a result the following recommendations were developed:

1) structure course around larger more holistic packages of learning;
2) create a ‘playground’ for unrestricted, unconstrained design thinking;
3) provide flexible and adaptable environment for organising teaching groups;
4) encourage a personalised and individualised teaching environment;
5) introduce formative ‘gateway’ reviews rather than formative assessments;

6) provide an explorative environment that integrates both traditional and advanced technologies for designing;
7) provide opportunity for professional and international engagement.

Many of these recommendations have been applied in October 2009 to the first two levels of our four year industrial design courses in CSAD. Early feedback collected via interview and focus group is positive – further data is being collected.

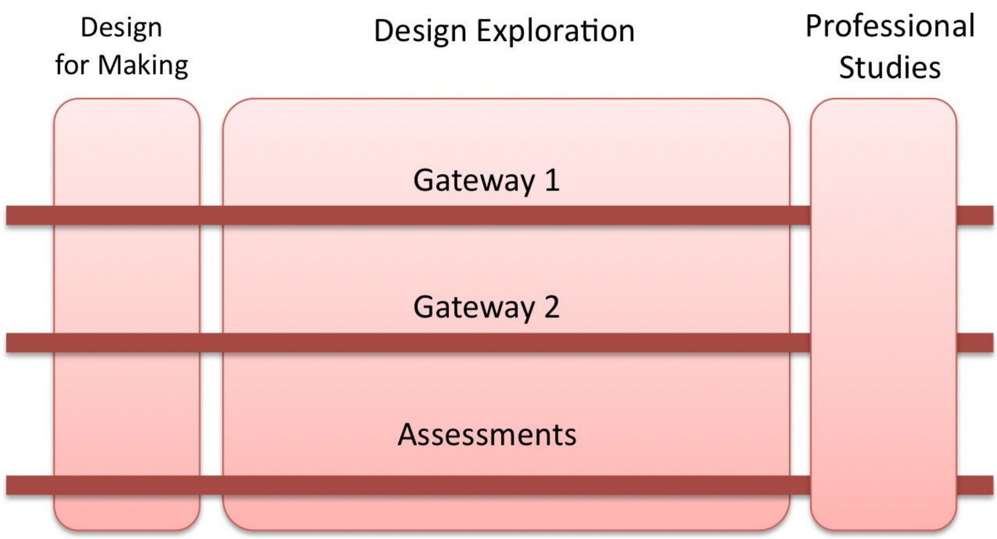


Figure 6: Simplified Curriculum Model (A year of learning)

The above simplified model (See fig. 8) based on a revised model of the industrial design course specification (Owen, 2009) shows design exploration being placed at the centre of the course, rather than being separated out within singular specialist module activities phased during the year. At level one and two multiple modules have been introduced. These enable a much more open learning environment that is not driven by a single brief. The objective is to have a number of smaller assignments with different emphasis and depth, some of which are interrelated. For example, new students were given a five week induction project (rather than the traditional one week) that: provided space to reflect upon personal aspirations, promoted broad design horizons; and, instigated an explorative and experimental approach without an assessment focus. The project required students to explore their own identity, design costumes against a fantasy scenario and present them in a social setting. The teaching environment encouraged a playful approach with little constraint. This appeared to give students confidence and a sense of their emerging identity as a designer. Following projects had more focused learning objectives, introducing ergonomics and other specialist subjects in a highly integrated way so students would engage with design learning as a whole rather than in assessment driven silos of study (See fig. 7).

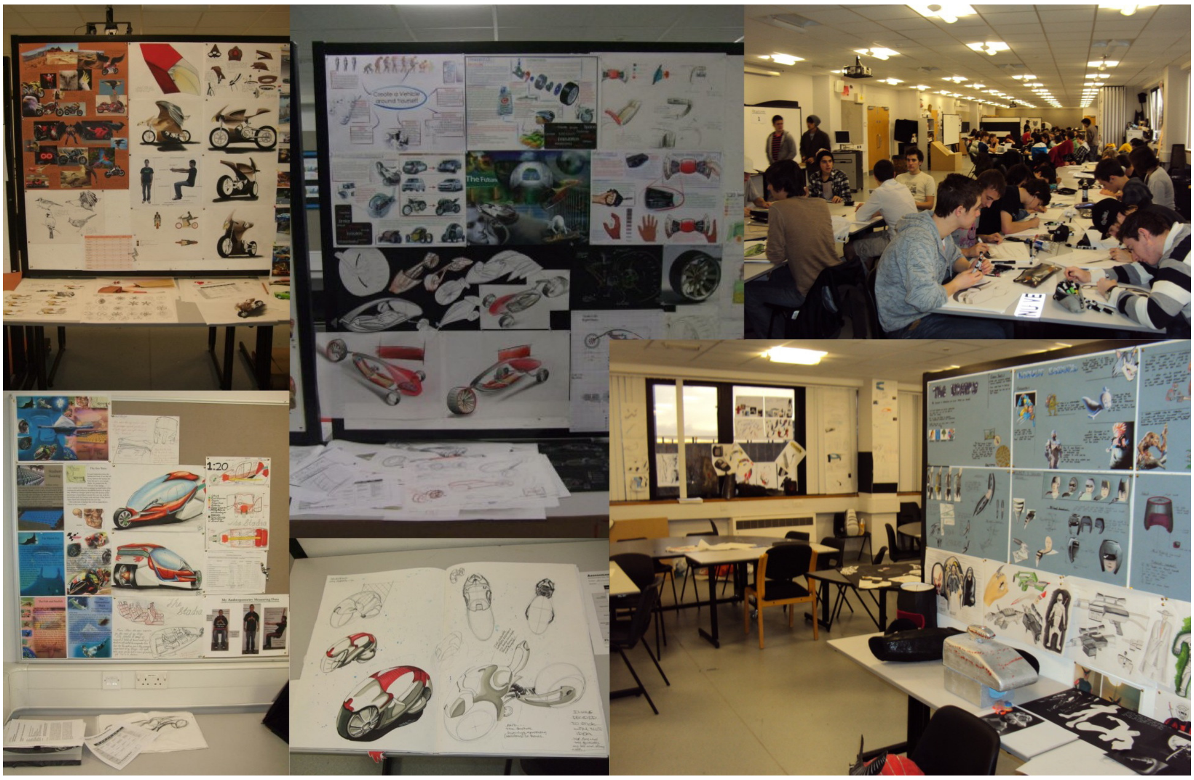


Figure 7: Students in first term of industrial design study

Because large group sizes also proved to be a problem for the encouragement of a personalised and individualised teaching environment, students were divided into smaller sub-groups for teaching at the early stages of their course. This enabled them to get to know a sub-group better rather than being lost in a sea of students. They were encouraged to develop a group identity.

The quadruple modules include small one day/ one week projects in the teaching mix. These have been labelled as 'Wild Card' projects. They enable students to engage with a project of very short or focused duration, such as a rapid concept generation project for car merchandising. Importantly, the choice to submit this work for review is given to the students. This is made possible by the Gateway model that has been adopted. It also allows the tutor some opportunity to provide additional teaching support where necessary, or to allow students the opportunity to relax and enjoy a bit more freedom after an intensive phase of activity.

Gateways (see fig 6) are review events that happen two to four times a year. They enable tutors to 'take stock' of student progress and provide formative feedback to students. The gateways are strongly centred on the student. Whilst they are themed according to level and some learning outcome requirements, the student is in most cases given a large amount of freedom to select and choose what they want to submit at the relevant Gateway. This requires the student to be more reflective and questioning about their skills and capabilities development and also allows them the opportunity to select the best of their work for presentation.

Bridging between the two: Uncertainty Threshold Diagram

Analysis

Problem Definition
The design task

Information Research
Data generation
Cultural context

Critique
Student feedback systems: The Buddy Technique (2 students recording – for one student during scheduled assessments)
Facility to support group Stereo viewing reviews for alias/bunkspeed designs – difficulty is in preparing suitable models rapidly to support.
Audio feedback to students – allows them to replay, capture emphasis, gain a more personalised set of comments.
PebblePad peer review activities.
PebblePad for stepping-stones for argument development and critical writing techniques.
Paper-based peer review activities: at levels one and two of course. To encourage reflection and critique by questioning and comparing other students work and personal work.

Face-to-face dialogue
Collaborative online projects across international boundaries

Student-student-expert
Portfolio surgeries
Client led/informed projects (Group projects with finalists)
Leonardo module development. Module set up to both be a tool for independent learning and directed and mentored with expert knowledge base.
Students come in to talk about their experiences.

Computer-mediated ideas sharing
Skype (Student projects – placement students)
Google Groups
Tanberg (Group conferencing – international staff collaboration
Facebook (Boat design students
Qube (Chinese students)
PebblePad (group work)

Synthesis

Design Studio Environment
Ownership of spaces – challenging in a mass-education culture – getting students to propose how to organise spaces for learning through client projects such as IKEA and in relation to finalists.
Portable projectors to enable practical demonstrations to be delivered to groups of students.

Creative Spaces
Design of the curriculum (introduction of periods of open play and discovery)
Adaptability of teaching spaces to shift from large group teaching spaces to small group teaching.

Playground for Visual Development
Clay heads to develop spatial understanding through sketching, modelling and freedom to develop form narratives – no prior constraint.
Digital form development projects – intensive 3D and digital animation input.
Workshop activities – making toys using laser cutting
Placement students engaging with learning about Motion capture
Development of new approaches to model making using technology e.g.
Tools provide a playground fro students across disciplines e.g. jewellery design students using rapid prototyping

Taking Risks
Wild Card projects that enable students to conduct a project and have the choice of whether they want to submit it for assessment
Holistic design of course allows more flexibility for 'risk taking' . Larger modules, more selection of activity, assessment focuses upon students selected work.
Gateway designs (each module has a set of Gateways that both allow students to select best work for presentation – enabling choice and focus on 'selection' and awareness of critical abilities.
Flexible course design – choices made in year two about specialist progression.

Challenge Conventions
New induction phase to ID course based on allowing students to take a highly explorative approach – a foundation to testing and trying out ideas
Highly conceptual phase to early learning – based on very individual and unconstrained briefs – unmarked.

Tactile Design Exploration
Clay heads and Trophy designs – students given freedom to engage with tactile form development with emphasis on hand sculpting.
Students are not allowed to progress their digital design exploration until they have engaged with the physical.
New course designed to emphasise the relationship between the tactile and the technological e.g. exploring form languages and methodologies emerging from the technology.
Example rapid prototyping to create new form possibilities and effects for jewellery design or for furniture construction.
Final year students make physical models in clay.

Figure 8: Bridging between the two: Uncertainty Threshold Diagram

CEPAD researchers observe that one of the best ways to increase student confidence is by nurturing them in an environment that is centred on professional engagement and cross-cultural experience. Students usually study with the goal of entering the professional community of practice, which is increasingly global in scope. The course has traditionally maintained good relationships with industry, but with shifts in industrial centres and the international perspective it is necessary to find opportunities beyond the placement as a means by which professional experiences are gained. To this end, school internships, international exchanges, cross-cultural collaborative projects have been reinforced within the curriculum. An ongoing example is a student collaborative project between Coventry industrial design students and students at EAFIT in Colombia (Atkinson, 2009). This enabled students to engage with different cultural approaches to designing, language and time-zone differences, collaborative project management over a distance. The culmination of the second year of this project was an exhibition in the Coventry Transport Museum. This useful exercise has supported our comparison of approaches in different countries and cultures to developing design capability (Osmond, 2010).

The curriculum design embraces a range of digital tools for communication and designing. To enhance and facilitate the analytical part of the design conversation we developed a number of communication techniques. Tools such as VOIP video conferencing, social networking tools such as Skype and Facebook have been adopted to support responsive and flexible communication.

The technology to facilitate the synthesis part of the conversation has been located in studios and creative spaces. To support spatial learning plentiful seats of Alias, Rhino, and Maya are available as well as physical tools such as rapid-prototyping, milling, laser-cutting and large scale printing. These enable students to work with digital visualisation as part of the processes of designing as well as at the representation stages. The integration of technology into the curriculum is organised around the philosophy of exploration and discovery. The aim is that technology can help to represent and review solutions as they develop such as by using the live projection of Alias models in 3D stereo. In addition teaching staff are encouraged to develop and engage with digital tools such as Cintiq to demonstrate sketch techniques to large groups of students.

Conclusion

This review of an analysis of spatial intelligence highlighted that there was a need to give greater attention to the Threshold of Design Uncertainty within the industrial design curriculum. It was observed that spatial design intelligence is a baseline capability that is hard to measure but a required attribute of applicants. Spatial intelligence itself is not specifically a measure of design capability, but a necessary component of it. However, the ‘nurturing’ of spatial understanding can be accommodated effectively in a dual-processing activity or ‘conversation’ that brings together analytical and synthetic approaches (See fig. 8). This is the process by which the Threshold of Design Uncertainty can be addressed effectively within the design curriculum. This can be challenging for students but they need to be able to develop confidence to take risks, deal with ‘wicked’ or ‘ill-defined’ problems and be solution-focused, even when they do not have all the information necessary to complete a solution. As a result of the findings made by CEPAD researchers a number of curriculum recommendations have been developed which incorporate the techniques which have been found to support effectively both parts of the design conversation. These include evaluative communication techniques and solutioning activities which centre on risk taking, playfulness in personalised, holistic and flexible study environments. Our first feedback from the implementation of these interventions is positive and encouraging.

References

Bodner, G. and Guay, R. (1997). The Purdue Visualisation of Rotations Test, The Chemical Educator, 2(4): 1-17.

Bull, K. (2004). Advanced Personal Telecommunications: Systems and Industrial Design [Phd Study]

Buchanan, R. (1995). Wicked Problems in Design Thinking. In Buchanan, R., and Margolin, V., *The Idea of Design: A design Issues Reader*, Cambridge US: MIT pres

Cousin, G. (2009). Researching Learning in Higher Education: An introduction to Contemporary Methods and Approaches, New York, Routeledge

Cross, N. (2006). Designerly Ways of Knowing, London, Springer and Verlag

Gardner, H.E. (1993). Frames of Mind: the theory of multiple intelligence. New York: Basic Book.

Lawson, B. (2005). How Designers Think. Oxford, Architectural Press

E. Lumsdaine, M. Lumsdaine (1995) Creative Problem Solving, McGraw-Hill.

McGilchrist,I. (2009) The Master and his Emissary: The Divided Brain and the Making of the Western World*,* Yale University Press

Meyer, J.H.F. and Land, R. (2003). Threshold concepts and troublesome knowledge: linkages to ways of thinking and practising, In Rust, C. (ed.), *Improving Student Learning – Theory and Practice Ten Years On*. Oxford: Oxford Centre for Staff and Learning Development (OCSLD).

Osmond J., (2010). "International Students and the Domain of Design Uncertainty'. To be presented at the *2010 Design Research Society (DRS) international conference Design & Complexity,* July 7-9 Montreal.

Osmond, J., Turner, A. (2008a) Measuring the Creative Baseline in Transport Design Education.' In Rust, C (Ed) *Improving Student Learning – For What?* OCSLD. Oxford.

Osmond, J., Turner A. (2008) 'The Threshold Concept Journey: from identification to application'. In *Threshold Concepts and Transformational Learning.* (Eds) JHF Meyer, R Land & C Baillie, Sense Publishers, Rotterdam. In publication

Osmond, Turner, Land (2007) in Land, Meyer and Smith (eds) Threshold Concepts within the Disciplines,

Owen, J. (2009) Programme Specification for Automotive & Transport Design Courses, Coventry School of Art and Design

Tovey, M. (1984) Designing with both halves of the brain, in *Design Studies*, Butterworth and Co (Publishers) Ltd.

Tovey M., Bull K., & Osmond J. (2010). Developing a Pedagogic Framework for Product and Automotive Design. To be presented at the *2010 Design Research Society (DRS) international conference Design & Complexity,* July 7-9 Montreal.

Tovey, M. and Owen, J. (2006). Entering the Community of Practice of Automotive Design, in Proceedings of the Sixth International Symposium on Tools and Methods of Competitive Engineering. Delft: University of Technology; Ljubljana: University of Ljubljana

Wenger, E (1998). Communities of Practice: Learning, Meaning and Identity. Cambridge University Press

Author Biographies

Professor Michael Tovey

A graduate of the RCA, Professor Mike Tovey was in industrial design practice prior to entering education. In 1973 he joined the institution which was to become Coventry University, as a lecturer in industrial design. He was appointed to Head of Industrial Design in 1985 and in 1989 was made Dean of the Coventry School of Art and Design. In 2007, he changed position to take on the University-wide post of Director for Design. Professor Tovey is responsible for developing courses and applied research in design across the University and is Director of the Centre of Excellence in Product and Automotive Design (CEPAD).

Dr Karen Bull

Dr Karen Bull is Deputy Director, Centre of Excellence in Product and Automotive Design at Coventry University. This centre focuses on evaluating spatial design understanding and identifying the transformative threshold concepts associated with students entering the Global community of practice for industrial design. Her expertise is in industrial design theory, design analysis and design context. Her background is in product design and her PhD is titled Advanced Personal Telecommunications Products and Industrial Design'. She has continued to research pedagogy in relation Art and Design and is especially interested in the area of critical and reflective learning, e-teaching and learning and e-portfolio.