

An International Overview of Assessment Issues in Technology Education: Disentangling the influences, confusion and complexities

S.V. McLaren, Senior Lecturer in Design and Technology Education,
Department of Curricular Studies, University of Strathclyde, Glasgow

Abstract

Set in the context of wider research, this review of international literature describes some of the issues that contribute towards the prevailing confusion regarding the 'what', 'when' and 'why' of assessment. It explores the complexities embedded within assessment of, for and as learning and the difficulties arising in Technology Education.

It discusses what comprises the goals and purposes, and precise nature of 'content' and how this impacts on what is considered as important to measure in terms of attainment, performance and achievement in Technology Education. The paper examines the influence of external assessment, the influence of the teacher and the influence of the various approaches and instruments of assessment on pedagogy, achievement and learner performance and motivation.

The dimensions and discriminators of performance and progression in Technology Education are complex. The key issues need to be disentangled to provide some clarity and inform practice. Greater creativity is needed to help devise multi-dimension, multi-expression assessment strategies which celebrate the complexity and influence pedagogy appropriate for learning in the 21st century.

Key words

assessment is for learning; formative assessment; summative assessment; holistic assessment; motivation and goal orientation; teacher influence

Background Context: current thinking about assessment

A progressive rethinking of education has created a climate where assessment is about more than marks of attainment. Assessment has the potential to enable learners to reflect on their own learning and make judgements on their strengths, recognise achievements and help identify aspects that require improvement. This creates a sustainable approach and attitude that is conducive for life-long learning.

In general, it is recognised that there are different purposes of assessment. These are sometimes referred to as:

- 'assessment of learning' (e.g. gauging attainment, as a summative measure for formal certification by awarding bodies. This traditionally serves as 'end of course currency' and is a link between the world of education and the wider outside world of work and society; assessment which uses a range of evidence to check progress against goals);
- 'assessment for learning' (e.g. interactive and learner-centred in approach, where teachers and learners share learning intentions and goals for formative and diagnostic purposes. Useful to recognise achievement and aid progression in various dimensions);
- assessment as learning (e.g. learners and teachers reflect on learning experiences through dialogue, peer and self assessment to clarify the purposes of learning, support learners, create a climate of learning how to learn)

A review by Black & William (1998a) of assessment practices indicated that increased adoption of, and engagement with, formative assessment strategies led to significant improvements in standards of attainment and achievement. They voiced concern that progress based on such evidence, had been slow to impact due to the imbalance of attention given to the various developments of summative assessments.

In addition, a review by Harlen & Deakin-Crick (2003) highlighted concerns that such a strong focus on summative assessment which have such 'high stakes' value for the learners, teachers, schools alike serve only to have a negative influence on motivation and subsequent willingness to learn. Teachers teach to the test, emphasise exam strategy, and encourage a performance orientated goal ethos.

Broadfoot & Black (2004) make the case for the need to look at how best to support learning rather

An International Overview of Assessment Issues in Technology Education: Disentangling the influences, confusion and complexities

than to judge it. They voice concerns about the limitations of conventional tests, and sheer volume of assessment that youngsters are exposed to. Educators need to explore what is possible and what is desirable. Over the past five years in the UK, as with other parts of the globe, there have been various national governmental initiatives to encourage teachers to integrate assessment more effectively as part of learning and teaching to aid progression.

Given this context, this paper reviews published research literature, available internationally, from the past 15 years, with a specific focus on assessment in Technology Education. It describes some of the issues that contribute towards the prevailing confusion regarding the 'what', 'when' and 'why' of assessment pertaining to Technology Education in order to inform future practice. The generic term 'Technology Education' is generally used throughout this paper and is inclusive of the various nomenclatures adopted in the range of countries represented in the review (e.g. Design and Technology in England).

For assessment to be meaningful, the central learning purposes of Technology Education need to be defined. From this definition, the purposes and goals of assessment may be identified and subsequently appropriate assessment methods can be developed. The initial section of this paper therefore summarises the ongoing debates that explore definitions of Technology Education and illustrate the complexities of this relatively new learning area. The next section explores aspects of 'assessment of learning' by examining the influence of external assessment procedures, guidelines and requirements (as determined by national examination boards and awarding bodies) on teachers, teaching and learning practices. The third section investigates 'assessment for learning' and 'assessment as learning'. It discusses the literature that explores relationships between teacher content knowledge and understanding, teacher attitude, and the influence this has on learning, teaching, assessment and motivation of the learners. There is discussion pertaining to assessment of 'performance in action'; 'holistic' versus 'atomised' assessment; assessment of creativity; of process versus product outcome; and technical knowledge versus technical know-how. This is underpinned by inter-related nature of formative and summative

assessments and illustrates the mutually supportive and inter-related nature of assessment for, of learning and as learning (Black & Wiliam, 1998b).

The final section of the paper discusses the potential of multi-dimension and multimodal expression assessment. It describes what digital technologies, adopted in recent research, offer future developments in assessment of, as and for learning. The review concludes with a summary which serves to provide a framework of considerations for future research.

Seeking clarity from confusion: purposes and 'content' of Technology Education and how this influences assessment

In order to identify what are the purposes and goals of assessment, there needs to be clarity as to what is central to the learning purposes of Technology Education. Several studies and government guidance (e.g. Kimbell et al, 1991; McCormick, 2004; De Vries, 2005; Kimbell & Perry, 2001, Moreland et al, 2000; Rophol, 1997; International Technology Education Association, ITEA, 1996 / 2000; Scottish Consultative Council on the Curriculum, SCCC, 1996; Department for Education and Employment, DfEE, 1999) have attempted to create descriptions to facilitate a greater understanding of the learning area and related experiences of Technology Education. Some common aims and themes are evident but there remains no definitive, universally held view, nor common categories of description. For the purposes of this paper, the following categories have been created from the various descriptions and rationales to indicate the general inter-related nature and the content of Technology Education in schools:

- *Technological conceptual knowledge*. Although this remains ill-defined, it is thought of as the 'knowing that', the declarative, belief type knowledge, the cognitive components, some of which are generic across the technologies and some more domain specific.
- *Technological procedural knowledge* and capabilities. This is thought to be the 'knowing how', the application of the knowledge as praxis, in designing, cognitive modelling, evaluating, identifying issues and opportunities.

An International Overview of Assessment Issues in Technology Education: Disentangling the influences, confusion and complexities

- *Technological competences and skills.* These overlap with practical, cognitive know how/ tacit knowledge in action and include psychomotor, communication, social, management.
- *Affective and societal knowledge.* This involves personal technological motivation and dispositions, the relationships between technology and society, cultures, economies, environment, values and attitudes.

The complexity in defining Technology Education and the various strands contained within has led to difficulties in attempting to assess learners (e.g. Kimbell et al, 1991; Boser et al, 1998). For example, when discussing issues of identification of technological knowledge, the Assessment of Performance Unit, 1991, cite DES/WO, 1988, Interim Report par.2.12, which states 'knowledge (here) is a resource inseparable from practical action, not a commodity to be stockpiled before action can begin.' Technology Education is thought of as an area of learning which draws on a wide range of knowledge and skills from various parts of the curriculum bringing them together through creative experiences and innovative activities. Reddy et al, (2003) note that difficulties arise when teachers do not plan experiences which explore the inter-relationship between these different bodies of knowledge and technological content knowledge, skills, attitudes and values.

Another difficulty lies with the complexity of assessing dispositions and the learner's 'performance in a subject where knowledge is a process.' (Harris & Wilson, 2003:13). With the majority of national compulsory school systems relying on internal teacher assessment of the learners (O'Donnell, 2004) unresolved difficulties can inhibit the learning potential of future citizens.

Petrina (2000) argues that technological literacy as an educational experience remains largely unresolved in terms of a consensus of content, knowledge, process, skills. Rather than expend energies and attempt to devise assessment for the inadequate models of Technology Education that exist, he argues for the reconceptualisation of the commonly adopted techno centric method and the development of integral and

appropriate assessment strategies for life long learning.

The lack of consensus as to what comprises the precise nature of 'content' of Technology Education impacts on what is considered of value. There seems to be confusion regarding what should be 'measured' and used to inform judgements in terms of attainment performance and achievement. There is little confidence that what is being assessed is indeed what is of value in learning. Several authors (e.g. Kimbell, 2000, 1997; Department for Education and Skills, 2003; Barlex, 2000; Atkinson 2000; Qualification and Curriculum Authority, QCA, 2005) question the suitability and validity of assessment methods as matched to the purpose of Technology Education.

Assessment of learning – influence of external summative assessment on teaching and learning

There is evidence in general education literature and specific Technology Education literature (Broadfoot & Black, 2004; Preece & Skinner, 1999; Shen, 2002; Kimbell, 1997; Atkinson 2000, McCormick et al, 1994, Newton & Hurn, 1996) that the requirements of summative tests and external certification assessments and examinations dominate the assessment practice of many teachers. Shield (1996) suggests that the data on attainment from the examination assessment model, in England, implies achievement in technological matters. However, he cautions that this is at the expense of secure understanding in terms of technical content and technological understanding. He examines issues of learning, engaging with and applying subject knowledge, versus teaching tactics and strategies, approaches and processes skills specifically to meet assessment requirements. His concern is that the latter strategic approach dominates the authentic and sustainable technological skills, procedures and processes for application autonomously by the learner. The Assessment of Performance Unit advise not to separate conceptual understanding from practical action for example in a written test to 'test understanding'. They suggest that such an approach is 'immensely damaging' (Kimbell et al, 1991:231).

Kimbell (2002) describes assessment as a hurdle, suggesting that the things that are deemed to be

An International Overview of Assessment Issues in Technology Education: Disentangling the influences, confusion and complexities

measurable are measured and the things that are deemed to be difficult to measure are not measured. He observes that current practices of assessment of design and technology activity, integral to many Technology Education courses, systematically reward formulaic, traditional, individual, technical and safe submissions that follow the checklist of contents of a portfolio, as stated in assessment guidance or assessment rubric used by examination boards. He distinguishes between 'baseline knowledge and skills (materials, systems, tools, processing)' and 'task related knowledge'. He notes that there is specific 'knowledge of the moment' that a student engaged in a task will need to identify and acquire in order to progress through the task successfully. Therefore it is not their performance against a test of this specific knowledge that is of importance. Kimbell considers that the student's ability to access the knowledge that they need at the time they need it in order to pursue the task that is a useful and important aspect for assessment purposes.

Barlex (2005) too differentiates between knowledge sought out and learned specifically for application in a specific (design) activity with that which is deemed as fundamental subject content. He suggests that 'knowledge for solution' can be taught in fairly traditional ways to ensure that students develop useful repertoires of underpinning skills, knowledge and processes on which to draw from at appropriate times. This implies two distinct sets of subject knowledge; that which can be acquired during design activities and 'stand alone' subject knowledge which needs to be taught to facilitate technological designing activity. In a historical critique of syllabi from awarding bodies in England, Lewis (2003) notes little or no explicit indication of a discrete body of subject knowledge for Technology Education. More recently it has become practice for curriculum authorities and exam boards to issue guidance to promote approaches where the students are expected to combine skills and knowledge in 'design and make' activities. Lewis (2003) notes that an additional written paper to test application of knowledge and understanding of materials, components, processes, techniques, technologies and evaluation is common practice. Lewis suggests that albeit there may be more sophisticated approaches evident in examinations, there still exists a separation between assessment of designing and

making, and knowledge and understanding.

There seems to be agreement that there is value in the task related action specific to Technology Education and that action is 'designing'. Barlex (2005) claims that designing has no specific subject matter of its own other than that which the designer deems to be of value. Barlex (2005:7) argues that it is designing that 'will develop pupils' high level cognitive skills, through which they will be able to handle uncertainty, seek relevant knowledge, solve problems, make and justify decisions and communicate effectively'. Stables (2004:169) describes design centred activities as, '...iterative, responsive and dependent on the integration of action and reflection, rather than sequential, prescriptive and managerial'. She suggests that teachers are reticent to value learner directed design activities due to their perception that this will limit the learner's ability in producing all the 'necessary documentation to get good grades'. Teachers feel the arrangements and guidelines issued by the awarding bodies do not 'allow' any risk taking or uncertainty. Atkinson (2000) discusses the impact of restrictive and prescriptive design approaches on student attainment. In general, inflexible assessment approaches are being used to judge learners' performance in an area of learning where flexibility and dealing with uncertainty is considered a positive value. Her evidence suggests such practices of assessment are detrimental, particularly for 'high creatives' (p.275).

Leung (2000) notes that the nature and structure of various tests, assignments and assessments proportion mark allocation towards various items and weight particular aspects. These small itemised marks are in turn aggregated to make a 'whole' mark to create a 'grade'. Reporting on research in Hong Kong, he argues that this pushes students to follow a common format that meets with the perspective of the examiner or the teacher as assessor. This results in evidence that does little in terms of indicating what the student's technological capability is when faced with an open ended design situation which requires a personal response and journey towards a resolution. Technological capability is 'an appropriate interaction of knowledge, skills and values, and not simply the aggregation of levels of understanding and performance in discrete areas.' (Elmer, 2002:19)

An International Overview of Assessment Issues in Technology Education: Disentangling the influences, confusion and complexities

Black (2001:78) agrees that the value is in the learner having the 'power to generate procedures and new structures of knowledge' and that assessment should be derived from both simple tests of facts and skills and a learner's response to complex task. Kalantzis et al (2003) recognise the limitations of any curriculum that focus on empirically right or wrong answers or assessment that measures knowledge for itself outwith a context. They emphasise the need for more appropriate assessment integral to a 'new learning and to measure more accurately the skills required for success in the twenty first century' which 'puts a premium on creativity, problem solving and the active contribution of every person' (p.16).

There are concerns (Broadfoot & Black, 2004; Newton & Hurn, 1996) that outdated and inappropriate assessment of learning regimes may be limiting teaching and learning. The preoccupations of gathering data, testing and reporting may obscure what others may consider to be of greater value. The usefulness to the learner and meaning in terms of next steps might be considered the priority by others. Welch (2001) reminds us that it is the 'assessment of student growth and achievement that is central' regardless of purpose of the assessment, i.e. to diagnose, to provide feedback, determine next steps, reporting to parents, or for national moderation.

Assessment of and for learning – influence of teacher attitude, knowledge and understanding on assessment, learner performance and motivation

Some (Davies & Elmer, 2001; Lewis, 2005; Atkinson, 1994, 2000) note the influence assessment methods have on a teacher's adopted teaching style. Others (Moreland et al, 2000; McCormick & Davidson, 1996) have noted the limitations of a teacher's capability to make meaningful assessment judgments due to their personal pedagogical content knowledge. Jones & Moreland (2005) explore the limitations the teacher's own technological capability imposes on the learning of the student and relate weak understandings of teachers to the limited progress of the learners. In their studies in New Zealand, it was observed that teachers with a less secure personal pedagogical content knowledge base tended to focus on more social and managerial aspects of the learning activity and interactions, feedback, prompting and direct

teaching tended to be devoid of technological aspects. When the teacher's formative assessment took a social and managerial focus the learners become confused as to what was most important about the purpose of the task. Broad generic procedural learning took precedent over technological aspects.

Boser et al (1998) discuss the difference between affective outcomes and cognitive objectives. Popham (1994) cited by Boser et al suggests that affective behaviours can undergo more sudden transformations than cognitive. Therefore, teachers may feel that they are supporting progression, when basing judgments on changes in affective behaviour. However, this may be less in terms of specific technological progression than intended. Jones & Moreland (2005) note that as the teachers increase their own understanding of the nature and purpose of technology education and appreciation of technological capability, they become more aware of the procedural, conceptual and technological ideas that underpin and are embedded within technological knowledge and understanding. This increased personal understanding and appreciation influences their planning, teaching and both formative and summative assessment practices.

Earlier studies of classroom practice in New Zealand, by Moreland & Jones (2000) noted that learners were engaged in processes of designing, constructing and testing when producing artefacts and that these processes were often staged, by the teacher, as discrete stages. This approach allowed very limited opportunity for iteration and did not encourage the learner to make connections between various phases and processes. The activities themselves seemed to dominate over the technological principles and processes. The latter received minimal attention in teaching and there was little evidence of assessment of technological practice. The teachers seemed unable to define the procedural and conceptual learning outcomes of tasks they devised for the classroom experience. This hindered the quality and usefulness of formative feedback and interaction. There was a lot of praise based interaction, mostly related to completion of task, not a great deal involving strengths and weakness of the work related to criteria or objectives of the task. Opportunities for development into procedural, conceptual or societal

An International Overview of Assessment Issues in Technology Education: Disentangling the influences, confusion and complexities

technological aspects were not taken. Some teachers held the belief that teacher intervention stifles creativity. Fox-Turnbull (2006), Davies & Elmer (2001), Stables (2004) Dow (2006), writing from perspectives from Australia, England and Europe, acknowledge the influence a teacher's own philosophy and knowledge base has on assessment and progression.

Recognition of motivational beliefs, dispositions, goal orientations and attitudes of a learner can inform teachers further and help them support learners to achieve. For example, learners whose goal orientations (Pintrich & Schunk, 2002) can be described as mastery-approach goals, set their own standards and aim for self improvement. Such learners focus on skill development, creativity and understanding. This contrasts with those who hold performance-avoidance goals. These learners often avoid asking for help when they need it and perhaps give up rather than persevering when things do not work out easily or readily. They try to avoid looking less able than others so may not try things in the first instance. They are less willing to engage effectively with design centred activity where technological capability is assessed on their response to an ill defined, multi-layered task and they are expected to engage with a high degree of uncertainty, take intellectual risks, generate a range of potential solutions to ascertain feasibility.

Learners who are performance-approach goal orientated may also find open ended design activities of Technology Education less engaging. These students are eager to gain the highest grade or be recognised as 'better' than others. However, evidence from Atkinson (2000) indicates that performance-approach goal learners and less creative learners can gain high attainment 'grades' in certain assessment task types. She conducted pre-tests to determine the creativity of the learners, their goal orientation characteristics and their level of motivation. She noted that learners who were considered to be highly creative performed less well than expected in assessed design and technology project work which followed the specification of the external awarding body. 'High creatives' often did not complete the work, whereas the 'low creatives' completed the project within the time given and coped well with the restrictive model of assessment (Atkinson, 2000: 275).

Atkinson identified that teachers had difficulties in identifying creative thinking. She suggests that innovation in 'designing' was not welcomed by teachers. She highlights issues that arise when a design process is identified as stages and labels of 'the stages' are used as units of assessment. The consequence of this is to influence the approach taken, limit flexibility and creativity. High marks can be gained by providing evidence of each 'stage' of the assessed process, regardless of the underlying quality in the thinking or the creativity. Learners who are willing to do a certain aspect when asked to, and do not deviate from what is asked, are seen to be rewarded by the assessment rubric. The prescription seemed to be favoured by teachers and less creative learners, and less so by highly creative individuals.

This concurs with the findings of Davies & Elmer (2001) and Ames (1992) who discuss the influence teacher control and formative interactions have on learners. Learners' motivational beliefs and goal orientations can be created, supported or altered. Davies & Elmer (2001:167) note that teachers have 'the power to promote or depress modelling, and hence learning, through their methods of assessment.' Students react negatively, become de-motivated and admit to lesser effort when a teacher imposes a particular generic procedure on all learners and then assesses against accordance and compliance (ibid. p.169). Another distinct reaction may be that of complete trust by the learner in the teacher's judgment. This leads to learners doing precisely as advised and adopting a performance goal orientation. As a consequence, quality of learning, cognitive development and outcomes are lessened.

The difficulties of assessing thought in action, as required for technological capability, lie with the complexity of communicating creative thinking in a way that it can be witnessed, evidenced and interpreted as such by others. It demands that creativity is displayed or recorded in a form that can be grasped by others to judge. As discussed in the previous section, interpretation of what is observed and what is drawn from the students' outcomes depend on informed teachers and the pedagogical and technological content knowledge of those assessing and carrying out the formative interactions. The less robust the pedagogical and technological

An International Overview of Assessment Issues in Technology Education: Disentangling the influences, confusion and complexities

content knowledge the more likely teachers are to emphasise the quantity rather than the quality of the performance. Newton & Hurn (1996) examine the influence of the teacher's own conceptualisation of Technology Education, and the organisational arrangements of their departments or faculties, on assessment judgments. They explore what each teacher takes as strengths from the same evidence of work. Their study provides evidence that the nature and purpose of Technology Education, as perceived by each teacher, is influenced by the teacher's specialist discipline (e.g. engineering, graphic, textiles, product design). This in turn influences the assessments made. In planning, teachers tend to select tasks and activities that reflect their own conceptualisation and preferences. Newton & Hurn, as with Moreland et al (2001), conclude that inconsistencies of teacher assessment, formative and summative, can have significant effects on learners. Potentially, assessment interaction between teacher and learner can result in a startling decline for the learner. Learners may avoid doing a particular type of technology work, develop low self esteem and become negative due to 'grade' awarded, or the feedback given by teacher, particularly when the learner themselves does not hold the same opinion of their work as the teacher (Elmer and Davies, 2001). Black & Wiliam (1998b) note that where a teacher seeks a particular response and lacks the flexibility to deal with the unexpected, the formative assessment is of no value. The teacher manipulates the discussion and reduces the value placed on thinking. Learners realise that they are not really required to work out answers for themselves. They start to guess what the teacher wants to hear and adopt the teacher's conceptions of what a worthwhile design and technology activity might be.

The literature has indicated that teachers, and examination assessment system, rubrics may be rewarding lower quality, but well presented, evidence rather than identifying high order skills which are embedded within creative design thinking. Learner goal orientations and motivation influence academic attainment and achievement so it is useful for teachers to monitor and develop positive attitudes, motivational strategies and share the learning intentions explicitly with the learners. The approach teachers take to evaluate, make and share judgments

of the learner's performance and achievements will influence the goal orientation of the learner. By adopting the inter-related principles of assessment of, for and as learning feedback can be more meaningful, negotiated and targeted to aid progression in the various aspects of Technology Education.

Discussion: Assessment of, for and as learning – disentangling assessment methods and evidence of achievement, attainment and performance

It is acknowledged that assessment aimed at determining learner's critical thinking, decision making, technological knowledge and design related capability is challenging. Kimbell et al, (1991), Custer et al, (2001) and others have attempted to define and clarify the various dimensions involved in Technology Education in general, and design and technological activities specifically. These dimensions are given different labels to describe complex and significant aspects of technological capability (e.g. problem identification, redefinition of problem and design clarification; exploration, generation and development of design ideas; modelling/prototyping/communication; evaluation/proving/reviewing/the design solution and processes. Attempts have been made to identify the key discriminators of achievement and performance. Studies (Kimbell et al, 1991; McLaren et al, 2006) indicate that learners tend to 'score' highest in the dimension that involves modelling/prototyping. Learners perform less well in the preliminary and preparatory, analytical and the evaluative aspects of designing. Novice and more expert designers alike find these the hardest dimensions. The ability to develop and synthesise initial ideas towards a resolution correlates fairly accurately with the holistic judgement of performance overall. Therefore this aspect of designing, i.e. the development and synthesis, serves as a good discriminator of technological capability. (Kimbell et al, 1991)

The domains, dimensions and discriminators that Meier et al (2006) identify as useful for assessment purposes in fuzzy ended mathematic tasks, have echoes with those of Technology Education e.g. maths knowledge, strategic knowledge, communication/explanation. Parallels are evident with a three instrument test strategy which Autio & Hansen

An International Overview of Assessment Issues in Technology Education: Disentangling the influences, confusion and complexities

(2002) used in Finland to find out if achievement in technological knowledge, competence and emotional engagement can be identified and measured. They described this as 'technical thinking'. The issues of making valid judgments of technological capability in terms of the processes and application of knowledge and value and attitudes in action were identified as problematic. As illustrated previously, the uncertainty of the purpose of technology education and confusion regarding what is of value, can result in low teacher confidence. Low confidence impacts of quality of teaching, the effectiveness, reliability and use of assessment. Assessment, as a result, is not used to help learners to improve. Teachers too often rely on 'incidental observations of practical work' (Her Majesty's Inspectorate HMI report 2350, cited in QCA, 2005).

Several studies (Lewis, 2005; Beattie, 2000; Cowdroy & Graff, 2005; Kimbell, 2006a) suggest that assessing 'creativity' holds specific challenges for Technology Education. These include differentiating between assessments of creative activity and the outcomes of the activity. There is evidence (Stein et al, 2002; McCormick & Davidson, 1996; Beattie, 2000) that teachers mix up assessment of the designed artefact or outcome against the design criteria with assessing the learner's performance in tackling the task and framing this against the related learning outcome and achievement objectives as stated as the purpose of the experience of task. Particular difficulties are noted when relating the use of criteria/rubric to the knowledge base, and experience in the domain, of the teacher as assessor. Cowdroy & Graff (2005) explore the limitations of 'letting the work speak for itself'. The work can hide the creative ability that led to it. They suggest a negotiated and formative use of assessment for learning which leads to a shared understanding between learner and assessor of achievement on which summative assessments were based. The 'highly creative' practitioners are able to articulate the conceptual and schematic underpinning at the start of their approach. Retrospectively this is also present, to some degree, in lower level creative learners too.

Many advocate a 'thought and performance in action model' of assessment for Technology Education (e.g. Barlex, 2005; McCormick, 2004; Kelly et al., 1987).

Discriminators of assessment of technology capability have been identified as: the ability to engage actively in having and developing ideas and proposals, procedural capability, and conceptual areas (Kimbell, et al 1991). These, underpinned with communication (clarity, confidence and complexity) can be used to arrive at a holistic judgment. Such holistic assessment must be reliable, valid and manageable (Kimbell et al, 1991; Kimbell, 2004). Within these categories, the discriminators need to be as varied as the task demands. The action based, practical design-centred technology projects require the learners to identify and use technological knowledge, concepts and procedures where and when appropriate to their specific task. The learners' ability to make use of a wide repertoire of understanding as they become appropriate is a useful measure. The learner can set the goals and the criteria for reviewing and evaluating outcome and process. Their personal interest in the technology project will influence their motivation and achievement. Davies & Elmer (2001:169) note that 'effort (mental and physical) is carefully rationed (by the learner) in accordance with this interest level'. Several others (Fox-Turnbull, 2004; McCormick, 2004; Kimbell et al, 1996) stress the importance of creating stimulating contexts and authentic scenarios for learning through design and technology activity in order to enable all learners to engage and develop.

Elmer (2002) suggests at the core of Technology Education is '*knowing how*' knowledge which empowers its holders in the realms of practical action. Elmer explores the attributes of meta-cognition, citing Hacker et al (1988) who offer 'knowledge of one's knowledge, processes, and cognitive and affective states; the ability to consciously and deliberately monitor and regulate one's knowledge, processes, and cognitive and affective states' (p24). Elmer relates these to design and technological activity. Although harder to distinguish, correlations have been made between assessments and personal characteristics, personality, cognitive styles, learning preferences, gender. Evidence (Lawler, 1996; Custer et al, 2001; Atkinson, 1994 & 2000; Kimbell et al, 1991) indicates these have significant influences on achievement and performance in assessment activities. Beghetto (2004) suggests that assessment of students' motivational beliefs can be part of teaching. He describes various approaches to self

An International Overview of Assessment Issues in Technology Education: Disentangling the influences, confusion and complexities

evaluation and self assessment e.g. exploring from the learner's perspective what is already known, what the learner still wants to know and what the learner feels was learned. Formative feedback, next steps, diagnostic assessments by teacher, peer or the learners themselves should be taken account of and changes in teaching and learning attempted.

Not all design activities allow different personalities (and genders) to participate and achieve equally. Planning for democratic teaching, learning and sustainable assessment should recognise the complexities and consider learners as active partners. Learners need to develop strategies that support the concept of learning how to learn. They need to evaluate their own learning and set their own goals. Learners need to be supported in developing a mastery goal orientation (Ames & Archer, 1988; Elliot & Dweck, 1988) where the learner is keen to learn skills, make an effort to understand their own work and feel a sense of achievement against self set criteria and quality standards. Teachers who aim to create an ethos of mastery goals, value independent thinking and support autonomous activity are more likely to develop the intrinsic motivation that will enable learner to engage with and perform creatively in design activity, with reflection and self awareness. The intrinsically motivated learner may challenge the teacher's assessment subtly and develop independent ideas, rejecting the teacher attempts to impose upon them. Black & Wiliam (1998b) state that for assessment as learning to work there must be a sharing of 'whole picture' which includes the purposes of the learning experience, the integral assessment, evidence of present position and the 'close the gap' type feedback processes which are understood by teacher and student.

In the context of Technology Education in the USA, Gagel (2004) writes of the need to create a technology disposition profile to aid identification of specific students for specific programmes; to make comparison of individual capabilities against a known group; determine technological knowledge and skills in a particular area of technology; arrive at classification of disposition towards technology. He explores models of profiling and considers the benefits of a 'typology' approach incorporated into the profile, i.e. knowledge, skills and attitudes regarding

technology with personality or temperament indicator tools. Whilst recognising the limitations, he suggests a 'battery of tests' to try to cover the range and breadth of Technology Education. Beghetto (2004:6) agrees, 'as with all assessment, no single method is sufficient.' The identification of what determines quality of thinking and performance in active capability remains elusive, as does the range of evidence against which professional and informed judgements of technological capability are made.

Welch (2001) discusses the usefulness and validity of different expressions of evidence. He describes transitory evidence as being where the teacher's observations and interactions are used to base judgements. Permanent evidence, he suggests, may be in the form of final product(s) from a 'design and make' type process and an accompanying portfolio to provide 'insights into the students mind'. Kimbell (2002), Doppelt (2003), Beattie (2000) note issues regarding assessment judgments which are based on permanent evidence such as folders of work, physical outcomes and artefacts.

Writing of studies in Israel, Canada and England, Barak & Doppelt (2000), Doppelt (2006), Welsh et al (2000) and Kimbell (2006a) have examined the way that designers use note books and journals of their design journey in order to identify possible authentic portfolio approaches for assessment purposes. Kimbell discusses one view of a portfolio as a being that of a container for assorted evidence that may be useful for 'judgement'. A portfolio can also be used as a report which documents and present the story of the design journey. Kimbell recognises the limitations in both and suggests that neither capture the 'dynamic capability dimension' of designing. This in turn limits the folio format in its usefulness as an assessment tool. Folios may become overly prescriptive following teachers 'imposing ever-more rigid formulas on student project portfolios to guarantee success' (Kimbell, 2006a:19) leading to 'well-organised, rule followers' being rewarded in examination project work. The student's freedom may be curtailed by the way in which teachers make demands on content, presentation, practices and procedures. Schechter (1998) suggests the teacher's interpretation of what is required, narrows things down to common denominator, driven by instruction

An International Overview of Assessment Issues in Technology Education: Disentangling the influences, confusion and complexities

against a rubric of assessment in the argument that it is imposed to achieve reliability and validity.

Capturing transitory, ephemeral evidence in such a way to create tangible permanent evidence that is valid, reliable and meaningful to learner, teacher and awarding bodies has been the focus of research by the Technology Education Research Unit (TERU) from the 'Assessment of Performance in Design and Technology Education (1989-1991)' to the more recent 'Assessing Design Innovation, 2002-2004' (Kimbell, 2006b). Their model of assessment of creativity and innovation through an 'un-pickled portfolio' (Stables & Kimbell, 2000) has been adopted by some awarding bodies in England (e.g. OCR, 2006). OCR guidance for teachers states that 'an open approach with flexible support from teacher will open the candidate's eyes and enable 'freethinking' to take place.'

Taking earlier themes of 'having, growing and proving ideas' (Kimbell, 2006b), a more recent project entitled 'e-escapes' (Kimbell et al, 2007) aims to exploit new, emergent and bespoke digital technologies to enable evidence to be captured authentically throughout the journey of 'a thought and performance in action activity' and to refocus the portfolio. A wide range of evidence is captured digitally, in real time throughout an interactive managed design activity experience, using a broad range of tools. The 'messy' design journey and the voice of the learner is evidenced as ideas are sparked off, grown, tested, reflected on, proven, etc. The evidence is digitally captured in sound, sketching, modelling, research activity, text and so on, prompted by the framework of the activity script but 'controlled' by the learner. Kimbell et al (2007) assert that e-portfolio, as a consequence, is analogous with dialogue. The portfolio as dialogue captures the essence of its purpose and lends itself to echo Schon's (1987) description of designing as being a conversation with oneself.

The e-escapes project team are confident that the evidence captured and the system developed using the Thurstone paired comparative method (Pollit & Elliot, 2003) provides high reliability assessment. At present this research has focused on summative assessment of innovation and creativity performance. It is intended that the approaches developed will be

integrated for formative purposes i.e. assessment *for* and assessment *of* learning. The use of holistic performance descriptors instead of atomised criteria should eliminate the urge to overwhelm teaching with external assessment.

The literature suggests that Technology Education involves the creative integration of the intellectual, conceptual, procedural, emotional and practical and that teaching, learning and assessment need to reflect this appropriately. In recognition of the complexities involved in assessment matters related to these various strands integral to Technology Education there have been developments in a number of countries which exploit a range of assessment approaches to arrive at some sort of profile of achievement. At present these tend to be translated into summative awards. Some approaches involve the learner in setting their own context for design activity, teacher devising tests and determining when the learner is best ready to take such assessments, some have only internal teacher assessment, others use a mixed economy. There is general agreement that methods of assessment ought to capture the learner's knowledge, achievements and performance through modes they, as learners, can best express themselves.

Conclusion

This review of literature has attempted to disentangle some of the central themes relating to assessment of, for and as learning. Assessment of Technology education is complex and has a significant influence on pedagogy. Pedagogy, too, has a significant influence on assessment as an integral part of learning and teaching. Recurring issues have been identified. These include the influence of:

- external assessment systems and examinations;
- a teacher's understanding of the aims and learning purposes of technology education, and their technological content knowledge on the quality and effectiveness of their planning, teaching and assessment;
- a teacher on learner motivation and performance;
- goal orientation and motivation on performance;
- the nature and effectiveness of formative interaction on learning and progress;
- a teacher's own technological philosophy, capability and specialist domain on interpretation of observations and assessment of evidence;

An International Overview of Assessment Issues in Technology Education: Disentangling the influences, confusion and complexities

- the affective domain, attitudes, motivational belief and goal orientation on learning, knowledge and capability;
- the context of assessment on performance;
- evidence type and the method used to capture on the quality of progress and learning;
- assessment by atomisation compared with holistic methods assessment for judging performance;
- effective formative interactions and feedback on learning and performance.

Prevailing modes of assessment seem to be reinforcing outmoded notions of what is of value, and what and how to 'measure' to judge the learning. However, this review has indicated that there is a will to challenge some inappropriate and damaging teaching and assessment approaches. There is improved appreciation that more can be learned about the learner, and by the learner, when knowledge and thinking in action is the focus of assessment. Inherent with assessing thought in action and task performance is the question of what evidence, in what expression, is valid as assessment outcomes.

The literature makes a strong argument for multiple sources of data to support inferences regarding a learner's intellectual functioning and creative design and technological performance. Recent thinking indicates that ideas such as portfolios, e-portfolios, records and logs of achievements, self and peer assessment, self set learning goals, targets and action planning each reflect a very different role for assessment. It becomes clear that evidence for assessment cannot be sourced from one format alone. The way assessments are used in terms of a learner's future causes concern if the consequences follow from indeterminate and inaccurate assessments. The emergent assessment paradigm for Technology Education needs to be well founded in evidence based research.

There remains a lack of clarity about:

- why we assess what we do in Technology Education;
- what is considered to be the value for learners in the 21st century;
- what we want to find out by the assessment processes adopted;

- what is the information gained used for;
- how assessments can be reflected on and used meaningfully by all relevant stakeholders;
- what constitutes technological knowledge in application, technological conceptual understanding and technological dispositions;
- how to ensure learners and teachers do not avoid the technical;
- the relationship between learning through design centred activity and meta-cognitive enabling strategies.

Future research agenda for assessment in the context of Technology Education

More research is needed to help the learning communities of Technology Education adopt and adapt the values of Assessment of, for and as learning. E.g.

assessment of learning

- greater integration of formative diagnostic experiences and summative assessment to aid progression;
- develop assessment which uses a range of evidence to check progress against goals;
- incorporate a wider range of tools, instruments and assessment types considering contexts, learning styles and characteristics;
- develop meaningful profiles for point of departure from schooling into further studies and world or work to share of attainments and recognise achievements.

assessment for learning

- determine the effectiveness of the range of tests, tools, experiences, activities and instruments in terms of progression of technological capability, knowledge, concepts and communication;
- identify meaningful authentic learning contexts to motivate and appeal to range of learners to encourage mastery goal orientations;
- establish longitudinal studies to create data evidence sets that indicate the effectiveness across a range of setting and a range of stages and phases of schooling for a range of abilities.

assessment as learning

- explore connections between developing attitudes, dispositions and actions pertaining to Technology

An International Overview of Assessment Issues in Technology Education: Disentangling the influences, confusion and complexities

Education with developing the attitudes and values of assessment as learning;

- develop strategies to scaffold learning 'how to learn' through ill-defined tasks, learner identifying what they need to know what they don't yet know but recognise they need to know;
- develop the language for dialogue with uncertainty;
- develop a range of peer and self assessment tools.

The multi-dimensional nature of assessment implies that there needs to be complimentary multi-dimensional assessment. The complex and inter-related nature of the discriminators of technological performance, knowledge and understanding, skills and communication also indicate the need for multi-modal and multi dimensional assessment instruments.

s.v.mclaren@strath.ac.uk

References

- Ames, C. (1992) 'Classroom: Goals, Structures, and Student motivation'. *Journal of Psychology*, 84, 3, 261-271.
- Ames, C. & Archer, J. (1988) 'Achievement Goals in the classroom: students' learning strategies and motivational processes'. *Journal of Educational Psychology*, 80, 260-267.
- Atkinson, S. (2000) 'Does the need for High levels of performance curtail the development of creativity?' *International Journal of Technology and Design Education*, 10, 3, 255-281.
- Atkinson, S. (1994) 'Key factors which affect pupil's performance in Technology Project work'. In J.S. Smith (ed) *IDATER 94* Loughborough, 30-37
- Autio, O. & Hansen, R. (2002) 'Defining and Measuring Technical Thinking: Students' Technical Abilities in Finnish Comprehensive Schools'. *Journal of Technology Education* 14, 1, 5-19.
- Barlex, D. (2000) 'Preparing Design and Technology for 2005: Moving beyond the Rhetoric'. *Journal of Design and Technology Education*, 5, 1, 5-15.
- Barlex, D. (2005) 'The centrality of designing- an emerging realisation from three curriculum projects'. In M. De Vries (ed.) *PATT 15*
- Barak, M., & Doppelt, Y. (2000). 'Using portfolios to enhance creative thinking'. *Journal of Technology Studies*, 26, 2, 16-24.
- Beattie, D.K. (2000) 'Creativity in art: the feasibility of assessing current conceptions in the school context'. *Assessment in Education: Principles, Policy and Practice*, 7, 2, 175-192.
- Beghetto, R. (2004) 'Towards a more complete Picture of student Learning: Assessing Students' Motivational Belief'. *Practical Assessment, Research and Evaluation* 9, 15, accessed on 07/11/2006 from <http://pareonline.net/getvn.asp?v=9&n=15>
- Black, P. & Wiliam, D. (1998a) *Inside the Black Box: Raising Standards through classroom assessment* PHI Delta Kappan, 80,2, accessed 06/11/06 from www.pdkintl.org/kappan/kbla9810.htm
- Black, P. & Wiliam, D. (1998b) 'Assessment and classroom learning'. *Assessment in Education*, 1, 7-74.
- Black, P. (2001) 'Dreams, Strategies and Systems: portraits of assessment past, present and future'. *Assessment in Education*, 8, 1.
- Boser, R., Palmer, J. & Daugherty, M. (1998) 'Students' attitudes towards technology in selected technology education programmes'. *Journal of Technology Education*, 10, 1, 4-19.
- Broadfoot, P. & Black, P. (2004) 'Redefining assessment? The first ten years of Assessment in Education'. *Assessment in Education*, 11, 1, 7-27.
- Cowdroy, R. & de Graff, E. (2005) 'Assessing highly creative Ability'. *Assessment and evaluation in Higher Education*, 30, 5, 507-518.
- Custer, R., Valesey, B. & Burke, B. (2001) 'An Assessment model for a Design Approach to Technological Problem Solving'. *Journal of Technology Education*, 12, 2, 5-20.

An International Overview of Assessment Issues in Technology Education: Disentangling the influences, confusion and complexities

Davies, T. & Elmer, R. (2001) 'Learning in Design and Technology: Impact of social and cultural influences on modelling'. *International Journal of Technology and Design Education*, 11, 2, 163-180.

Department for Education and Science (1988) *The Interim Report of the National Curriculum Design and Technology Working Group*. London: DES.

Department for Education and Science (2003) *Good Assessment practice in design and technology* HMI 1471, London: DES.

Department for Education and Employment (1999) *Design and technology, the national curriculum for England*. QCA

De Vries, M. (2005) 'The Nature of Technological Knowledge: Philosophical Reflections and Educational Consequences'. *International Journal of Technology and Design Education*, 15, 2, 149-154

Doppelt, Y. (2003) Implementation and Assessment of project-based learning in a flexible environment. *International Journal of Technology and Design Education*, 13, 3, 255-272

Doppelt, Y. (2006) 'Assessing creative thinking in design-based learning'. *International Journal of Technology and Design Education*, accessed online 11/02/07 from www.springerlink.com/content/q25887k760141nw1/fulltext.pdf

Dow, W. (2006) 'The need to change pedagogies in science and technology subjects: a European perspective'. *International Journal of Technology and Design Education*, 16, 3, 307-321

Elliot, E.S. & Dweck, C.S. (1988) 'Goals: An approach to motivation and achievement'. *Journal of Personality and Social Psychology*, 54, 5-12

Elmer, R. (2002) 'Meta-Cognition and Design and Technology Education'. *Journal of Design and Technology Education*, 7, 1, 19- 25.

Fox-Turnbull, W. (2006) 'The influences of Teacher Knowledge and Authentic Assessment of students learning in Technology Education'. *International Journal of Technology and Design Education* 16,1, 53-77.

Gagel, W. C. (2004) 'Technology Profile: An Assessment Strategy for Technological Literacy'. *The Journal of Technology Studies* 30, 4: 38-44.

Harlen, W. & Deakin-Crick, R. (2003) 'Testing and Motivation for Learning'. *Assessment in Education*, 10, 2: 169-207

Harris, M. & Wilson, V. (2003) *Designs on the Curriculum? A review of the literature on the impact of Design and Technology in schools in England*. Report for DfES

O'Donnell, S. (2004) *International Review of Curriculum and Assessment frameworks comparative tables and factual summaries – 2004*. National Foundations for Educational Research.

ITEA, (1996) *Technology for All Americans: A rationale and Structure for the study of technology* Reston, VA : ITEA

ITEA, (2000) *Standards for Technological Literacy: Content for the Study of Technology* Reston, VA : ITEA

Jones, A. & Moreland, J. (2005) 'The importance of pedagogical content knowledge in assessment for learning practices: a case study of a whole school approach'. *The Curriculum Journal*, 16, 2, 193-206.

Jones, A. & Moreland, J. (2000). 'Emerging assessment practices in an emergent curriculum: Implications for Technology'. *International Journal of Technology and Design Education*, 10,3, 283-305.

Kalantzis, M, Cope, B., & Harvey, A. (2003) 'Assessing Multi-literacies and the new basics'. *Assessment in Education*, 10,1: 15-26

Kelly, A. V., Kimbell, R. A., Patterson, V. J. & Stables, K. (1987) *Design and Technological Activity: A Framework for Assessment*, Assessment of Performance Unit/HMSO, London

An International Overview of Assessment Issues in Technology Education: Disentangling the influences, confusion and complexities

- Kimbell, R., Stables, K. & Green, R. (1996) *Understanding Design and Technology Education*. Open University
- Kimbell, R. (1994) 'Progression in Learning and the assessment of Children's Attainments in Technology'. *International Journal of Technology and Design Education*, 4, 1: 65-83
- Kimbell, R. (1997) *Assessing Technology International Trends in curriculum and assessment*. Open University Press
- Kimbell, R. (2006a) 'Innovative performance and Virtual Portfolios – a tale of two projects'. *Design and Technology Education: An International Journal*, 11,1, 18-30
- Kimbell, R. (2006b) 'Innovative technological performance'. In J. R. Dakers(ed.) *Defining Technological Literacy: Towards an epistemological framework*. New York: Palgrave MacMillan, 159-178
- Kimbell, R. (2002) 'Assessing design innovation: The famous five and the terrible two'. *Journal of Design and Technology Education*, 7,3, 172-180
- Kimbell, R. (2004) 'Assessment in Design and Technology Education' in H. Middleton, M. Pavlova and D. Roebuck (Eds.) *Learning for Innovation on Technology Proceedings of the 3rd Technology Educational Research Conference* Griffith University, 2, 99-111.
- Kimbell, R. & Perry D. (2001) *Design and Technology in a knowledge economy*. Engineering Council.
- Kimbell, R. (2000) 'Creativity in Crisis'. *The Journal of Design and Technology Education*, 5,3, 206-211.
- Kimbell, R., Wheeler, T., Miller, S.& Pollit, A. (2007) *E-scapes portfolio assessment phase 2*. Report for DfES and QCA. London : TERUGoldsmiths College
- Lawler, T. (1996) 'The use of cognitive style analysis and the APU assessment strategy as a means of clarifying and describing student work'. *Design and Technology Journal*, 1,1, 4-11
- Leung, C. F. (2000) 'Assessment for learning: Using SOLO taxonomy to measure Design Performance of Design and Technology Students'. *International Journal of Technology and Design Education*, 10, 2: 149-161.
- Lewis, Theo. (2005) 'Creativity – A framework for design/ problem solving discourse for Technology Education'. *Journal of Technology Education*, 17, 1, 35-52,
- Lewis, Tim. (2003) 'DT subject knowledge and its relationship with design and making'. In E.W.L. Norman, & D. Spendlove (eds.) *IDATER 2003*, 69-81.
- McCormick, R. (2004) 'Issues of Learning and Knowledge in Technology Education'. *International Journal of Technology and Design Education*, 14, 21-44.
- McCormick, R. & Davidson, M. (1996) 'Problem solving and the tyranny of product outcomes'. *Journal of Design and Technology Education*, 1,3, 230-241.
- McCormick, R., Murphy, P., & Hennessy, P., (1994) 'Problem solving processes in technology education: a pilot study'. *International Journal of Technology and Design Education*, 4,1, 5-34.
- McLaren, S.V., Sables, K & Bain, J. (2006) *Creativity and Progression in Transition through Assessment is for learning – Design and Technology CAPITAL – DT*. Report for Determined To Succeed & SEED. Glasgow: Strathclyde University
- Meier S, Rich B, & Cady, J. (2006) 'Teachers use of rubrics to score non-traditional tasks: factors relating to discrepancies in scoring'. *Assessment in Education*, 13, 1, 69-95
- Moreland, J., Jones, A. & Northover, A. (2000) 'Enhancing Teachers' Technological Knowledge and Assessment Practices to Enhance Student Learning in Technology: A Two-year Classroom Study'. *Research into Science Education* 31, 1, 1-184
- Moreland, J., Jones, A., & Chambers, M., (2001) 'Enhancing student learning in technology through enhancing teacher formative interactions'. *Research Information for Teachers*, 3, 16–19.

An International Overview of Assessment Issues in Technology Education: Disentangling the influences, confusion and complexities

Newton, D. & Hurn, N. (1996) 'Teachers Assessing Design and Technology: An Effect of Curriculum Organisation'. *International Journal of Technology and Design Education*, 6, 2, 137-149

OCR (2006) *Product Design (pilot) GCSE Combines Marks scheme and report on units*. Oxford Cambridge and RSA examinations.

Petrina, S. (2000) 'Ecology of Design and Technology Education: An Enquiry into methods'. *International Journal of Technology and Design Education*, 10, 3, 200-237.

Pollit, A, & Elliot, G. (2003) *Finding a proper role for human judgement in the examination system* accessed on 15/02/07 from: www.ucl-research.cam.ac.uk/nferencepapers/QCA2003APGE02.pdf.

Popham, J. (1994) 'The Instructional Consequences of Criterion-Referenced Clarity'. *Educational Measurement: Issues and Practice*, 13, 4 : 15-18,30.

Pintrich, P. R. & Schunk, D. H. (2002) *Motivation in Education: Theory, research and Applications*. Columbus. OH Merrill-Prentice Hall.

Preece, P.F.W. and Skinner, M.C. (1999) 'The national assessment in science at Key Stage 3 in England and Wales and its impact on teaching and learning'. *Assessment in Education*, 6,1:11-26

Qualifications and Curriculum Authority (2005) *Design and Technology 2004/2005 annual report on curriculum and assessment*. QCA

Reddy V, Ankiewicz, P., de Swardt, E., & Gross, E. (2003) 'The Essential Features of Technology and Technology Education: A Conceptual Framework for the Development of OBE (Outcomes Based Education) Related Programmes in Technology Education'. *International Journal of Technology and Design Education*, 13, 1, 27-45.

Ropohl, G. (1997) 'Knowledge Types in Technology'. *International Journal of Technology and Design Education*, 7, 1&2: 65-71.

Schechter, B. (1998) 'The local benefits and burdens of large scale portfolio assessment'. *Assessment in Education*, 5, 3, 335-352 .

Shen, C. (2002) 'Revisiting the relationship between students' achievement and self perception of competence and rigour of mathematics and science'. *Assessment in Education*, 7,2, 237-254

Scottish Consultative Council on The Curriculum(1996) *Technology Education: A statement of position* Dundee SCCC

Schon, D. (1987) *Educating the reflective practitioner: Toward a new design for teaching and learning in the professions*. San Fransisco: Jossey-Bass.

Shield, G. (1996) 'Learning technology through a process approach: The implementation of curriculum innovation through the pragmatic interventions of the teacher'. *International Journal of Technology and Design Education*, 6,1, 1-14

Stables, K. & Kimbell, R. (2000), *The unpickled portfolio: pioneering performance assessment in design and technology*. In R. Kimbell (Ed.), *Design and Technology International Millennium Conference* (pp. 195-202). Wellesbourne: The Design and Technology Association..

Stein, S., McRobbie, C., Campbell J., & Ginns, I. (2002) 'Implications of Missed Opportunities for Learning and Assessment in Design and Technology Education'. *Teaching and Teacher Education*, 18, 1, 35-49

Welch, M., Barlex, D. & Lim, H. (2000) 'Sketching; Friend or foe to the novice designer'. *International Journal of Technology and Design Education*, 10, 3, 125-148

Welch, M. (2001) *Assessment in Technology Education: What, Why and How* Proceedings of the second AAAS Technology Education Research Conference accessed on 06/11/2006 from www.project2061.org/cgi-bin/print.pl