# Technology Education: An International History

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**Abstract**

Major themes running trough the history of technology education are: moving from craft to technology education, dealing with the vocational-general education dichotomy, the relation with science education in STS and STEM, the emergence of concept learning in technology education and the contribution of technology education to the 21st Century skills.

**Keywords**

History of technology education • Craft • STS • STEM • Technological literacy • 21st Centrury skills

## Contents



Writing an international history of technology education seems like an impossible enterprise. There are many countries that have technology education, and the developments have been quite varied in different countries. In a previous

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international handbook, published by Sense Publishers, there was a special section for historical accounts for individual countries (Jones 2009). In this new handbook, a different approach will be taken. Rather than having descriptions of individual countries, some overall themes that run through the history of technology education in various countries will be taken as organizing principles for describing how technology education has emerged as a domain that more and more developed an international dimension. Due to the series of international conferences and the international journals for technology education, the exchange of ideas and information has led to a certain merger of approaches, and a lot of cross fertilization has taken place over the years.

The bird's-eye view that is offered here focuses on technology education as a school subject. Of course, teaching about technology also takes place in subjects like physics, history, economics, and the like, but here the focus will be on a distinct learning area in the curriculum that is entirely dedicated to technology. The main basis for this rough historiography is the programs of international conferences on technology education, of which the Pupils' Attitudes Towards Technology (PATT) conferences are the most long-standing series. They started in the early 1980s when many countries went through a transition from craft education to technology education and are still ongoing. The table of contents of the proceedings for those conferences form as it were a timetable of developments in technology education internationally. Of course they also form the material for a history of PATT research, but that is the focus of a different chapter in this volume.

## The Craft Origin

In most countries, technology education emerged from craft education (either as part of general or vocational education). This background throughout the history of technology education has been a plague for its reputation. Craft education is seen as a subject of low status. It is in the same realm as physical education or religious education. It is nice to have in the curriculum as it offers some "distraction" for pupils in the midst of the more "demanding" and more important subjects. In a way, that is a strange idea, because originally craft education was seen as of generally high educative value (Holdsworth 2006). Pedagogues like Comenius, Fröbel, Montessori, and Pestalozzi emphasized the importance of learning craft skills for the total development of the child. In Scandinavia, the tradition of Sloyd education was developed in the late nineteenth century by Otto Salomon in Sweden and Uno Cygnaeus in Finland. The Sloyd tradition is particularly of interest as here we also find a national-cultural dimension (Olafsson and Thorsteinsson 2009). Making traditional local or national products contributed to the child's and pupil's self-awareness as an inhabitant of a certain area of country. For some time, the Sloyd "paradigm" was influential throughout Europe, and teachers came from all over Europe to Sloyd centers such as Naas (near Gothenburg in Sweden) to learn how to teach Sloyd. Even today, Sloyd is taught in schools.

The purpose of craft and Sloyd education was learning the skills for making useful products. In the beginning, that was done by using hand tools. Later also machines entered the workshop. The machines allowed for production in larger numbers. Thus the effects of the Industrial Revolution also reached education. In some countries, that led to a shift toward "industrial arts" education. Particularly in the USA, this type of education became a fairly stable part of the school curriculum. Along with it came the foundation of a teacher association for this subject: the American Industrial Arts Association (AIAA). Typical for industrial arts in schools was that all pupils in a class would make exactly the same product. The quality of the product was the main criterion for assessing the pupils' performance in the subject. A major step forward in the development of industrial arts education in the USA was the developments of standards for that subject. A group led by Dr. William E. Dugger produced a document in the late 1970s (Dugger 1987). From those standards, and also from the influential Jackson Mills Curriculum Theory document that was published in the early 1980s, it could be read that more than craft was at stake (Starkweather 1992). Other aspects of industrial making processes, like organization and professions, were part of the curriculum. But still the making of useful products, both by hand tools and machines, remained the main activity in the workshop.

## The Vocational Versus General Discussion

Another background of technology education that has plagued its reputation throughout its history is its close ties with vocational education. In the previous section, the general formative dimension of craft education was highlighted. But there is a second perceived benefit of the learning of craft skills, which is its contribution to vocational education. The reason that this became an image problem for technology education is that vocational education in itself is seen as lower status than pre-university or pre-college education. Whether or not the origin of this is the ancient Greek preference for cognitive rather than manual labor, it is a fact that in most countries education in which cognitive skills are the primary purpose is valued more than education in which manual skills take that place. One can question if that does justice to the nature of humans, but for technology education, the association that was and often still is made to vocational education causes a lack of appreciation for that subject (Shield 2003).

In most countries, the choice between general and vocational education is not made directly after primary education, but in some countries, like in the Netherlands, it is. Pupils of ages 12 or 13 years make this choice that has an enormous impact on their future school life and beyond. The Netherlands is an extreme case to show how much technology education originally was tied to vocational rather than general education. In the Dutch curriculum, a school subject called general techniques was featured in the curriculum in the 1970s and 1980s but only in the vocational education curriculum (the name of the school type was "lower vocational education," which further decreased the perceived value of that type of education; de Vries

2003). The low status of the subject was further enhanced by the fact that there were no official attainment targets; schools in fact could give it any content they liked. In some schools, it was a woodwork or metalwork course, and in other schools, it could even be a bookkeeping course. The confusion was partially caused by the term "techniques," which can mean a clever way of doing any kind of activity (the technique of piano playing, for instance). When later, in 1993, the new subject technology was introduced in both general and vocational schools, many people saw it as a sort of continuation of the old subject general techniques, and with that the status of technology education in the Netherlands was problematic from the start.

## STS and Beyond

Another problematic issue in the history of technology education is its relation to science education. In the late 1970s, the social critique on science and technology that had emerged in the late 1960s and early 1970s began to get a foothold in education in the form of science, technology, and society education (Cheek 1992; Ratcliffe 2001). In this type of education, the social dimension of science was the main focus. It was obvious from the start of the STS movement that technology would have a prominent place, because most of what we experience in terms of socially problematic effects of science is through technological applications. At least, that was the perception in the "technology as applied science" paradigm, which at that time was still in the mainstream of thinking about the science-technology relationship, both in philosophy and in education. This same paradigm caused the whole design process with all its decision-making based on many other considerations than the use of science knowledge to remain hidden from pupils and teachers. Consequently the effect of the STS movement was that the term "technology" increased in importance in education, but the true nature of technology was still largely absent. Yet, the fact that the term "technology" suggested that now technology was dealt with in education hampered the development of a subject in which that true nature of technology was made clear. Science teachers now could easily claim that they "did" technology and that there was no need for any further attention for technology in the school curriculum. Technology had risen in status because of its association with science rather than craft but at the cost of its real character.

There were major STS projects in various countries. In England, for instance, there were two major projects, one called science in a social context (SISCON) and the other science and technology in society (SATIS). In the Netherlands, the PLON project (Project Leerplan Ontwikkeling Natuurkunde, that is, Project Curriculum Development in Physics; Eijkelhof and Kortland 1988) had an international reputation for being a well-elaborated effort to realize STS education in a very practical way. In the USA, a special association for STS education was founded: the National Association of Science, Technology, and Society (NASTS). This association was very instrumental in disseminating the idea of STS education nationwide.

Unfortunately the whole STS movement was almost entirely unrelated to technology education, for the simple reason that technology education was still in the process of getting out of the craft phase. Besides that, craft or industrial arts teachers usually did not have a background in science, which of course made contact with science education problematic anyway. A rather different approach was taken in Sweden, where social aspects of technology became an important part of the technology education curriculum, but without the dominance of science that had characterized the STS movement.

## Design

So far we have seen three problematic background factors in the history of technology education. All three are characterized by a strong reduction of the meaning of technology: either in the sense of technology being mainly handicraft work or technology being the application of scientific knowledge. Neither of these reductions contains what gradually became a core element in technology education, namely, the activity of designing. It was particularly in England and Wales that this dimension emerged as an important component of technology education. This happened in a stepwise process that is reflected in the consecutive names of the subject: craft; craft, design, and technology (CDT) (early 1980s; Penfold 1988); and finally design and technology (D&T) (late 1980s; McCormick 1993). The introduction of D&T was part of the introduction of a national curriculum, which at that time was new to that country. One of the positive aspects of the relative freedom of the previous period in which CDT could be given different content in different schools is that the best schools got every opportunity to develop excellent practice. The flipside of that coin, of course, was that poor schools would give poor content to CDT. The national curriculum provided a means for the inspectorate to maintain a certain minimum level for all schools. The position of design became stronger as the years went on. For CDT teachers, implementing design activities was often still a struggle, but by the time the transition to D&T was made, a sound position for design activities in the classroom practice had been established. The strong emphasis on design had a positive and a negative effect. The positive effect was that England and Wales became a source of inspiration for the rest of the world in the development of technology education. Whole groups of teachers came from the USA to visit schools in England and watch CDT/D&T practice. The negative effect was that the engineering council expressed doubts about the disciplinary status of the school subject, as it seemed to lack knowledge content. Later, a perceived lack of epistemological basis was again brought forward as a critique and then almost led to the change of status in lower secondary education. One of the unique features of CDT and D&T in England and Wales is that they were taught in all levels of primary and secondary education (Key Stages 1 through 4). In the 2000s, the compulsory status of D&T in KS4 was changed to an elective, and the lack of epistemological basis almost led to a similar change in KS3. Fortunately that did not happen, but it showed that the chosen bias toward design had its pros and cons.

## Technological Literacy

In the late 1980s, the social concern about science and technology, expressed in the STS movement, turned to a new terminology, namely, that of scientific and technological literacy. The transition was more than a terminological one. Scientific and technological literacy had a less "activist" association than STS had had. The term technological literacy did not only comprise the ability to critique technology, although that was definitely still an important part of it. But it also meant being able to live and work in a technological society by making responsible and sophisticated use of technology. The term became so important that in the USA a Council on Technology Teacher Education (CCTE) handbook was dedicated to this term in 1991 (edited by Dyrenfurth and Kozak; Dyrenfurth 1991). The real importance of the term in the USA (and soon also in other countries) became evident when a new set of standards was developed under the title of Standards for Technological Literacy. Again Dugger led this project, and it was executed under the umbrella of the International Technology Education Association, the former American Industrial Arts Association that had changed its name in 1985 (Dugger 2006). In the 1980s important developments had taken place in the USA that justified this name change for which the before-mentioned Jackson Mills Curriculum Theory document had laid the foundations. Technology education (this was the term that was now used for the subject) was defined in terms of technological systems in four domains: manufacturing, construction, transportation, and communication. It is clear that this approach was much closer to technology as we find it in society than the former approach in terms of industrial production and related disciplines (Foster 1994). Strategically the choice for developing Standards for Technological Literacy than for technology education was very wise. The new term suggested that technological literacy is not only a matter of one subject (technology education) but something that other subjects (like science education) could also contribute to. Another strong point in the development in the Standards for Technological Literacy was that the "blessing" of the National Academy of Engineering was sought. This Academy was a socially strong partner. The NAE had a lot of requirements before acceptance, but in the end these were all met in the final document, and the NAE agreed to support the Standards for Technological Literacy. This link to engineering would later on become even more important (see the section on "STEM").

One of the side effects of the new emphasis on technological literacy was an increased interest into the philosophy of technology. After all, to be a technologically literate person, one must at least have a proper image of what technology is and how it interacts with humans and society. This is precisely what (continental) philosophy of technology is concerned with (see ▶ Chap. 2, "Philosophy of Technology: Themes and Topics" in this volume). One of the ways to promote interaction between philosophers of technology and technology educators was to invite the philosophers as keynote presenters at technology education conferences. This happened at the Jerusalem International Science and Technology Education Conference, organized by Tamir, and later in Glasgow at the International Seminar on Design and Technology Education Research, organized by Dakers and Dow in 2007. The relation with philosophy of technology would also become more important due to a next development that emerged in the 2000s and which is the focus of the next section.

## Concept Learning

For many school subjects, there is a disciplinary canon that can be taught. For physics, for instance, this entails basic concepts like energy, force, field, current, voltage, temperature, and pressure, just to mention some of the many. Such concepts and the principles or "laws" that inform about relations between them form the disciplinary core of a subject. As long as technology education remained close to craft, such a disciplinary core had not been a real concern. Even when design became an important activity in technology education, the interest for a disciplinary core of basic concepts could remain modest (as was the critique of engineers on the curriculum in England and Wales as was described in the section on "Design"). But in some countries, concept learning had been a focus for a longer time already. Two prominent examples of such countries are the former East Germany and West Germany, later to be merged into Germany. In East Germany, as in other countries in the former Eastern communist bloc of Europe, polytechnic education was an important school subject. The reason for this was not in the least a matter of ideology. In communism, production is where the social power is, and therefore teaching about this production was seen as a core task of education, not only vocational but also general education. Although practice was often focused on the making process, in teacher education institutes, there was substantial interest in developing theories to be taught in polytechnic education. Blandow was one of the experts who did a lot of work on this (Blandow 1988). Nowadays his schemes have a strong flavor of complexity, but in the 1970s and 1980s, they were seen as important foundations for polytechnic education. Meanwhile in West Germany similar developments took place, be it with a more specific focus on systems thinking. Learning about systems, the system hierarchy, input, process, output, and feedback was at the heart of the curriculum (although here, too, often practice in classrooms was much more making oriented).

In a way, the concept of systems had also found a place in the USA curriculum (see the section on "Technological Literacy") but on a very basic level. The deeper learning of technological concepts caught on in the 2010s when research into how pupils understood systems began (e.g., in the Netherlands and in Sweden). In 2009 an international Delphi study was done by Rossouw, Hacker, and De Vries to identify the basic concepts in technology and engineering according to a panel of engineering educators, technology educators, and philosophers of technology (Rossouw et al. 2011). The outcomes of this study were used in a consecutive project led by Hacker on Engineering For All in which modules were developed for concept learning aa a primary goal. The fact that philosophers were present in the panel indicates that this concept learning development was another reason for seeking contact with this reflective discipline.

Perhaps the most extreme use of philosophy of technology to seek a conceptual basis for technology education curriculum development was found in New Zealand. In the New Zealand curriculum for technology education that was published in 2007, we find explicit references to insights from the philosophy of technology as they had been gained in the technological knowledge and nature of technology project that had been led by Vicky Compton (University of Auckland) (Compton and France 2007). She even went to dedicated philosophy of technology conferences (e.g., one in the Netherlands on the nature of technological knowledge) to speak to philosophers of technology. The New Zealand developments were also of interest because of the way various relevant actors worked together. The ministry worked with technology education researchers and teacher educators to develop a curriculum that was supported by industry and carried out by teachers who met in an active teachers' association (Technology Education New Zealand, TENZ) (Jones and Moreland 2000).

## 21st Century Skills

In the late 2000s, an old idea revived under the title of "21st century skills." These are broad and general skills that all citizens need to have and that should be learned in education. The idea was old in that skills like creativity, working together, problem-solving, presenting and communicating, and the like were already mentioned often when technology education began to emerge out of craft-like subjects. The claim was often made that technology education would be the best school subject for teaching and learning such skills. In the 1980s in (West) Germany, the term "Schlüsselqualifikationen" ("key competencies") became popular as a primary goal for technology education (Lutherdt 1995; Theuerkauf 1995). This idea was stimulated particularly by industry who realized that education could never be as up-to-date as industrial companies in terms of the latest technologies being taught and that therefore it would be more valuable if schools would concentrate on more generic skills with which the future workforce would be able to keep learning on a continuous basis. Also the industries became increasingly aware of the importance of problem-solving and communication skills for people working in business companies as the lack of these skills had often caused failures on product development and implementation in the past. For some decades, the term disappeared from the programs of technology education conferences but in the late 2000s revived in interest. Although technology educators had become more modest in their claims about what technology education could mean for these skill, it was still clear that at least potentially technology education could play a role in the teaching and learning of those skills (Pavlova 2016; Ritz and Bevins 2016). The interest in 21st century skills among technology educators can be read from, e.g., the series of articles on this topic that appeared in Children's Technology and Engineering, the primary technology education magazine that is published by the International Technology and Engineering Education Association (ITEEA; formerly the ITEA, without the E for Engineering). The National Academy of Engineering in the USA linked the promotion of 21st century skills with pre-university (K-12) engineering education. That brings us to a next issue in the historical development of technology education.

## STEM

STEM is the acronym for science, technology, engineering, and mathematics. The term began to catch on in USA politics as a result of a growing concern about the future workforce in what was called the STEM disciplines (mark the plural). In that terminology, STEM is a set of disciplines that are not necessarily connected in content or pedagogy. The term was adopted by UK politicians also. At first there was a grounded suspicion among technology educators that STEM might well be a revival of STS in which the role of technology education had been marginal (Barlex 2011). But in the UK, for instance, a serious influence of technology education was safeguarded, not in the least by the efforts of David Barlex.

STEM clearly has an attractive potential for solving some of the issues that have troubled the position of technology education in the curriculum from the start. STEM would bring technology education in the realm of science and mathematics education that are subjects with a high status from which technology education could gain. Science education has long been searching for possibilities to get rid of its abstract image among pupils, and technological applications were the answer that was exploited in STS, but never really worked because the specific characteristics that make technology attractive for pupils (design activities that allow for real ownership of pupils) mostly remained hidden. If STEM could do better than STS in that respect, it might solve both science (and mathematics) education's image problem and technology education's status problem. The challenge, however, is to find such activities that integrate S, T, E, and M in such a way that it appears a natural combination to pupils. Doing an experiment in a design activity without the outcome of the experiment having any relevance for the design is artificial and pupils have a good sense for that.

STEM also raises the question: how about the E? In primary and secondary education, we have S and M education for a long time already, and since the 1970s, we have the T also, but E is still absent in most countries' primary and secondary curricula (with some exceptions, for instance, in New South Wales, Australia). Is the E different from the T anyway? There are good reasons for answering that question with a firm "yes." Generally speaking, technology education is largely qualitative while engineering is more quantitative. In technology education, there are modeling activities, but the nature of models is never discussed as explicit as in engineering. In engineering, the focus is on the development of products, while technology education also has the consumers' perspective. And finally, engineering is primarily a specific professional domain, while technology education aims at preparing for all possible roles in society. Given these differences, STEM also has the potential to add new content on engineering compared to what technology education has offered so far.

## Looking Back to the Future

This brief history of technology education shows some of the challenges the subject has faced through times. Due to these the position of technology education in the curriculum was and still is debated in many countries. It is striking how influential, though, an international lobby for having technology education in the curriculum can be. In more than one instance (Australia, South Africa, Sweden), a call for help by a technology education colleague to his international colleagues helped to save the place of technology in the curriculum. By writing letters to governments and other decision-making organizations, colleagues from around the world were able to convince policy makers that doing away with technology education was not a good idea and certainly not in line with international developments. Still, in some countries, there is every reason for concern. Germany used to have several centers for technology education research and teacher education. Now there are few, although fortunately they are growing in influence, also due to making international connections (as, for instance, in the Centre of Excellence for Technology Education that is led by Mammes in Duisburg-Essen). In the Netherlands, there is a movement in the direction of more and more schools integrating technology into science education, which has deadly consequences for technology education in the case of schools having a weak technology education program, but seems to be beneficial for the status of technology education in the case of a strong technology education program. In Finland, technology education used to have its own inspector (for a long time that was Kananoja, who was very important for the emergence of technology education in that country; Kananoja 1988), but now there is no longer that position. Even in the UK, with its long-standing tradition in having genuine technology education in the curriculum (Wilson and Harris 2004), design and technology use to be compulsory for all stages in primary and secondary education (Key Stages 1–4), but it lost that status in KS4 and it making D&T an elective subject in KS3 was also debated (fortunately the debate was won by those in favor of keeping the compulsory status). In the USA, the position of technology education is not questioned but the struggle for status is still there. In New Zealand, the position of technology education with the new curriculum seemed inconvincible (Ferguson 2009), but the shift toward "reading, writing, and arithmetic" and to the interests of vocational education give reasons for concern. All this shows that technology educators can never sit back and relax. Governments want immediate effects of technology education on enrolment in science and engineering academic programs, even though this is an unrealistic demand for a relatively new school subject and the impossibility of proving causal relations between school subjects and academic enrolment. Such demands are never made to question the position of science or mathematics education in the curriculum. But technology education because of its short history is in a vulnerable position. That sets a challenge to technology educators. Their survival depends on their success in developing and maintaining excellent practices with sound support in high-quality educational research. Such a stimulus perhaps is a blessing rather than a curse. But it certainly provides strong motivation to work on constant improvement of technology education, both in research effort and in curriculum development. Hopefully in due time, there will be a second *International Handbook of Technology Education* with a new chapter in the history of technology education that will show that technology education has been able to overcome the hurdles of survival and flourishes in many countries worldwide.

## References

Barlex, D. (2011). The STEM Programme in England – help or hindrance for design & technology education? In M. J. de Vries (Ed.), *Positioning technology education in the curriculum* (pp. 63–74). Rotterdam/Taipei/Boston: Sense Publishers.

Blandow, D. (1988). The system of polytechnic education in the GDR. In J. Raat, R. Coenen-van den Bergh, F. de Klerk Wolters, & M. J. de Vries (Eds.), *Basic principles of school technology. Report PATT-3 conference 1988* (pp. 116–135). Eindhoven: Eindhoven University of Technology.

Cheek, D. (1992). *Thinking constructively about science, technology and society education*. New York: State University of New York Press.

Compton, V., & France, B. (2007). Redefining technological literacy in New Zealand: From concepts to curriculum constructs. In J. R. Dakers, W. Dow, & M. J. de Vries (Eds.), *PATT-18 International Conference on Design and Technology Educational Research* (pp. 259–272). Glasgow: University of Glasgow.

Dugger Jr., W. E. (1987). Standards for the Technology Education Programs project. In R. Coenen-van den Bergh (Ed.), *Report PATT-conference 1987. Vol. 2. Contributions* (pp. 239–256). Eindhoven: Eindhoven University of Technology.

Dugger Jr., W. E. (2006). Twenty years of educational standards for technology education in the United States. In I. Mottier & M. J. de Vries (Eds.), *International handbook of technology education: Reviewing the past twenty years* (pp. 65–82). Rotterdam/Taipei/Boston: Sense Publishers.

Dyrenfurth, M. J. (1991). Technological literacy synthesized. In M. J. Dyrenfurth & M. R. Kozak (Eds.), *Technological literacy. Council on technology teacher education 40th yearbook* (pp. 138–183). IL, Glencoe Division, Macmillan/McGraw-Hill: Peoria.

Eijkelhof, H., & Kortland, K. (1988). Broadening the aims of physics education. In P. J. Fensham (Ed.), *Development and dilemmas in science education* (pp. 282–305). London: Falmer.

Ferguson, D. (2009). *Development of technology education in New Zealand schools 1985–2008*. Ministry of Education: Auckland.

Foster, P. N. (1994). Technology education: AKA industrial arts. *Journal of Technology Education, 5*(2), 15–30.

Holdsworth, I. (2006). Teaching making. A brief history of secondary school craft education textbooks. *Paradigm, 2*(2), 2–11.

Jones, A. (2009). The development of technology education internationally. In A. Jones & M. J. de Vries (Eds.), *International handbook of research and development in technology education* (pp. 13–16). Rotterdam/Taipei/Boston: Sense Publishers.

Jones, A., & Moreland, J. (2000). From technology national curriculum statement through to sustaining classroom practice and enhancing student learning: The New Zealand experience. In I. Mottier & M. J. de Vries (Eds.), *Proceedings PATT-10 conference* (pp. 65–76). Reston/Eindhoven: ITEA/Eindhoven University of Technology.

Kananoja, T. (1988). Technical work as an academic discipline in Finland. In J. Raat, R. Coenen-van den Bergh, F. de Klerk Wolters, & M. J. de Vries (Eds.), *Basic principles of school* *technology. Report PATT-3 conference 1988* (pp. 76–88). Eindhoven: Eindhoven University of Technology.

Lutherdt, M. (1995). Key qualifications - contents of general and vocational education. In K. Langer, M. Metzing, & D. Wahl (Eds.), *Technology education, innovation and management. Proceedings of the WOCATE conference 1994* (pp. 91–100). Berlin/Heidelberg: Springer.

McCormick, R. (1993). Technology education in the United kingdom. In R. McCormick, P. Murphy, & M. Harrison (Eds.), *Teaching and learning technology* (pp. 15–27). Milton Keynes: Open University.

Olafsson, B., & Thorsteinsson, G. (2009). Design and craft education in Iceland, Pedagogical background and development: A literature review. *Design and technology education: An international journal, 14*(2), 10–24.

Pavlova, M. (2016). 21st century skills: How to identify and address them in technology education. In M. J. de Vries, A. Bekker-Holtland, & G. van Dijk (Eds.), *PATT-32 proceedings. Technology education for 21st century skills* (pp. 378–385). Utrecht/Delft: Utrecht University of Applied Sciences/Delft University of Technology.

Penfold, J. (1988). *Craft, design and technology: Past, present and future*. Stoke-on-Trent: Trentham Books.

Ratcliffe, M. (2001). Science, technology and Society in school science education: Some key issues in the development of STS education. *School Science Review, 82*(300), 83–92.

Ritz, J., & Bevins, P. S. (2016). Exploration of 21st century skills that might be delivered through technology education. In M. J. de Vries, A. Bekker-Holtland, & G. van Dijk (Eds.), *PATT-32 proceedings. Technology education for 21st century skills* (pp. 400–410). Utrecht/Delft: Utrecht University of Applied Sciences/Delft University of Technology.

Rossouw, A., Hacker, M., & de Vries, M. J. (2011). Concepts and contexts in engineering and technology education: An international and interdisciplinary Delphi study. *International Journal of Technology and Design Education, 21*(4), 409–424.

Shield, G. (2003). Vocationalism and accountability: Two threats to design and technology education. In J. R. Dakers & M. J. de Vries (Eds.), *PATT-13 international conference on design and technology educational research* (pp. 277–280). Glasgow: University of Glasgow.

Starkweather, K. (1992). Status of technology education in the United States. In E. A. Bame & W. E. Dugger Jr. (Eds.), *Technology education: A global perspective. ITEA-PATT international conference proceedings* (pp. 17–40). VA, International Technology Education Association: Reston.

Theuerkauf, W. E. (1995). Entrepreneurship and Employment. A didactic dimension of technology teaching. In J. H. Raat, I. Mottier, & M. J. de Vries (Eds.), *Teaching technology for entrepreneurship and employment. Proceedings PATT-7 conference* (pp. 32–46). Via Afrika: Cape Town.

de Vries, M. J. (2003). Technology education in the Netherlands. In G. Graube, M. J. Dyrenfurth, & W. E. Theuerkauf (Eds.), *Technology education. International concepts and perspectives* (pp. 229–240). Frankfurt a/M: Peter Lang.

Wilson, V., & Harris, M. (2004). Creating change? A review of the impact of design and technology education in schools in England. *Journal of Technology Education, 15*(2), 46–65.