

Underpinning The STEM Agenda Through Technological Textiles? An exploration of design technology teachers' attitudes

Chris Hughes, PhD student, Department of Education Research, Lancaster University
Dawne Bell, Senior Lecturer, David Wooff, Senior Lecturer, Edge Hill University

Abstract

This paper discusses ongoing research into the role of design and technology education in emerging post industrial economies. Previous work (Hughes et al., 2010) focused on the changing characteristics of textiles technology in modern times and discussed how this could inform a design and technology curriculum related to the needs of a modern textile technology workforce. This current paper reports on the second stage of the grounded theory programme in which theoretically sampled data from the first phase provides the direction and purpose for the work presented here. Within this context, this research explores practising teachers' perceptions of textile technology associated with the emergent STEM agenda. Data gathered supports the view that technological aspects of design and technology closely linked to the STEM agenda are needed to provide a firm foundation for the design aspects of the subject. Without a STEM focus, the subject may lose its hard won importance in the UK schools and colleges' curriculum. This is especially the case in an economic climate in which curriculum design stakeholders may be forced to review the content of the national curriculum across all key stages as a whole.

Key words

STEM, textiles technology, design and technology pedagogy, teachers' attitudes, constructivist grounded theory, theories-in-use

Introduction and context of the study

This paper questions the nature of design and technology in the UK schools' curriculum. The work presented forms part of ongoing research into the role of design and technology in emerging post industrial economies, and argues the case for maintaining a STEM (Science, Technology, Engineering and Mathematics) focus to ensure its status in an era of political and economic uncertainty. Research is supported by empirical work into textile technology teachers' perceptions of STEM and our findings are discussed in terms of the following:

- (i) the current economic landscape and how this may affect the structure of the schools' curriculum;
- (ii) the probable re-emergence of manufacturing industry as a catalyst for recovery and growth in the UK economy;
- (iii) how current economic issues may affect pupils' academic choices at the school, college and university level.

Previous work (Hughes et al., 2010) argues that textile technology is an essential subject to introduce pupils to the types of technology encountered in modern industrial and business environments. However, it is suggested that in order for the subject to become applicable to a modern school curriculum it should retain a technological focus and that the technological features of the subject should be tightly coupled to the design function. For example, the subject could combine design creativity, knowhow and application with an understanding of textile issues such as needle heating and seam pucker, the mechanics of the fabric/machine interface, the effects of automated equipment on design decisions and how advances in operations management may affect design thinking.

The research methodology selected for the programme is constructivist grounded theory (Charmaz, 2005, 2006) in which theoretical sampling, memo-writing and concurrent data gathering and analysis have been used to enter the research field, provide direction for the study and help build an understanding of how the realities of design and technology teaching relate to wider economic issues. This paper illustrates how we are using the research programme to develop design and technology teachers' awareness of STEM issues and encouraging them to think critically about STEM in their own curriculum delivery. This approach relates to the notion of reflexive (Finlay and Gough, 2003; Alvesson and Skoldberg, 2009), and critically oriented (Shacklock and Smyth, 1998; Murphy and Fleming, 2009) research whereby we encourage teachers to situate design and technology learning in the wider social and economic context.

Hargreaves (2003), for example, regards schools as learning organisations involving all who work in them. This provides an opportunity to understand and harness the useful professional knowledge that teachers create. Much of this knowledge is tacit and leads to 'theories-in-use' (Argyris and Schon, 1974) about educational issues. These often evolve from the teachers' day-to-day experiences. Thus, as teachers begin to explore their own 'theories-in-use' about design and technology the more they begin to use them to inform their practice. We see this as an important strategy in encouraging teachers to help shape educational direction rather than simply functioning within it.

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Design and technology and relationship to changing technological needs

This study has been carried out against a background of large scale economic cuts, resulting from the UK government's need to reduce an exceptionally high national deficit. This we believe will have consequences for design and technology education at all levels. As university fees increase it is envisaged that students will consider, much more than before, the career utility of the subjects they are studying. Furthermore, research (Independent Education, 2010) suggests that participation in higher education would fall by around 10% with a £5000 per year fee, but the fall could be as much as three times this figure if the fee increased to £7000.

Throughout the last decade, successive governments have continuously funded technologically significant subjects which contribute to the STEM agenda. Given that this focus will be passed on to stakeholders responsible for curricular developments it is likely that this in turn will affect student choice at both undergraduate and postgraduate levels. The growth of design and technology in the UK schools' curriculum has, in the main, been in response to such changing technological economic needs (Penfold, 1997). Since the early 1970s the subject has been in the vein of pedagogic and technological developments in fields such as pupil centred learning, creative thinking and matching pupils' capabilities to the essence of technological thinking (Davies, 2002) (Kimbell and Pery, 2001).

However, the rapid growth of the subject, from a predominantly hand-skills basis to one that now embraces the technological world in which we live, has led to contested views of the subject. In some educational circles there is the opinion that physics, chemistry and mathematics deserve a higher academic status than design and technology; opinion that has been explored by Lewis et al. (2007) and Barlex and Pitt (2000). This perspective is reinforced by universities who require applicants to have A Levels in science and mathematics in preference to technology for entrance onto technologically orientated courses. In so doing, these institutions privilege the epistemology of traditional scientific subjects over the skills, knowledge and understanding that design and technology provides. Providing empirical evidence to take issue with this line of argument is one purpose of this study. In particular, we seek to explore teachers' understanding of the relationships between design and technology pedagogy and STEM and how these understandings provide a critical forum to empower teachers in arguing a case for their own subject' place within an ever increasingly complex and crowded curriculum.

Our argument begins with the notion that design and technology will invariably be in a state of flux as it endeavours to keep up to date with technological and design advances in society. This is markedly different to many other subjects such as mathematics and, to a certain degree, science where subject content may not have significantly changed for a number of years. In relation to Bernstein's (1971) contested view of the curriculum, subjects such as design and technology may therefore be seen as being loosely classified and framed. For Bernstein, the schools' curriculum has been dominated by highly defined subjects with highly articulated programmes of study e.g. mathematics. He argues that status in the schools' curriculum derives from subjects having well defined and classified bodies of knowledge which largely remain consistent over time.

Design and technology has difficulty in conforming to such 'tight' criteria because of the need to embrace changes in technological development. This may help explain why design and technology teachers often have to justify its importance in their schools' curriculum when compared with the more strongly framed and classified subjects that tend to dominate educational curriculum thinking and school league tables. With this argument in mind our interest in the role and purpose of design and technology in post industrial economies has been stimulated by the need to maintain design and technology's high status as a school curriculum subject, especially in an era of potential economically driven change.

STEM implications for design and technology

There are a number of commentators that support the view that STEM should underpin aspects of design and technology UK schools' curriculum (for a concise and relevant overview see Barlex 2009) and regard design and technology as a primary contributor to the UK STEM agenda. In addition the Design and Technology Association (<http://www.data.org.uk>), have discussed the relevance of design and technology for the 21st century in providing practitioners who are expert in utilising STEM applications in high quality design and manufacturing applications. Furthermore, through design and technology young people can continue to study technological subjects which relate to the needs of a contemporary work force and experience the way in which STEM operates in the world outside school (www.schoolsscience.co.uk).

The focus for Design and Technology is on project-led work in relevant, real life contexts which stimulates creativity and problem solving. It fosters the ability to make decisions, plan a course of action and carry it out working as an individual and as a member of a team to tackle

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technological problems. Young people can use learning from across the curriculum to enhance this decision-making and at the same time improve their understanding of other subjects. In his work Barlex (2007) advocates that to maintain its influence, design and technology will have to demonstrate the effective use of science and mathematics within teaching and learning of design and technology itself.

Textile technology and design and technology

Initial research focused on textile technology and its relationship to the STEM agenda because of the significance textile technologies have had on the economic, social and industrial structure of the UK. Industry has had to change due to STEM driven market forces especially in the context of changes in niche marketing (Parrish et al., 2006; Hines and Bruce, 2007), increased globalisation (Tyler, 2003; Kaur and Gale, 2004), product and process innovations (Forza and Vinelli, 1997; Catling and Rothwell, 2002; Abernathy et al., 1999) and changing workforce needs (Lowson et al., 2002; Tyler, 1989).

Central to these changes have been rapid advances in the use of microprocessor technologies, in particular Computer Aided Design (CAD) and Computer Aided Manufacturing (CAM), in all areas of the textile industry. Clothing machine manufacturers, for example, have introduced a number of innovations including tension free stitching with little or no intervention from the operator, new and improved fabric feeding and machines that operate with various degrees of automation (Hughes and Hines 1993); Cooklin et al., 2006; McLoughlin and Hayes, 2008; Collier, 1990).

With increased automation there is a need for textile technologists, whether involved with design or product 'make up', to predict and understand how fabrics will behave, cut and sew during operations with little or no operator intervention. It is, therefore, important for all textile practitioners to understand such technologies in both design and manufacture and this has implications for education and curriculum design.

Grounded theory methodology

Constructivist grounded theory methodology was selected because its concurrent data gathering and analysis approach allows outcomes from each phase of the programme to set the purpose and direction of subsequent phases. Thus, this research has been informed by findings from previous work and its relationship to modern industrial design practices (Hughes et al., 2010).

Central to the methodology is the constant comparison of conceptual insights that emerge, both within and between data, during analysis, and where theoretical sampling takes place concurrently with data analysis as data understanding becomes apparent. Data can be selectively collected and the properties identified as analysis unfolds. The theoretical sampling procedure for this research follows the following strategy:

- generation of analytical concepts within the data;
- constantly comparing concepts to examine links between data sets;
- generating theoretical constructs that describe and characterise elements of the data;
- constructing explanations that help describe the work under investigation.

Theoretical sampling helped keep data gathering and analysis closely related to the realities of design and technology teaching and learning (Pandit, 1996; Elliot and Lazenbatt, 2005) adding validity and reliability to the research outcomes (Cresswell 1998; Seale 2003).

In its original form (Glasser and Strauss, 1967), grounded theory emphasised concept generation from data without recourse to prior theoretical knowledge i.e. primarily using an inductive methodology. Charmaz (2006) advocates an abductive methodology which combines both inductive and deductive theory generating procedures. When doing so, theoretical frameworks derived from literature and other sources can be used to orientate research design and analysis, and can sensitise the researcher to issues within the data set. Strauss and Corbin (1998) and Corbin and Strauss (2008), discuss how theory can be part of a pragmatic and structured approach to theory building whereby the researcher is encouraged to mix grounded theory with other methodologies and apply existing insights and experiences to the subject matter. Charmaz (2006) describes how theoretical concepts are constructed, rather than being 'discovered', and how the researcher's biography and reflexive relationship to data will influence research outcomes. Data for this element of the work has been generated from the following sources:

- semi-structured interviews;
- teacher focus group dialogue;
- email conversations.

Respondents were chosen for their abilities to provide rich (Geertz 1973) and varied accounts of the design and technology experiences and how these relate to STEM. Analysis focused on how theoretical aspects of the study relate to what is happening in practice and represent some of the complexities found in the schools' environment.

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Data gathering and analysis

Face to face interviews were carried out with eight practising teachers. The key questions focused on the respondents:

- perspectives of STEM in relation to their textile technology teaching;
- engagement with the research and how this has informed practice (in relation to STEM).

In addition, two focus group sessions gained collective dialogue about the teachers' experience. All teachers in the sample (n=8) took part in focus group work. Kitzinger (1995) sees this number of teachers to be an ideal number for effective focus group discussions and outcomes. The aim was to study the processes whereby meaning was collectively constructed within the group (Bryman 2004). Particular attention was paid to how respondents engaged with elements of dialogue and which opinions seemed to be common amongst the participants.

During the sessions, participants were encouraged to talk to one another, exchange anecdotes, comment on each other's point of view and to discuss issues which were important to them. Prior to each session the aims of the work were explained. Participants were assured that all dialogue would remain confidential and that their identities would remain anonymous.

Ethical practices described by BERA (2004) were followed during interviewing. These include the rights of respondents to refuse any materials to be published in this paper if they thought necessary and that anonymity of institutions and people would be observed. As such, names of respondents and workplaces have been changed.

Selected findings

Four vignettes, built up from elements of research data, have been selected to present aspects of the findings as a whole. The vignettes briefly describe the biographical background of each respondent, their experiences and their perceptions of and use of STEM applications in their school settings.

Vignette 1: Anne (A teacher of electronics and textiles based in an 11-18 Specialist Science College in North West of England)

Anne has just embarked upon her fourth year of teaching and has been involved in the organisation and delivery of the school's STEM club since taking up her post as a newly qualified teacher. Anne studied for a first degree in surface textiles. During her PGCE year, she developed some electronics expertise and is now able to confidently teach

the subject up to Key Stage 4. Anne has developed a number of textile projects which incorporate basic electronics and smart materials.

During interviewing, Anne commented that she "was very keen on STEM work...[and]...saw it as a challenge...I feel that the electronics work I do really gets the pupils thinking about some aspects of technology...I feel that combining some of my electronic knowledge with the textiles I do helps the children think about design in much more broader ways."

The STEM club runs after school one evening a week and is open to all pupils at Key Stage 3. The club had fourteen members at the time the interview took place, and is staffed by teachers from the science and design and technology disciplines; a strategy which Anne believes "...allows both departments to work together."

During both face-to-face interviewing and her contribution to the focus group discussions, Anne stressed the importance of underpinning her work with STEM applications. She described a mini project she was doing with the pupils in the STEM club in which she "...used electronics and created 'wearable' electronic garments."

She also commented that her science colleague was "...excited about this application of electronics..."

Anne sees clear links between textiles and STEM. For Anne, textiles is "...one of the best areas of design and technology to cover STEM...through any textile lesson you can teach the children all about sizes, measurements and marking out...and then there's the science behind the materials you use."

Vignette 2: Susan (Head of Department of an 11-16 secondary school with Technology College Status in Lancashire, UK)

Susan participated in the previous study (Hughes et al., 2010) and has been working to incorporate STEM into her lessons. She has a 'self-taught' knowledge of textiles and is very keen to develop and deliver technological textiles in the school she is working at.

Susan joined the school eight years ago straight from teacher training college. She had previously worked in industry. Susan's degree focused on resistant materials and product design and, by her own admission, a "...very small amount of textiles..." Susan has worked hard over the last few years to update her "...knowledge in the textile technology area and has been on a small number courses..." but most of the work has been "...self taught."

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Three years ago, the most experienced textile teacher in the school retired. This teacher had spent a number of years building up a "...very strong textile base..." and during this time had gained good results in the area. The textile classes being run at the time were three GCSE (AQA) groups and an A Level group.

At this point in time, it became evident to Susan that her limited knowledge of the area combined with a strategic need to rationalise some of courses within the school "...forced her to make the textiles course more art focused..." The textiles courses within the school are now shared between the Art and, Design and Technology Departments. The topics taught have moved away from "...the more technical aspects of the subject...for example automatic sewing machining and fabric testing...to projects which include more [textile] embellishing..."

As part of the previous research phase, Susan discussed that one of the problems is that she "...struggles to find courses that will stretch her knowledge in modern, industrially based textile technical aspects...There are a lot of art based courses on offer...[but] not a lot on construction...I have a good range of equipment to teach textiles with...programmable sewing machines, heat presses and CAD equipment...but I could do with more knowledge and experience in this area...I have also been developing my own knowledge in smart and other material areas...I work in an area which has lots of good industrial examples of up to date processes...in the past I've been on visits to factories making carbon fibre weaving and one making kevlar bullet proof jackets for the army and police."

Through her participation with this study Susan has become aware of the need to update her knowledge in certain aspects of textiles, especially how it might relate to STEM. To help her update her knowledge of the area she attended a workshop on technological textiles at the '2010 North West Design and Technology festival' held at Daresbury laboratories, Warrington. Susan comments that her "...competence and confidence in relating STEM applications to her textile work increased after the workshop."

Vignette 3: Holly (Textile teacher at an 11-16 school in Greater Manchester)

In this vignette, in which some of the work has also been previously reported (Hughes, Bell and Wooff 2010), we explore the case where textiles teaching has recently moved from a design and technology department to an art department.

Holly has taught apparel oriented textiles for eight years having completed a textile technology degree and a PGCE in design and technology education. However, due to economic and resource issues at her school the decision was made to move her textile course into the Art Department.

Due to a lack of resources, Holly found it more and more difficult to cover the examination specification to the required depth. She had no CAD/CAM textile facilities in the school and there was no money available to buy such equipment, she commented that "...now or in the future. This would have had an effect on my results... and I was not really prepared to let this carry on. This limits what I can do and leads to lots of work which moves away from the sort of technical work I wanted to do."

The move to art was a "...mutual decision..." between herself and "...the Art Department..." She went on to comment that "...the Head of Art was excited about the move because the results would go up [in art] because instead of just doing pattern applications...the pupils can make what they design into a product."

This was disappointing because in the previous study (see Hughes, Bell and Wooff 2010) both Holly and the Head of Art were excited about the possibilities open to them through collaboration. However Holly was keen to point out that this scheme, based upon a multi-cultural project previously undertaken with Creative Partnerships, was their first joint project and she hopes to be able to deliver more skill based textiles next year.

Holly reports that during lessons pupils were given stimulus material and encouraged to design. Pupils were shown how to replicate their design to create a 'pattern' and whilst not all pupils did so, they were introduced to the concept of half drop repeat patterns (similar to those used in printmaking and by wallpaper designers). "If we had the equipment and a little more time it would have been interesting to assemble a garment or item using other textiles based skills. I would hope to be able to build this into the next project."

From the studies included in this paper Holly was the least confident about her contribution to STEM. Her work has clear links to maths and whilst the connections were not always explicitly made to pupils it is worth noting that with support, and some cross-curricular work with colleagues, this project has potential to reach a large number of pupils during lessons unlike those activities accessible only to pupils engaging in STEM clubs.

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Vignette 4: Claire (Recently qualified teacher in an 11-16 secondary school in Liverpool)

Claire qualified as KS2/3 teacher and has skills in all areas of design and technology. She is currently in her third year of teaching and specialises in teaching food and textiles technology. At school she also helps run the school's STEM club with two other members of staff: one from the mathematics department and the other from science.

The club has been designed for Year 9 Gifted and Able (G&A) pupils, and runs during one lunch time and sometimes an evening each week. Claire explained that "...staff involved are keen to expand the club and have plans to take pupils to Europe on an educational visit."

"A main aim of the club is to introduce to the pupils to projects which involve exploring smart materials and conducting experiments with them..." Claire explains "I came across the materials when I trained to teach and they are expensive but working with small numbers the club enables us to undertake these types of projects".

Work with smart materials included exploring the properties of smart fabrics, conductive threads, thermo and photo-chromatic pigments where "...pupils explored the properties and scientific principles behind the fabrics and threads..." and encouraged to comment on STEM principles such as "...the changes and reactions to the materials when being used, making notes on benefits and disadvantages...before considering useful applications for the technologies." Claire also comments that "sometimes it's hard to get a project that involves all elements of STEM."

Discussion and conclusion

This paper has discussed the importance of maintaining a strong STEM focus in design and technology teaching and learning for two reasons. Firstly, the need to relate many aspects of design activity to the technological, scientific and mathematical principles that affect the way products are to be made and how they will perform in service. Secondly, the need to consider the perceptions pupils and students may have of the utility of the subject in an era of economically driven change and the effect this may have on work and higher educational choices.

We argue that design and technology's ability to adapt to changes in technological and economic circumstances has been an underlying feature of the subject's role in the UK schools' curriculum over the last forty years.

A further indicator of the importance of the subject in the curriculum is its ability to relate pupils' creative capabilities

to many scientific and mathematical principles they encounter in other subject areas. Designers, for example, need to consider factors such as the way the product will be made, how design decisions will affect environmental issues and how cost implications may place constraints on the materials and processes used. Such decisions invariably involve a consideration of a range of engineering, scientific and mathematical factors that underpin these aspects of design. Using textile technology we have discussed some of these issues e.g. how material properties may affect the efficiency of garment make-up and the economic justification of using computer controlled equipment in the production process. Such insights can be transferred to other design and technology areas.

Our study highlights pockets of work being undertaken in a number of schools to address the STEM agenda and emphasise how textile technology is an effective subject to do so. However, it is also evident through our examination that within the textiles area that STEM project work sometimes occurs as a result of the extra work individual teachers do rather than curricular planning.

We have also illuminated how teacher engagement with our research has helped them question their own 'theories-in-use' about STEM issues and how critical engagement with STEM dialogue may empower teachers to become agents of change in this area. Evidence also indicates that the STEM/design and technology relationship is more likely to flourish where support from external agencies is available. This has been illustrated by STEM club funding and schools seeking to secure technology college status. However, even when funding support exists, it seems evident that success in STEM application is often attributable to the dedication, motivation and hard work of individual teachers involved, and who frequently give up their own time in addition to their timetabled working week.

The vignette discussions represent only a small sample of work currently being undertaken by teachers in schools across the North West of England. The four vignettes focus on textiles as a vehicle to deliver the STEM agenda, and it is acknowledged that there are many other excellent examples of this work in other areas of design and technology education.

One finding from this study is that whilst there is evidence of 'good practice' in many schools, teachers tend to be unsure, that they are actually addressing the STEM agenda. This suggests that, irrespective of the discipline or curriculum area within which to deliver STEM learning, its

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purpose is the most important. With this respect, feedback from the focus group discussions suggest there is need for greater guidance of what STEM entails and how STEM principles could be more transparently incorporated into lessons. The best examples of reported STEM projects were through the extra-curricular activities put on by individual teachers.

If the potential benefits of the STEM agenda are to be realised then this is an issue which should be addressed. Staff, such as Holly, must be encouraged to recognise their contribution to STEM, and others given training and the confidence to recognise and draw out all potential links to address the STEM agenda.

Whilst the authors recognise the limitations of these findings, in terms of research duration, scale and sample size, there is emerging evidence that the delivery of the STEM agenda through other curriculum areas is viable and requires significant exploration. Drawing any firm conclusions from such a small sample is difficult, but the findings presented suggest that STEM teaching and learning should permeate through all curriculum areas in the form of a National STEM Strategy.

In this context further work, in the form of a constructivist grounded theory programme, will now begin to explore design and technology teachers' understanding and application of STEM in a broader curriculum context. A focus of this work will be on how design and technology can be of value to the STEM agenda through cross-curricular applications, developing skills for life and enhancing technological problem solving within the National Curriculum. A prime aim is to provide research to support the pro design and technology STEM argument through case study evidence of good cross-curricular STEM practice.

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chughes22@fsmail.net
Belld@edgehill.ac.uk
wooffd@edgehill.ac.uk