# Pedagogical challenges facing Design and Communication Graphics

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**Abstract**

Complementing curriculum reform with pedagogical innovation is the focus of the challenge facing technological education in Irish second level schools. In 2007, responding to the evolving needs of society, the Department of Education and Science philosophically shifted the focus of graphical education. The introduction of *Design and Communication Graphics* (DCG) *to* replace the vocationally originated *Technical Drawing* brought with it a need to review traditional norms and practices.

This new subject provides students with the opportunity to develop a skill set that will allow them explore and learn in a variety of disciplines through the medium of design. Students are encouraged to become enterprising, creative and empowered during their learning experience. This paper explores some of the contemporary challenges facing teaching, learning and assessment in graphical education.

An action approach was taken was to investigate the activities and outcomes of a core graphics module within the Initial Technology Teacher Education programme at the University of Limerick. 121 third year undergraduates undertook a module, which provided the impetus to explore the relationship between what they had previously studied (traditional – TD) and what they will be expected to teach (DCG) as professional graphics educators.

Using students performance, the paper explores the relationships between declarative (What), procedural (how), conditional (when), and contextual (why) knowledge and argues that this holistic acquisition of knowledge predicates creative expression and innovation. The paper discusses the role and effectiveness of graphical tasks and activities in meeting the objectives of Design and Communication Graphics and presents a proposed pedagogical framework.

Key words: Graphical Education, Design Graphics, Pedagogy

**Background**

The position of Technology Education in the Irish curriculum has evolved from a place where its traditional goals were to provide technical training and skills in a vocational education setting. Traditionally technology education forced on three general areas, Woodwork, Metalwork and Technical Drawing. With little exception, second level teachers who taught *Technical Drawing* had also majored in either of the material biased disciplines (Wood or Metal). From its introduction in 1984, *Technical Drawing* was studied as an optional subject in high schools by on average approximately 10% of the senior cycle student population. Considering the practical subject uptake by comparison, *Technical Drawing* offered students a popular option to expand their educational experience (See figure 1). The subject aimed to develop competency in plane and descriptive geometries and applied engineering or construction drawing (depending on the teacher's discipline). Mastery of technical draughtsmanship was at the heart of a subject that aimed to develop geometric problem solving.

In 2007, responding to the evolving needs of society, the Department of Education and Science philosophically shifted the focus of the entire suite of technological subjects[1], but most significantly graphical education. The introduction of *Design and Communication Graphics* (DCG) *to* replace the vocationally originated *Technical Drawing* brought with it a need to review traditional norms and practices. This new subject provides students with the opportunity to develop a skill set that will allow them explore and learn in a variety of disciplines through the medium of design. The analytical and design driven approach is envisaged to form the core of a subject that encourages students to become enterprising, creative and empowered during their learning experience.

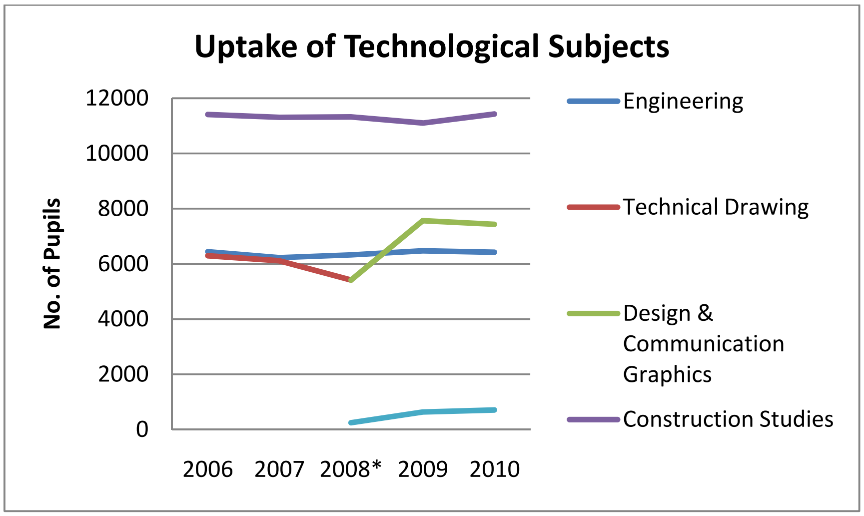


Figure 1 – Numbers taking technological subjects in Leaving Certificate examination (*2008 scores for Technical Drawing and DCG are combined)

Developing new content and specifying content driven outcomes forms an explicit challenge that calls for a tangible response. However aligning this content with a philosophical shift presents a dichotomy for the practicum. Preserving past knowledge and practices must not be a limiting factor of future progression (Benjamin, 1939). Revealing and understanding what to value is the primary challenge facing contemporary teaching, learning, and assessment in graphical education. The global debate emerging highlights the importance of identifying these values. Foster (1999) highlights the argument that suggests the place of Technology Education is becoming increasingly difficult to justify due to a lack of agreement in either policy or practice over its definition and function. This is also supported in an Irish context where a lack of continuity between the formal curriculum and the implemented curriculum exists due to lasting traditions of the vocational focus (Dunbar, 2010). Ritz (2009) calls for educators and policy makers to "*look beyond the development of engineers, industrial technologists, or craft workers*" and argues that we must take educators beyond the limits of specific professions.

Identifying the contemporary values and goals that underpin a new conception of technological education is important in order to contribute to the greater education of the student rather than its specific traditional purpose. Lewis (2009) claims that there are a

[1] The traditional technology suite of subjects included Construction Studies, Engineering, and Technical Drawing. New syllabi included Architectural Studies, Engineering Technology, Design and Communication Graphics and the introduction of a new subject Technology.

variety of generative cognitive processes that are more likely to occur in technology education than elsewhere in the curriculum. Shifting from the provision of technical skills to a broader education agenda supports the global consensus that that values problem solving, construction techniques, creativity, and design (Rasinen, 2003). Achieving the educational outcomes of creativity, autonomy, fulfilment etc. are critical in adopting skills and aptitudes that our rapidly changing global society necessitates (Seery et al, 2010). Although the design of four new syllabi at Leaving Certificate level[2] forms the basis of a sound approach to technology education in Ireland, there is little empirical evidence to support or question the effectiveness of traditional practices in achieving a meaningful realisation of the syllabi objectives.

Curriculum change independent of revised pedagogical strategy is often benign. This study aims to investigate the limitations of the conventional approach to graphical education, with emphasis on the efficacy of traditional drawing activities in developing metacognitive knowledge and contemporary graphical competencies.

## Limitations of current educational practices

The age old education discussion that questions the essence of teaching and learning and calling for a participative approach to education has never before been so important. Many commentators highlight the failing of current educational practices and identify its lack of flexibility in facilitating the learner in making meaning as critical. Lindeman (1926 - cited in Hansen, 2010) claims that "*Too much of learning [in schools] consists of the vicarious substitution of someone else's experience and knowledge."* Edwards et al (2002) supports this claim by arguing that the defined curriculum is often distinctly different from the student's experiential inherent knowledge and the knowledge that they require on completion of formal education. Edwards also argues that *"that passive regurgitation is prized over a disposition to enquire; and that teachers are assessed on their ability to deliver knowledge rather than assure understanding and support children's disposition to be learners"*. Prashnig (2004) highlights the misguided emphasis being placed on "*what people know*", and argues the importance of a paradigm shift from "*knower to learner"* placing value on *"how people learn"*. Therefore we need to question the entire structure of education and radically rethink our view of education (Robinson, 2006).

Pink (2005) argues that one way forward is to begin developing attributes that align with contemporary demands. He argues the limitations of left brain aptitudes of logic, quantitative reasoning and analysis need to be complemented with more conceptual right-brain, softer oriented aptitudes. Outlining the development of six core aptitudes; Design, Empathy, Play, Story, Symphony and Meaning. Pink argues that these aptitudes are essential for learners to succeed in a quickly changing society.

## Graphical Education

Striking the balance between the traditional norms and practices and the contemporary goals of education forms the context for *Design and Communication Graphics*. The new syllabus values an exploration of the core geometries, where: *"Plane and descriptive geometries are central in developing an understanding of the graphical coding and decoding of information*

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[2] Two of which were implemented in 2007 - Design and Communication Graphics and Technology Architectural Technology and Engineering Technology are pending implementation

*(graphics code), and in developing spatial abilities and the problem solving skills*, married with a more contemporary view that *"The design activity and the communication of design will inform all areas of the course"* (NCCA, 2006). The new subject embraces the concept of design-without-make while encouraging students to become enterprising, creative and empowered without restriction.

Although the integrated design approach is largely welcomed and supported within education circles, there is a concern that its potential may be limited by employing the traditional approaches to graphical education. Including a design activity as a major element of a syllabus (25%) with no constructive alignment in approach may contribute to a superficial engagement and generation of criterion referenced outputs. The creation of *'limited experiences'* (Johnston-Wilder and Mason, 2005), '*neat nonsense'* (Mike Ive, cited in Barlex and Trebell, 2008) and '*formulaic*, routinised *and predictable'* (Kimbell, 2004) outcomes must be avoided in favour of meaning, exploration and synthesis of ideas. Ensuring pedagogical flexibility and fluency is critical in facilitating meaningful engagement and success in conceptual development, design progression, and communication. The development of essential building blocks to support communication as both a depictive process and also a graphical ideation tool to develop the cognitive refining of concepts is essential. The process of designing must engage students in the iterative and dialectic utilisation of the specific stages and functions of design, with an emphasis on the process over the product, context over dogma.

Understanding the value of a design driven activity implies a comprehension of how important it is to ensure students have the capacity and tools to engage with the activity. Students must be afforded the opportunity to not only explore their metacognitive knowledge within the discipline, but also their metacognitive control and self regulated learning processes within the activity. How do we liberate and support students to engage in meaningful design activities? Baynes (2009) argues that it is becoming increasingly important that we understand the mental capacity of designing. It is becoming necessary to codify the interdependence of declarative (What), procedural (how), conditional (when), and contextual (why) knowledge and the relationship between knowledge generation and the norms and practices of graphical education. Kimberly Elam (2001) reflects on her experience as a design professional and educator and outlines that too often excellent conceptual ideas suffer during the realisation stage due to a lack of comprehension of the *"visual principles of geometric composition"* and suggests that it is important to reveal visual relationships by comprehending geometric principles. Therefore it is hypothesised that the holistic acquisition of knowledge predicates creative expression and innovation, with a lack of knowledge limiting the successfulness of design outcomes.

**Future educators**

Having identified the specific content of the new syllabus with its governing philosophical approach and establishing the general concerns and needs of contemporary learning it is important to look at the facilitators of learning. Edwards et al (2002) outlines a hierarchical series of questions focusing on the type of learners a progressive knowledge economy is likely to need? What kinds of pedagogical practices are likely to support this type of learning? And what kind of teachers will facilitate this learning?

McCormick & Davidson, (1996) outlines that the dominant pedagogy in technology is hegemonic, allowing the dominant culture to maintain its dominant position. This cultural mismatch between traditional practices and contemporary learning causes a debilitating environment preventing teachers from adapting their pedagogy. The resulting Didactic Transposition as described by Johnston-Wilder and Mason (2005) misses the objective of the learning activity, thus rendering the outcome of the activity in its self the value.

The next generation graphical teacher must establish the cultural norm that will ensure effective pedagogical strategy. This paper is concerned with establishing the initial evidence to derive meaningful graphical education, presenting an opportunity to explore the essence of teacher education.

**Case study - Action research approach**

This study audits the effectiveness of aligning the traditional pedagogical practices with contemporary needs, and forms the basis of a larger action research project aimed at codifying the contemporary pedagogical practices within graphical education. The research investigated the activities and outcomes of a core graphics module within the Initial Technology Teacher Education programme at the University of Limerick. The undergraduate students engaged in a module that began the transition from what they had studied (traditional – TD) to what they were expected to teach (DCG).

The module centred on three main areas, comprehension of plane and descriptive geometry, parametric modelling proficiency and a design task. The plane and descriptive activities focused on the derivation and application of topics such as oblique and tangent plans, conic sections, solids in contact, polyhedra, and intersections and development of surfaces. Students developed geometric proofs in plane geometry and constructed solutions to geometric problems. The drawing portfolio addressed specific topics during scheduled laboratory sessions every week. The portfolio facilitates showing evidence of student work and the end of semester examination assesses students' comprehension of plane and descriptive geometry concepts and principles. Some examples of student work are illustrated in figure 2.

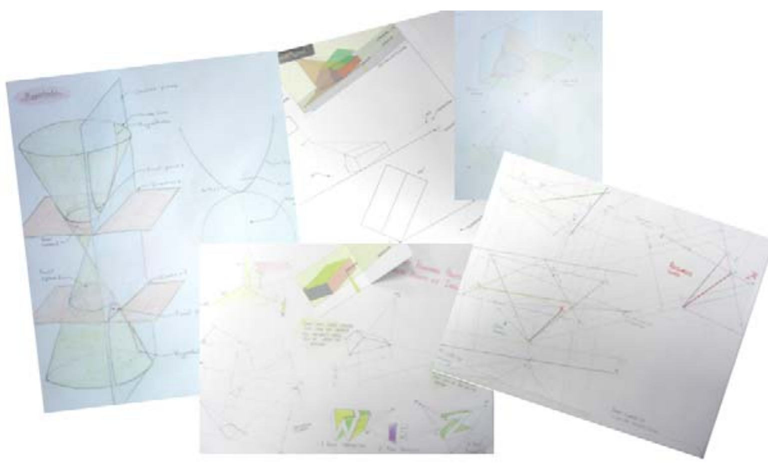

Figure 2 – Examples of the Plane and Descriptive graphical activities

The second area of the module focused on developing an ability to effectively and efficiently utilise Solidworks. Students completed that explored the parametric modelling skills necessary to produce intelligent, robust models. The activities progressed from fundamental skills building exercises to the development of modelling strategies (see figure 3).

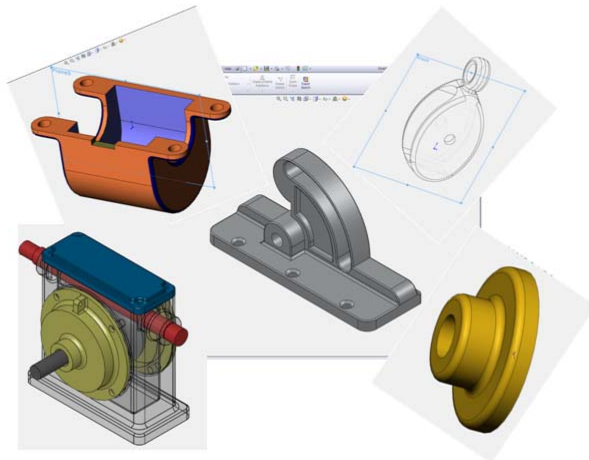

Figure 3 – Examples of the Parametric modelling activities

The third element of the module included a design activity. The design activity utilised a thematic brief reinforcing the link between technology and society. The output of the design activity expected students to demonstrate a mastery of the graphical skills developed to date.

The research focused on the interdependent relationship between teaching methods, learning strategies, and evaluation methods.

### Approach.

The research approach employed a non-invasive exploration of causation and attempts to gain empirical evidence identifying the underlying principles governing effective engagement in design driven graphical education. The case study research strategy aims to investigate the hypothesis that traditional graphical activities and emphasis are insufficient in scaffolding students towards acquiring conceptual age competencies. The performance of 121 year 3 Materials and Engineering Technology and Materials and Construction Technology student teachers was analysed as the basis of the study. To avoid apathetic participation, the module structure ensured that the four main elements of the assessment were equally weighted (25%) with a passing grade required in all elements of the assessment.

### Data collection methods.

The design of the data collection methods focused on three general areas; psychometric testing of cognitive attributes, traditional assessment mechanisms (Drawing portfolio, Assessment of Geometric Principles) and contemporary skills (Parametric CAD Assessment and a design task) as outlined below.

- ***Cognitive attributes*** – A selection of psychometric tests from the Kit of Factor Referenced Cognitive Tests (Elkstrom et. al.: 1976) were employed to indicate the level of spatial abilities of each student prior to the learning activity. This approach was used to diagnose the relationship between key cognitive factor measures and performance in graphical education activities. The kit of factors tests were selected to gain an insight into student's visualisation, figural flexibility and speed of closure competencies.

- ***Drawing Portfolio* -** Traditionally students completed a portfolio of work; the portfolio traditionally ensured a high level of draughtsmanship. It also serves as an evidence record that demonstrates the comprehension of key principles applied to both the practical and theoretically conceived problems. The portfolio accounted for a significant element of the student's workload, focusing on declarative and procedural knowledge.
- ***Parametric CAD Assessment* –** Although CAD formed an element of the Technical Drawing syllabus, the focus of DCG centres on parametric modelling. The design of the assessment focused on Strategic modelling, geometric identification, deconstruction, reassembly, and synthesis, embracing the conditional and contextual knowledge domains. This was achieved by using a 2 hour terminal assessment.
- ***Assessment of Geometric Principles* –** The terminal assessment (2.5 hours) tests the declarative and procedural knowledge of geometric principles. However, this assessment as it forms the core of the graphical discipline was modelled on Thordikes identical elements theory. 72% of the questions were identical to questions completed in the portfolio with the remaining 28% based on near and lateral transferability. The assessment focused on the application of core geometrical principles exploring declarative, procedural and conditional knowledge,
- ***Design Task* –** Students were given a thematic brief focusing on social context and were allowed to communicate their design solutions based on knowledge acquired (formally and informally). No criterion was given in relation to output, students were instead encourage to engage in the stages and functions of design as they deemed appropriate.

**Data analysis.**

- The data collected was subjected to descriptive analysis to establish data type and generality of pattern.
- Statistical analysis was employed to explore the relationship between the assessment mechanisms in an attempt to indicate a predictive relationship.
- The relationship between cognitive attributes and assessment measures was also tested to indicate validity of the learning activities.

**Results and findings.**

The results of the students' performance in the 6 psychometric tests are presented in Figure 4. The Toothpick and Storage tests explore figural flexibility scores, while the Formboard and Surface tests represent visualisation performance.

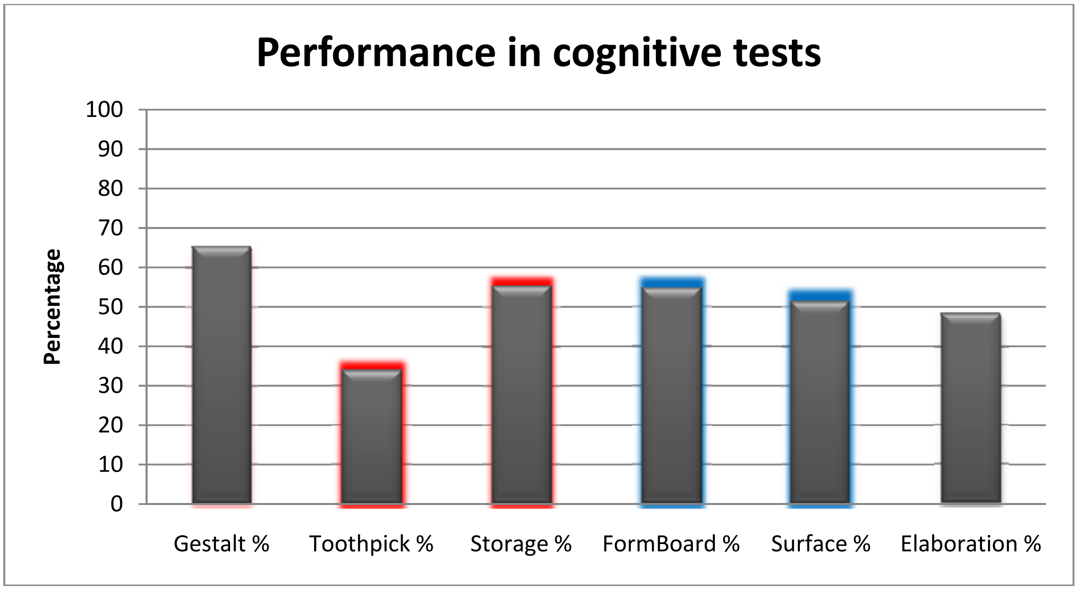


Figure 4 - Performance in cognitive tests

As illustrated in the figure 2, students recorded a mean score of 65% in the Gestalt test which focuses on speed of closure. The combined mean score for figural flexibility of 44% highlights a deficiency in student's ability to generate new and different solutions to figural problems. Recording a combined mean of 55% in the visualisation tests suggests a deficiency, especially when considering that this cohort is comprised of year 3 student teachers studying graphics as a major element of their degree. Also a mean performance of 48% was recorded in the figural fluency test.

The overview performance in each element of the assessment is presented in Figure 5. Considering the near transfer design of the assessment of geometric principles, the poor performance is notable. This performance when compared to the drawing portfolio performance asks significant questions about the type of learning students engaged in while completing the portfolio of work.

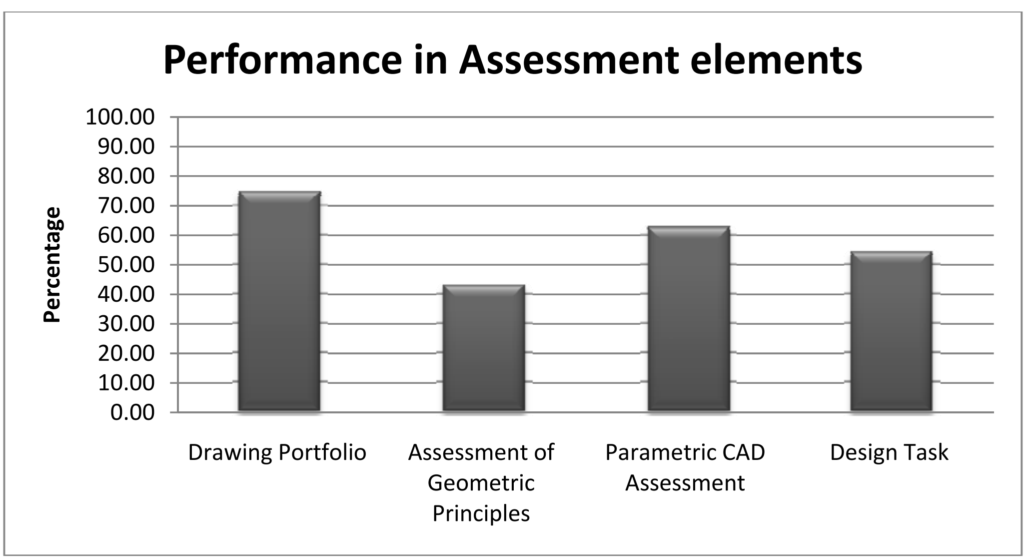


Figure 5 - Performance in assessment elements

In an attempt to gain a better understanding of student performance, an independent samples t-test was conducted to compare the performance of the students in the *Drawing Portfolio* and the *Assessment of Geometric Principles***.** There analysis returned a significant difference between both elements of the assessment, M = 43.48, SD = 14.11, p = 0.001. This is a notable difference when considering the portfolio focused on declarative and procedural knowledge, which was also the focus of the terminal assessment.

***Analysis of relationship between elements.***

The Spearman rank correlation coefficient was used to assess the relationship between the assessment elements. All measures correlated significantly with a positive direction (Table 1). Students that preformed well did so in all elements of the assessment.

Table 1 – Relationship between assessment elements

| Relationship between assessment elements | | | |
|---|---|---|---|
| | **N** | **Correlation Coefficient** | **Sig.** |
| ***Assessment of Geometric Principles / Drawing Portfolio*** | 121 | 0.408** | **0.001** |
| ***Assessment of Geometric Principles / CAD Assessment*** | 121 | 0.255 | **0.005** |
| ***Assessment of Geometric Principles / Design Task*** | 121 | 0.238 | **0.008** |
| ***Drawing Portfolio / Design Task*** | 121 | 0.545 | **0.001** |
| ***Drawing Portfolio / CAD Assessment*** | 121 | 0.245** | **0.007** |
| ***CAD Assessment /Design Task*** | 121 | 0.354 | **0.001** |
| ***Correlation is significant at the level 0.05(2 tailed)**<br>****Correlation is significant at the level 0.01(2 tailed)** | | | |

The relationships between the assessments of performances provided the foundation to explore the student's cognitive scores. The relationship between the performance in the cognitive test and the assessments elements was investigated to predict the relevance of the activities in terms of cognitive development. The correlation coefficients are tabulated in Table 3.

Table 3 – Relationship between cognitive tests and assessment elements

| Relationship between cognitive tests and assessment elements | | | | |
|---|---|---|---|---|
| | **N** | **Correlation Coefficient** | **Sig.** | |
| ***Gestalt /Assessment of Geometric Principles*** | 108 | .139 | .152 | Speed of Closure |
| ***Gestalt / CAD Assessment*** | 108 | .213* | **.027** | |
| ***Gestalt / Drawing Portfolio*** | 108 | .021 | .830 | |
| ***Gestalt / Design Task*** | 108 | .114 | .239 | |
| ***Toothpick /Assessment of Geometric Principles*** | 110 | .302** | **.001** | Figural Flexibility |
| ***Toothpick / CAD Assessment*** | 110 | .314** | **.001** | |
| ***Toothpick / Drawing Portfolio*** | 110 | -.077 | .423 | |
| ***Toothpick / Design Task*** | 110 | .039 | .686 | |
| ***Storage /Assessment of Geometric Principles*** | 110 | .325** | **.001** | Figural Flexibility |
| ***Storage / CAD Assessment*** | 110 | .343 | **.001** | |
| ***Storage / Drawing Portfolio*** | 110 | .322** | **.001** | |
| ***Storage / Design Task*** | 110 | .249** | **.009** | |
| ***Formboard /Assessment of Geometric Principles*** | 110 | .251** | **.008** | Visualisation |
| ***Formboard / CAD Assessment*** | 110 | .425** | **.001** | |
| ***Formboard / Drawing Portfolio*** | 110 | .005 | .926 | |
| ***Formboard / Design Task*** | 110 | .103 | .285 | |
| ***Surface /Assessment of Geometric Principles*** | 90 | .306** | **.003** | Visualisation |
| ***Surface / CAD Assessment*** | 90 | .123 | .249 | |

| | | | | |
|---|---|---|---|---|
| ***Surface / Drawing Portfolio*** | 90 | .483** | **.001** | |
| ***Surface / Design Task*** | 90 | .119 | .262 | |
| ***Elaboration /Assessment of Geometric Principles*** | 110 | .230* | **.016** | Figural Fluency |
| ***Elaboration / CAD Assessment*** | 110 | .162 | .091 | |
| ***Elaboration / Drawing Portfolio*** | 110 | .015 | .874 | |
| ***Elaboration / Design Task*** | 110 | .138 | .152 | |

***Correlation is significant at the level 0.05(2 tailed)**
****Correlation is significant at the level 0.01(2 tailed)**

Statistical significance was found in a number of tests. Significance between the Gestalt test and the CAD assessment is logical considering strategic CAD thinking and speed of closure. There were a large number of significant relationships found in the assessment activities and the figural flexibility test. These relationships will need further investigation when considering the poor performance in both the Toothpick and Storage tests. The relationship between visualisation and the terminal assessment and portfolio shows significance; however it would be expected to have a relationship with the design task, if the essence of the activity is to conceive original solutions of value. The figural fluency supports the value of exploring the geometric principles aligned with figural flexibility competency.

## Discussion

The central design driven approach to graphical education requires the identification and development of critical knowledge and skills. This paper explores the efficacy of traditional graphical activities within the context teacher education focusing on *Design and Communication Graphics.* The paper identifies the supporting pillars perceived to scaffold design activities and explores there impact when grounded in traditional pedagogy. As educators we expect good design solutions that are innovative and creative, but without appropriate supporting knowledge constructs and skill development students cannot synthesise and form new links of value. Securing the insecure foundation that has evolved through either didactic transposition or hegemonic facilitation must form the focus of future graphical research and investigation.

Relaxing the constraints of traditional pedagogies and assessment criteria allows students to engage with a design activity that fosters a broad exploration of the problem with limitless opportunity, but at what price? The thematic design approach reduces the capacity for students to approach on a criterion referenced level. However it appears that open design tasks can result in a lack of meaningful cognition, as the importance of the previously '*learned*' content is lost in terms of relevance and application. This lack of metacognitive control and self regulated learning manifests itself particularly with ill defined problems (such as design task) as students are required to employ individual heuristic rather than algorithmic strategies (Amabile, 1996). The failure to devise a meaningful individual heuristic lies in the lack of comprehension in the declarative and procedural knowledge acquired. The poor performance in the terminal assessment (examining 72% of the content which was identical to that completed in the portfolio) demonstrates one of two things;

a) Students did not develop self regulated learning and engage on a concepts and principles level or
b) The nature and objectives of a drawing portfolio as an education tool is questionable

The true value of a portfolio must lie in the *elaboration* and *organisational* metacognitive strategies and not in the *rehearsal* and draughting of surface tasks. Considering the education value of a well draughted portfolio, it is possible to conclude the course of study with well presented 'neat nonsense' and little or no comprehension (Portfolio M = 75%). It appears to miss the point – the role of the portfolio has become an endurance task with behavioural skill development benefits that serve to significantly limit the cognitive value. Therefore the educational strategy must shift from a *'Can you find ….?'* approach to a philosophy of *'in how many ways can you find …?'* The use of invariance and variations of geometric problems coupled with strategic problem solving (Polya, 1957) must form the building blocks for students to engage with more 'high concept' creative activities.

The relationship between the cognitive factors and the elements assessed (See table 3) indicate that there is potential to develop graphical students figural flexibility and visualisation abilities when exposed to the core activities outlined in this paper.

The Irish education system has provided practitioners with a theoretically sound and philosophically sophisticated syllabus. However, the didactic transposition of traditional practices can unintentionally render the learning experience and activities benign. Further investigation is essential in developing a flexible and dynamic experience that will not only embrace diversity but ensure it.

This paper documents the initial stage of an action research project that attempts to understand and interpret the norms and practices of graphical education with a view to future improvement. Figure 4 illustrates a proposed pedagogical framework that treats designerly activities as a dependent variable and not an innate ability. The proposal suggests equipping students with the tools to successfully engage with a design task. Figure 4 illustrates a number of aspects for consideration;

- Successful designing is predicated on having fundamental knowledge and skills. The diagram proposes that to adequately engage with the stages and functions of design, comprehension of geometric principles and CAD competency is essential.
- The decreasing reliance on declarative and procedural knowledge is proportional to the increase in conditional and contextual knowledge. Engaging in evaluation, reflection, and enquiry practices serves to encourage metacognitive engagement and autonomous learning. The engagement should surpass the limitations of the subject content.
- Although supported by the fundamental graphical framework, the model allows for non-educational based (external) influence when challenged with a design activity.

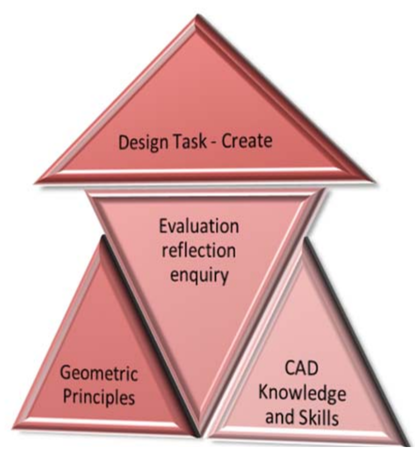


Figure 4 - Proposed Graphical Design Pedagogical

The purpose of proposing this framework is to stimulate discussion surrounding the efficacy of graphical pedagogy.

## Conclusion

In conclusion this paper suggests that the three main areas, comprehension of plane and descriptive geometry, parametric modelling proficiency and design are a logical and valid core to form the basis of graphical competency. However, analysis of student performance in this module would suggest that there are clear deficiencies in terms of learning transferability and metacognitive development. The difference in performance across the activities would suggest that the value of the activity may be undermined by the nature of the instruction and the resulting type of student learning (Surface/Deep). The didactic transposition of activities for one syllabus context to another forms the basis of an inference that lacks meaning.

This paper illustrated that there is a relationship between the assessed elements and the cognitive development as defined by the kit of factors tests; this suggests that the graphical activities have the capacity to affect spatial cognition and visualisation. The paper proposes a framework to facilitate conceptual design and communication competencies and presents a starting point to explore alternative pedagogical strategies. It is hoped that this paper will stimulate investigation into graphical education with a vision to provide empirical evidence for future developments.

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