

**A CURRICULUM FOR EXCELLENCE  
REVIEW OF RESEARCH LITERATURE**

**DESIGN AND TECHNOLOGY EDUCATION**

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**Introduction**

Evidence suggests that there is a common concern that the aspirations of the rationales for Technology Education curricula are not yet making significant impact in classrooms (e.g. Kimbell, 2000; McLaren, 2003a; McCormick, 2004a; Barlex, 2000). The various international guidelines and national curricula indicate a consensus as to purpose and potential contribution such learning experiences offer. The most recent revisions of relevant curricular advice (e.g. in Scotland, England, New Zealand, South Australia and Sweden) purport that Technology Education is about preparing young people to be creative, productive and informed citizens, able to cope with uncertainty and with the confidence to identify problems and take subsequent, appropriate actions.

Words and phrases such as creativity, design centred approaches, higher order thinking, environmental awareness and sustainability, enterprise, ethical values, etc. have not been translated into the core of the pedagogy common place in implementation. Many countries continue to report of the difficulties of managing the required paradigm shift in overall value and purpose that the new curricula strive for and implementing the associated pedagogical changes that are required to facilitate this (e.g. Sanders, 2001; Jones and Moreland, 2004, De Miranda , 2004; Davies, T, 2000; Davies D, 2003).

The overarching aims of supporting the technologically capable citizen, developing their conceptual understanding and attitudes seem to continue to be overlooked in favour of procedural mimicking, development of psycho-motor skills of the traditional instructional mode of previous curricula. Technology Education displays a clear dichotomy of opinion about the purposes, focus and values among the teachers. Therefore, there is confusion with regard to teaching programmes and pedagogy. There are many examples of the continuation of the industrial arts and vocational–technical education methods where teaching centres around tools, processes, equipment and projects in various media of food, textiles, wood, metal, plastic (Dakers and Dow, 2004; Hansen and Lovedahl, 2004; Sanders, 2001).

It seems that teachers may, on a personal level, appreciate social-constructivism, cognitive theories such as meta-cognition, concept mapping, reflection, situated learning, cognitive apprenticeship, collaborative and pupil-centred approaches, cooperative learning, socially distributed expertise, student as designer, and project-based learning and accept how essential such theories and practices are in learning. However, for the most part, very few integrate such theories into their programmes (Rowell, 2002; McCormick, 2004a; Brown, D. 2001; Folkestad and DeMiranda, 2000; Sanders, 2001). As a consequence, Technology Education has difficulty in

establishing itself as 'an equal partner in general education' and gaining recognition of its value in education for the 21<sup>st</sup> century (De Miranda, 2004).

### **Characteristics of Effective Technology Education**

*Core 'concepts' : creativity; authenticity; decision making; environmental, economical, technical, ethical and social values; contextualised/situated learning; problem and project based learning.*

Distortions can occur where teacher knowledge of the 'subject' is limited as this is related directly to adopted pedagogy. The influence a teacher's personal understanding of the nature and purpose of technology education, and their own previous experience of technology, has been noted to have a pronounced impact on their personal pedagogical content knowledge. This has in turn an influence on what they as teacher highlight as important and on the overall effectiveness of their teaching (e.g. Davies, D. 2003; Jones and Moreland, 2004). Resources and frameworks used as support mechanisms to increase teacher confidence and capability have yielded results in terms of enabling teachers to develop meaningful, focused, learning activities, appropriate to the topic and to the needs of the students. Such resources should aid the conceptualizing and planning units of work in technology and create frameworks that may help structure thinking for authentic classroom planning and sequencing of lessons or learning experiences (Stein, McRobbie and Ginns, 2001; Ginns, McRobbie and Stein 2003; Barlex, 2002; Givens, 2000).

Characteristics or features of pedagogical content knowledge that are identified as important for effective teaching and learning in technology can be summarised as:

- enhanced teacher knowledge about technology, including the nature of technology, areas of technology and specific technological knowledge;
- changes in pedagogical approaches including conceptual, procedural and technological approaches; enhanced teacher student interaction;
- knowledge of relevant technology curriculum goals and objectives and refinement of appropriate learning outcomes and planning frameworks;
- knowledge of student learning progress and negotiated intervention;
- specific teaching and assessment practices of technology leading to improved teacher confidence;
- appreciation of the context setting for, and role of, technological problem solving and critical decision making;
- and an appropriate and creative classroom environment with appropriate resources.

Effective classroom technology education takes a socio-cultural view of learning where human mental processes are situated within their historical, cultural and institutional setting.

### **Creativity and Design in Technology Education**

The pedagogy of design is about learning how to think, reflect and act. There is too often an imbalance in programmes of work with reflective-active aspects under represented, yet dealing with complexities and arriving at a solution requires such aspects to be given weight (Barlex and Welch, 2001). Designing lags behind making,

because pupils are either not introduced to a sufficient wide range of designing strategies or are not taught to use them effectively.

Warner (2003) emphasises that teaching design involves more than instruction on manipulative skills of using tools and making drawings. Various ways of fostering creativity are required, using various starting points, strategies and processes to cater for the various learning styles and preferences (Howard-Jones, 2002; Hill and Anning, 2001; Murphy and Hennessy, 2001; Turnbull, 2002; Atkinson, 2000). For example, Howard-Jones (2002) states 'The generative thought processes that give rise to original ideas appear to be very different to those analytical thought processes required to refine them. Thus, design and technology provides a unique challenge to the teacher, since he/she must be able to support and encourage both types of thinking in the classroom.'

The role of 3-D sketch modelling is important in helping learners to: articulate, express and manipulate ideas; think things through in concrete terms, share and talk about them to others including the teacher; and have 'conversations' with one's self. Therefore, this has value in terms of progression and emotional satisfaction. The benefits of reiterative, sketch modelling as opposed to the linear sequence of 'draw then make' is that cognitive modelling is a fundamental and useful mental process by which to conceive of the future. However, students are reluctant to accept that 3-D sketch modelling and rough sketches will do the job. They, as are many teachers, are keen to see finished, beautiful looking outcomes and seem to discard the ideas if not well presented, no matter how well conceived (Smith, Brochocka and Baynes, 2001, Welch, Barlex and Limm, 2000). Students and teachers have to be coaxed to appreciate the role that modelling serves in the process and accept it as part of the creativity and risk taking culture (Kimbell, 2004). The interaction between new technologies, such as ICT, CAD, CAD/CAM and RP, and the modelling process requires attention in order to resolve the rising tensions between concrete and virtual modes of modelling (e.g. McCormick, 2004a).

Design and Technology involves teaching learners to use their minds and hands to solve problems. There is evidence (Walmsley, 2003; Leung, 2000) to indicate that design-based technology education classes develop higher-order thinking skills. This makes demands on teachers to adopt a pedagogy that may be outside their existing personal frame of reference. Equate design-based education with problem based, experiential, pupil centred learning and teachers may be more receptive to acknowledging the methodology. Mindful of their initial 'teacher training', teachers attempt to balance learner-centred instruction while allowing for greater student autonomy and control. Molwane (2001) analysed a range of teaching styles and how teacher time was spent. He observed interactions between teacher and students (e.g. directed class input compared with supporting individuals) and related these to assessment practices. Results concur with Walmsley (2003) and others (e.g. HMIE 1999; McNair, Daliat and Clarke, 2000) indicating that teachers may be emphasizing doing over thinking, making meaning and planning, passive over active learning.

A four year study (Autio and Hansen, 2002) compared teaching methods of instructional, technical craft education with a project based, problem solving technology education to ascertain learning and technical knowledge, motor skills, and emotional engagement/attitude. The study, conducted with various grades of school

children, boys and girls, examined whether such learning could be measured and which method was more effective. It concluded that the value of psychomotor exercises should not be underestimated; there is a lot of thinking involved and with every thought and action there is emotion. However, through a combined technical craft and project based technology education, a combination of all three involving cleverness, competence and emotional will can be achieved. A balanced curriculum should be valued in pedagogic terms (Autio and Hansen, 2002).

Achieving a balance between procedural knowledge related to technological activity and conceptual knowledge related to content and processes of design, problem solving, systems approach, invention, and manufacturing ought to enable teachers to meet the various learning styles of all students (e.g. Barlex, 2000; McCormick, 2004b; Williams, 2000; Newcomb, 2000).

Although the potential is recognised, there are also cautionary notes that a design-based pedagogy as the only method for Technology Education could be detrimental to over-arching aims and aspirations. Development and implementation of flawed models of the design process is influencing teacher's classroom practices and continued adherence to such models is having a detrimental impact on children's learning in technology. Clearly a wider range of pedagogical approaches is required (Mawson, 2003; Fatt and Joo, 2001). This view is supported by France and Davies (2001) who stress that technology education provides an 'opportunity for societal issues to have equal space with technological capability and knowledge' and urge consideration of teaching approaches to engage students in issue-based learning beyond the design process mantra that has been adopted.

The contribution of social learning, collaboration, talk and gesture toward technological development is recognised in the early years (Rowell, 2002; Carr, 2000; Twyford and Järvinen, 2000; Davies, L. 2000; Newcomb, 2004) and yet these features seem to become less apparent as students continue through their schooling. Koutsides (2001) is concerned that valuable pedagogy such as cooperative learning is not being exploited more fully in design and technology (DandT) contexts. Evidence indicates that it improves achievement, retention and creates positive relationships with others as they work together on common tasks in defined roles. He argues that DandT is well placed for involving procedural problem solving activities where cooperative learning between peers relates to physical manipulation and feedback integrating concrete modes of learning, graphic representation playing an important mediating role.

### **Influences on pedagogy**

Assessment seems to be an inhibiting factor in developing the notion of creativity, innovation, enterprise and risk taking as core aspects of technology education. There is evidence that teachers and learners are playing safe in order to be rewarded (Atkinson 2000; Kimbell, 2000, 2003; Barlex, 2000). The requirements of exam boards, league tables and performance scales combine to result in an ethos that is not supportive of a pedagogy that facilitates and actively encourages risk taking in the classroom. The 'look beautiful' folio and final product (Stables, Sprake and Kimbell, 2002, p105) is crushing out real design and leading to what Lave (1988) calls a 'vener of accomplishment'. School-based designing has, as a result, become characterised by a lonely, linear, un-spontaneous, laboured process, rather than the

quick thinking, instant 'trying things out', 'thinking things through', iterative process of design ethic with practical engagement embedded throughout (Murphy and Hennessy, 2001; McCormick and Murphy, 1996).

Teachers are good at making holistic judgements and the atomisation of assessment is seen to be having profound impacts of the development of effective design based pedagogy.(Barlex, 2000) Summative assessment instruments, tools and strategies for, and of, design thinking, innovation and process rather than product have been a focus of research for a number of years and continue to be so. Progress has been made but much has yet to be resolved.(Kimbell, 2004) [Work is currently underway to address issues of transition between primary and secondary schools in Scotland through formative assessment approaches embedded in to creativity and enterprise in design and technology education.]

Jones and Moreland (2000) examined emerging assessment practices in relation to the implementation of the technology education and noted that 'the existing subcultures in schools, teachers' subject expertise and the school wide policies impacted on the teachers' assessment practices.' Assessment was often seen in terms of social and managerial aspects such as teamwork, turn-taking and information skills, rather than procedural and conceptual aspects of technological capability. The formative assessment interactions distorted the learning and regularly focused on more generic skills rather than student technological understanding.

Others have explored the limitations of assessment and the influence it has on pedagogy. These studies serve to highlight the importance of developing teacher expertise in three dimensions of knowledge about the subject, knowledge in the subject and general pedagogical knowledge.

### **Enjoyment, motivation and authenticity**

From the available research evidence, the general reaction of pupils in most year groups to the 'subject' of design and technology is positive (e.g. Hughes, 2001; Twyford and Burden, 2000). Primary students overwhelmingly stated DandT was fun and that they enjoyed it because they were making things, they had some ownership, were allowed to talk. This became more pronounced when they offered a contrast between DandT and other subjects. Consensus was less pronounced when students were asked if DandT was work. It seems that something enjoyable and affording pleasure is less likely to be considered as work and as such has less significance in context of 'proper' subjects, particularly at transition to secondary school (Twyford and Burden, 2000). There is no direct relationship between enjoyment and perceived degree of difficulty. Aspects and projects considered difficult are still enjoyed by students and some projects considered easy are not enjoyed. More research is required to explore the relationship more closely, but it serves to indicate that pupils do not want necessarily to enjoy every project. Evaluation and written work were generally 'not enjoyed' and yet considered 'easy'. This response became more pronounced as students 'progressed'. A curriculum area that is essentially a practical subject needs to adopt appropriate teaching strategies to approach such essential aspects of learning and cannot avoid them just because children prefer the practical aspects. As students move through the secondary school the disappointment in not having a finished, tangible product becomes less marked (Hughes, 2001). This implies that students

themselves may recognise the value of virtual experiences of computer control, computer modelling and simulation, construction kits, and conceptual design whilst the core of the subject remains 'making things'.

The appropriateness of what is taught in school DandT and how it effects motivation to learn is of central to the restructuring of the syllabus. There is value in activity for activity's sake and the absorption of learning through setting out to achieve a goal that they have set for themselves. The 'act of creation' is held important and links directly to Bruner's three modes of learning, by action, image and by symbol.

The role of 'authenticity' in technology education has been recognised as a powerful motivator for a long time (e.g. McCormick, Murphy and Hennessey, 1994; Turnbull, 2002). Teachers have been urged to consider the nature and context of the task in order to motivate and engage the learner. By involving students in activities that are authentic to technological practice or real world technology, teachers are able to provide stimulating and relevant learning for students. It is, however, important to distinguish the nature of the authenticity by considering for whom the task is authentic and considering authenticity with regard to the nature of technological practice in the world of industry and commerce.

The relationship between the 'school-situated design' elements of Technology Education and industrial practice and design consultancies has been the focus of research on the search for authenticity in methods and processes, which might inform developments at the core of Technology Education. Issues of portfolio creation (Barlex and Welch 2004), use of modelling (Smith, Brochocka and Baynes, 2001; Welch, Barlex and Limm, 2000; Kimbell, 2003, 2004 ) and drawing (Hope, 2000, 2005) for various phases of communication, teamwork (Hill and Anning, 2001; Maymon, Harel and Barak, 1999) all inform the adopted teaching approaches. However, in order to promote such authentic experiences, technological tasks need to be devised such that the pupils are afforded degrees of freedom and decision-making that many teachers are less than comfortable with. (Hill and Smith, 2005)

Technology education approached through authentic project based learning can significantly contribute towards increasing motivation, initiative, problem solving, engaging with and applying knowledge (including engineering knowledge) and independence in procedure and design making (Doppelt and Barak, 2002; Verner and Hershko, 2003; Barak, 2004). Research indicates that through authentic situated learning activities greater interest in technology can be developed in, stereotypically, the less inclined, e.g. 'low-achievers' and girls (e.g. Volk, Yip and Lo, 2003; Mammes, 2004). In addition to increasing attainment, scientific-technological problem based learning, as a method of imparting thinking competencies and creating flexible learning environments, has been shown to elevate pupils' self-image at all levels and achieved significant affective learning (Doppelt, 2003; Moriyama, Satou, and King, 2002).

Enhanced learning can be achieved by exploiting opportunities offered by integrated, project-based approaches, e.g. maths, science and technology (Venville,Wallace, Rennie and Malone, 2000; Ginns, Norton and McRobbie, 2005; Zubrowski, 2002).

Resources and frameworks used as support mechanisms to increase teacher confidence and capability have yielded results in terms of enabling teachers to develop meaningful, focused, learning activities appropriate to the topic and to the needs of the students. Such resources should aid the conceptualizing and planning units of work in technology and create frameworks that may help structure thinking for authentic classroom planning and sequencing of lessons or learning experiences (Stein, McRobbie and Ginns, 2001; Ginns, McRobbie and Stein 2003; Barlex, 2002, Givens, 2000).

## **Progression**

Generally, there is a limited, divided, inconclusive body of research on progression in design and technology education and even less on technological capability (e.g. Solomon and Hall, 1996; Kimbell, 1994). Solomon and Hall (1996) dispute Kimbell's notion of a non-linear pathway of progression that is unique to each individual learner. They argue that cognitive psychology provides evidence that a structured progression is possible. This evidence indicates that primary school children can progress better at technology with regard to their development of autonomy and level of discussion on matters technological and are more self directed (despite the reported lack of self confidence of primary school teachers). Primary school technology, it is argued, is better at contextualising tasks and using cross-disciplinary approaches, all of which are beneficial to cognitive development. Secondary pupils, being more teacher dependent, particularly in their first high school year, become de-skilled learners and regress in technological capability whilst developing very specific craft skills relating to various media.

Generally, elements of progression can be classified into broad categories:

- Communicating ideas, i.e. drawing, talking, gesturing, modelling and manufacturing. There are many benefits of modelling reiteratively, as opposed to adopting a linear sequence of drawing first and then making, which is all too common in current pedagogy. Such experiences of concrete modes of thinking develop cognitive modelling as a fundamental and useful mental process to conceive of the future in terms of ideas, places and products.
- Value judgements and a growing sensitivity towards others people's needs, making informed judgments, critiquing and evaluating.
- Conceptual understanding, specific knowledge and skills
- Analysing, 'spark finding', 'spark generation', 'growing and proving ideas' (Kimbell, 2003, 2004).

Conceptual knowledge and skills vary with the context of the problem or scenario and some argue these are learned on a need-to-know basis (e.g. Kimbell 1994). However, there is debate as to what constitutes technological content and the technological knowledge domain and, therefore, progression in concepts and knowledge is lively and has been ongoing since the conception of technology as a curriculum area. (Note: this is beyond the parameters of this review and would require extending the review to concepts and knowledge domains in science and art concurrently with that of technology education.)

It is argued that the key technological cognitive skills are yet to be fully identified. However, spatial ability is acknowledged as one of the key attributes of progression.

Fundamental to a design and technology education is the ability to think in terms of shape, form, space, motion and rotation; create mental models; visualise; work in 3-D and 2-D. This leads to skills in drawing and perceptions of graphic representation, i.e. the learned skills of 'graphicy' such as foreshortening, perspective, diagrams, etc which are known to be culturally dependent. Progression in technology is also inter-related to communication skills. In order to progress in terms of technological capability, essential aspects of cognitive development must include the acquisition of an appropriate and expanding range of vocabulary (spoken, physical and graphic) and a modelling repertoire (in 2D and 3D). Yet drawing seems to have low status compared with reading and writing in the curriculum. Structured input and directed teaching is needed to progress the skills of communication, drawing and modelling and to develop the ability to construct internal images which behave as finished artefacts (e.g. Hope, 2005; Smith, Brochocka and Baynes, 2001; Welch, Barlex and Limm, 2000).

Hope (2000, 2005) has explored the role of drawings as used by young children engaged in design activity and classified the drawing type by age and experience. She concludes that there is no linear sequence clearly identified, but generally the earlier years do see the drawing as a picture, a static pictorial image, whereas the older pupils see it as something that represents ideas that can change and develop. There were also those who provided interactive features. Hope cautions that teachers 'cannot rely on children's ability to produce pictures which become more representational with age...' (2000, p113). There are those that will use the drawing to progress their ideas and there will be those who re-draw to make it tidier, to improve the drawing but not the idea. The ability to turn thought and idea into drawn form and use the result for action is a sophisticated one and an approach to scaffold such learning is required as part of the learning strategies of the developing mind.

Craft knowledge is most effectively learned by doing, through related craft skills (material and media related). Such learning is only possible by doing and cannot easily be talked about. These are tacit skills learned by ordered mimicry, through apprenticeship and practice. The know-how and the physical 'how to do' is procedural and as such is learned by exposition and demonstration and hands-on practice rather than described or analysed. This includes any 3-dimensional modelling that requires physical manipulation of materials, tools and equipment.

Evaluation is the capability to make informed comparisons between an initial design drawing and the proposed resolution arrived at. This is an exercise in meta-cognition. The process demands that pupils recognise what they have learned by trying to carry out their first plans, identifying and articulating reasons for changes. This reviewing and testing against a client's brief is fundamental to technological learning. A higher level of understanding may be achieved if time is allowed for rethinking and reflection on actions taken and outcomes produced to date. When students engage with a redesign of their "completed projects", there is increased opportunity to develop knowledge and understanding that hitherto was not made explicit. Current practice tends not to recognise the value of evaluation and modification cycles nor that the developed reflective skills will aid decision-making and the development of higher order thinking skills (Mioduser, 2002 ; Neumann, 2003).

Although no empirical research has been conducted, it is believed that evaluation of, and reflection on, systems, artefacts and environments of everyday life of their own culture and time, and that of other cultures and times, can enable students to progress in their appreciation of the complexity of values and judgements that impact on society and the environment ( McLaren, 2003).

A longitudinal study following a group of students through seven years of primary school design and technology input and engagement in technological activity, initially indicated that the learners were more creative, better at modifying designs and more able to develop their own ideas than those who had not had the experience (Brown, 2001). The learners seemed to have greater appreciation of stability, better conceptual understanding and working knowledge of mechanical and electronic control and were more comfortable using the processes of designing. When 'revisited' after a 4-year gap, the study group students had stronger memories of primary school Design and Technology than they had of lower secondary school. The students themselves were readily able to identify the benefits of their primary school experience and noted that there was no 'hands on' elsewhere in the curriculum. They felt equipped to persevere, cope with the future and had the required skills and attitudes to proceed, make choices and have confidence in their actions. Interestingly, the study group students did not fall into the stereotypically unbalanced gender patterns of GCSE choices. Similar findings have been noted by others (e.g. Foster and Wright, 2001).

*Note* Teacher capability and teacher education (initial and continuing professional development, primary and secondary) is beyond the immediate scope of this report. It does however form a very large part of the body of recent research and is seen to be an obstacle to realising and exploiting fully the potential of technology education (Banks, 2004; Bybee, 2003; Ginns, Stein and McRobbie, 2000; Harwood and Compton, 2003; McRobbie, Ginns and Stein 2002; Dakers and Dow, 2001; McLaren, 2003c). Much can be achieved by investment in developing teachers perception, capability and philosophical understandings of technology education (e.g. Harwood and Compton, 2003; Jones and Moreland, 2004).

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