Chapter 14
Research Challenges for the Future

Marc J. de Vries

Starting with a brief review of research in technology education, this chapter goes on to propose research that continues to be needed in the context of technology education, a school subject that continues to have uncertain status and a problematic image. While remarkable progress has been made in technology education research over a relatively short period of time, significant work remains. First, research questions and research findings need to connect more closely with teachers. An important possibility here is involving teachers more closely in the research. Second, targeted policy-oriented research is needed and policy makers need to be recognised as an important audience for future technology education research. Third, more sophisticated research is needed on how to better support students' technology learning. For this, a design-based methodology may be particularly fruitful. The extent to which researchers are able to realise closer links between their work and educational practice, and enhance their understanding of policy processes, will likely significantly impact the future of technology education.

Introduction

In this chapter I will present a perspective on future directions for technology education research. In doing so, I will first look back on the (short) history of technology education research and show where this has brought us. In the course of time, it has become evident that technology education research still needs some careful rethinking to be really effective in the context of a still developing school subject with uncertain status and a problematic image in many places. Although

M.J. de Vries (✉)
Delft University of Technology, Delft, Netherlands

Eindhoven University of Technology, Eindhoven, Netherlands
e-mail: m.j.devries@tudelft.nl

PJ. Williams et al. (eds.), *The Future of Technology Education*, Contemporary Issues in Technology Education, DOI 10.1007/978-981-287-170-1_14

technology education research cannot on its own address all the problems, there is certainly potential for contributing—but in order to realise this, new directions will need to be taken.

In this chapter, I will pay special attention to the issue of the research-practice link. This link is problematic not only for technology education, but for other school subjects as well. However, the often fragile position of technology education in the curriculum increases the need for this link to work well. This is related in part to the contribution of technology education research to the justification for having technology education in schools, a point also raised in Chap. 13 by Kendall Starkweather. While it may seem that this motive for doing research is fairly defensive, the current situation in technology education justifies such an approach. It does, however, not mean that there is not also an important 'offensive' role for technology education research, namely to support the further development of technology education by providing insights into what works and what does not work in teaching and learning about technology. This is probably what most researchers are themselves primarily interested in, and justly so. Further, an enthusiastic researcher who comes up with stimulating ideas for improving technology education practice is also the best defence agent for the school subject. In designing and organising technology education research, a focus on directions that will also enhance the defensive role of the research is timely.

The Road Travelled So Far

Research in technology education is a relative newcomer in the educational research domain. This is due to the fact that technology education is relatively new in the school curriculum. While there have been craft-type school subjects for a much longer time, technology education is generally understood to be far broader. Technology education entails not only training in manual capabilities, but also design capabilities, knowledge development and attitude formation—and it is the design and knowledge components in particular that gave rise to an interest in investigating technology education. This is somewhat surprising since even a subject that only aims for manual skill development offers good reasons for investigating how this can best be learned and what pedagogy is needed. For some reason, and probably this is simply the undervaluing of manual skills in general, academic researchers have seldom taken an interest in this. However, as the design and knowledge component have increased in importance, research in technology education has emerged as a separate research domain. This has happened in a fairly short period of time—only three to four decades. Before then, there were no academic research journals specifically for technology education; neither were there international conferences dedicated only to technology education research.

In the late 1990s, some review studies were undertaken to determine the kinds of research studies that had been done up until then (de Vries 2003; Foster 1992; Petrina 1998; Zuga 1997). The results were fairly disappointing: many studies were theoretical, focusing on the identity of the subject (understandably, given its newness), curriculum content and educational goals for technology education. In terms of methodologies, the range was small. Most studies at that time were quantitative in nature. Studies into classroom practice were few. Most research was done in the UK and USA. While there has been no systematic investigation of changes since then, my impression as the editor-in-chief of the *International Journal for Technology and Design Education* is that the number of theoretical studies has dropped significantly (to almost zero) and the number of qualitative studies in classroom contexts has grown from almost none to a fairly steady flow of articles.

In terms of topics covered in research, three main areas can be distinguished (de Vries 2003): (1) research into what is to be taught (standards, curricula), (2) to whom and by whom it is taught (pupils', students' and teachers' attitudes, knowledge, skills, social background, etc.), and (3) in what ways it is taught (pedagogy, use of media). In the early years there was a lot of attention on the content of the curriculum. For example, there was interest in comparative studies in which approaches in different countries were analysed. Gradually an interest in learning from the philosophy of technology, design methodology, and from the history and sociology of technology emerged. Some, like Sven Ove Hansson, John Dakers and myself, even became active in both fields to enable immediate transfer from such domains to technology education research.

Later, studies into the practice of conducting design projects in technology education appeared in research journals. It was particularly in the UK that such studies were carried out, not surprisingly because design was the heart of the school subject Design and Technology. In the context of research into design projects in schools, various sub-topics have been covered, such as drawing (2D and 3D, by hand and using CAD programs). One topic in particular that has received considerable attention is the assessment of design projects. Here, the efforts of the research team at Goldsmiths College Technology Education Research Unit, led by Richard Kimbell, should be mentioned. This research line continues today and has led to numerous useful insights (see, for example, Kimbell and Stables 2007 and Chap. 7 of this volume by Kay Stables). Independent of all this, research into design education has slowly emerged. In leading design methodology journals, such as *Design Studies*, articles on design education research are published. Such articles can also be occasionally found in journals for engineering education. In the future, design education research may become another relevant field to learn from, as has happened with the philosophy of technology and design methodology.

The current situation for technology education is that we have several academic journals: the *International Journal for Technology and Design Education* (published by Springer, a commercial publisher), the *Journal of Technology* (published by the International Technology and Engineering Education Association in the USA), the *Design and Technology Education: An International Journal* (published by the Design And Technology Association in the UK), *Studies in Technology Education* (published by Epsilon Pi Tau, a North American fraternity) and recently the *Australasian Journal of Technology Education* (supported by New Zealand and Australian technology teachers' associations). In addition, there is a series of conferences in which research in technology education plays an important part (such as the Pupils' Attitude Towards Technology Education—PATT—conferences, the DATA Annual conferences in the UK, the TERC conferences in Australia, and the PATT sessions at the Annual ITEEA conferences). Taken together, these outlets show that research in technology education has matured to a certain level. This was a reason to set out the status of the domain in the *International Handbook of Research and Development in Technology Education* (Jones and De Vries 2009).

Although the remainder of this chapter will describe ways in which technology education research will have to take new steps moving forward, I want to emphasise here that what has grown in a relative short period of time is remarkable. Research in technology education is a well-established discipline with a high quality that meets scholarly standards.

The Research-Practice Link

One of the urgent challenges for future research in technology education is to create a better connection with teaching practice. This is not only a challenge for technology education research. For other educational research, too, a complaint can often be heard that it is too heavily oriented towards developing theoretical insights, interesting though they may be, while failing to have an impact on educational practice (Broekkamp and Van Hout-Wolters 2007; Wicklein and Hill 1996). This can arise for several reasons. In the first place, the research questions are often developed by researchers and teachers have almost no say. They are merely the people that provide research data. Additionally, in the analysis phase, it is the researchers who tend to make all the decisions. This is understandable, because the researchers almost by definition are the ones who have the knowledge and expertise to make these decisions. But the consequence is that opportunities are missed to derive research questions directly from teachers' experiences: What do they see as problematic? In the publication phase, the researcher's priority is to get the material published in an academic journal, as this is what they have to account for professionally: their number of international scholarly articles. Writing for a teachers' magazine is viewed as 'wasted time' by some researchers, even when they are aware of the need to inform teachers about the outcomes of the research. Teachers do not read academic journals, as a rule. In addition, it can be difficult for them to understand the content of what the researcher has written, and even more difficult to see what the research might mean for their practice.

It would be an interesting exercise—but beyond the limits of what I can do in this chapter—to compare what is in teachers' journals with what is in research journals in technology education. Being a reader of both, my estimation is that a striking mismatch would be found. Teachers' journals (for instance, the ITEEA's *The Technology and Engineering Teacher*) are full of ideas for new topics in and suggestions about how to teach these. Such ideas are largely absent in research journals. In addition, not many scholarly articles use a design-based research approach in which a concrete intervention is designed, its effects investigated and the outcomes used to improve the intervention, which would give a better connection to what teachers are interested in. I will come back to this approach later.

There are several possible responses to the issue of the gap between research and practice, and the minimal impact that research has tended to have on practice. In the first place, research could be better embedded in the whole process of educational development. Organisationally, it is often isolated from other parts of the development chain. At best, a research programme is attached to a teacher education programme, and even then the researchers are not necessarily the same as those who are involved in teacher education. It would probably require additional education for both researchers and teacher educators to be able to exchange places in a ‘research and teacher education programme’, but it is certainly worth seeking closer relations between the two activities.

A second response to the issue of low impact on practice is to more closely involve teachers in research. This can be done in the traditional types of exploratory and experimental research. Teachers could actively be involved in the processes of problem definition, selection of research methods, collection and analysis of data, and concluding the outcomes. Of course their role cannot be to replace the researcher’s methodological expertise, but they can provide a meaningful addition by bringing in their experiences from practice. Scientific research focuses on specific aspects of reality and that concentration makes it strong in that it allows in-depth investigation. Life, however, is a complex mixture of multiple aspects and classroom teachers tend to have a stronger awareness of this knowhow than researchers. They can help researchers identify ‘blind spots’ that result from their attitudes as researchers to confine their study to certain aspects only. This does not mean that researchers have to give up their focus, but it can help to get the focus ‘right’ by choosing from a broader range of possible aspects.

The most intense mechanism for involving teachers in research is through educating them to become researchers. Several countries, such as Sweden and the Netherlands, offer teachers an opportunity to do a Ph.D. funded by government. In Sweden this has led to two separate research ‘schools’ for (science and) technology education, FontD (Forskarskolan i naturvetenskapernas, teknikens och matematikens didaktik; transl. National Graduate School in Science, Mathematics and Technology Education Research) and TUFF (Teknikutbidning för framtiden; transl. Technology Education for the Future) (Skogh and Gumaelius 2012). These have resulted in a series of Ph.D. dissertations. After finishing their research study, the teachers return to schools with new capabilities that can make them better teachers in their own schools, and better equipped for working with university researchers in the future. Also in some countries, like in the Netherlands, there are ‘academic’ primary and secondary schools in which teachers do research based on a school-wide research plan that is defined by the school. Early experiences with this show that the quality of the research is often poor and the activity should be regarded more as a form of professional development for the teacher rather than a serious academic research effort. Even so, it can still work as a mechanism that improves the relation between academic research and teaching practiced in that teachers have a better understanding of researchers' work.

A third response to the problem of the missing link between research and practice goes even further and deals with the very methods that are used by researchers. All previous suggestions are still limited compared to what is probably the most fundamental approach to the problem, which is to shift to a whole new research paradigm, of which design-based research is the best candidate (see The Design-Based Research Collective 2003). Design-based research should almost by definition appeal to technology education researchers, as design is a vital element in technology education.

Design-based research means working as a designer would do. The purpose of design is twofold. In the first place, a designer aims to bring forth a new artefact, system or process. In order to reach that goal, a prototype is made, tested, and the outcomes are used to improve the prototype, which then is tested again until a satisfactory design is reached. But apart from the artefact, there is a second purpose fulfilled, namely that the designer has gained new insights that are tested empirically. During the experimentation on the prototype insights into the relations between properties of the prototype and the behaviour of the prototype are gained. This knowledge is transferrable to similar situations. In the beginning this knowledge will be fairly 'local', that is, specific to situations that are very similar to the original prototype that was tested. But by building up a series of design experiences, larger numbers of opportunities to generalise this 'local' knowledge emerge and more generic knowledge is developed. This is also very much the way knowledge is developed in engineering sciences. The methodological problem is that it is not easy to compare the prototype to a 'control' situation, as too many variables change at the same time, which is deadly for a true experimental or quasi-experimental set-up. One can similarly question how problematic multiple variables are for educational research, where very large numbers of classes and pupils are needed for experimental or quasi-experimental research to compensate for all the background noise caused by the fact that classes differ, teachers differ, circumstances differ, etc. If one critically examined current educational experimental and quasi-experimental research, one would, no doubt, find many cases in which the reliability and validity of these studies can be questioned on the basis of this consideration. This indicates that the loss of precision due to a shift from more traditional and quantitative research methods towards more design-based and qualitative set-ups may be much less than one would estimate at first sight.

The value of design-based educational research for practice is, however, much higher than for the more 'classic' studies. Here, too, there is a twofold benefit: an improved educational outcome (a new teaching pedagogy, new lesson material, new media, etc.), that is, the design. Second, there is the additional knowledge that was gained during the testing of the 'prototype'. While it may seem more difficult to get these sorts of studies published, we can already see more journals accepting such studies. This is partially because qualitative research, in spite of its original challenges in identifying validity and reliability, is now generally accepted as a legitimate form of research. The activities of the Design-Based Research Collective (www.designbasedresearch.org) have been helpful here, their studies showing that this type of research can have high validity and reliability, albeit in different ways to more traditional experimental or quasi-experimental quantitative studies. In addition, action research, which is very similar in nature to design-based research, is gaining ground. The advantage of design-based research over action research is that the former necessarily results in concrete and usable outcomes for educational practice, whereas action research may still remain in the realm of theoretical interests. Design-based research is, therefore, a very attractive option for investigating how design and technology activities can be optimised in their learning effect, particularly where both skill and conceptual development are targeted. In this case, design is both in the method and the content of the research.

The methodological debates referred to above reflect a tension between two perspectives on the relation between research and reality. Traditionally, a realist stance was taken and research outcomes were assumed to be a one-to-one mirror image of reality. More recently, an alternative approach has emerged in which research outcomes are understood to reflect more of the researcher's perspective of reality rather than an objective reality independent of the researcher. The view I take in this chapter is that both are invalid. My stance is that of 'soft realism', in which there is awareness that there is a distance between research outcomes and reality, caused by the interpretation that is involved in data collection and analysis. But soft realism believes that this distance does not mean giving up on the possibility of gaining knowledge about a reality that exists independent from the observer. I think soft realism is in a better position to justify educational interventions based on research outcomes. Finally, it is useful to point out that the dichotomy should not be confused with the difference between quantitative and qualitative research, as if quantitative research is necessarily connected to a naïve or soft realist stance and qualitative to a postmodern constructivist stance. Both types of research can be used in both stances.

Policy-Oriented Research

As pointed out by Kendall Starkweather in Chap. 13 of this volume, technology education research can play an important role in dealing with one of the subject's major struggles, namely evidencing its impact on pupils and society. Policy makers are often impatient and want to see concrete evidence that technology education at least to some extent fulfils its intentions. In the past, we have been quick to claim that technology education develops technological literacy, creativity, communication and cooperation skills, and that it supports science, mathematics and language learning. But does all this really happen in practice? We still believe it to be true, at least to some extent, but the evidence is not so definitive.

It seems that it should not be too difficult to collect evidence of the impacts of technology education, as the research methodology can be fairly straightforward. Large-scale quantitative studies should be able to do the job, as has been tried in the past with quantitative pre- and post-test set-ups. In the report Tech Tally (Garmire and Pearson 2006) an extensive survey of existing instruments for assessing technological literacy was presented. Importantly, it showed that either the instruments assess higher order skills and are too complicated for large-scale quantitative studies, or they are suitable for large-scale studies but do not assess higher order skills. This does not mean that large-scale assessments of higher order skills are impossible, but it does show that efforts to assess higher order technological literacy skills—an important desired outcome of technology education—have thus far been unsuccessful.

It has been difficult to develop valid instruments for testing high-level capabilities, such as means-ends reasoning, cause-effect reasoning, decision skills for responsible citizenship, etc. Therefore, while technology is now included in TIMSS, there is concern that this way of testing outcomes of technology education is far too simple to reveal what really has been learned. It is, for instance, virtually impossible to assess design creativity skills by means of a standardised paper-and-pencil test. This type of skill, however, is very important in technology education. The work of the Assessment Performance Unit at Goldsmiths in the UK has shown that assessing design skills require more sophisticated instruments, such as portfolios (Kimbell and Stables 2007, see also Chap. 7, this volume). Nevertheless, policy makers will likely look at the outcomes of international studies like TIMSS and draw conclusions with respect to the future presence of technology education in the curriculum.

In this respect, studies such as PISA and TIMSS seem to do more harm than good for technology education. For example, studies in the context of the ROSE project (Sjøberg and Schreiner 2010) have shown that they should be read with care as there are quite concerning findings, such as the inverted relation between scores of PISA and interest in the subject: often the better scoring pupils do not like the subject and for this reason may drop it as soon as they can. This, then, highlights the ongoing need for the development of valid and reliable instruments for measuring higher order technological literacy dimensions (knowledge, skills). It does not mean that TIMSS and PISA studies can be ignored in the field of technology education, as they do have a certain status. We should, however, not focus on getting high TIMSS and PISA scores as an aim in itself, but rather hope and expect that good technology education will also result in positive outcomes in studies that have been more broadly conceived.

Policy makers should be recognised as an important audience for future technology education research, but more will be needed in order to get their continuous support for strong positioning of technology education in the curriculum. What also needs to be done is to develop another new type of research study—one that focuses on the process of educational change, with particular attention to the role of policy making. In general education research, this is not new. Such studies have been reported in the past and they are still being conducted. However, they do not give specific insights into how this works for technology education. Such specificity is needed because of the particular situation of technology education as a relative newcomer in the curriculum still struggling with its public image and to some extent also with its identity, although the latter issue has been addressed extensively and much has been gained.

In technology education, we are still taken too much by surprise when policy makers decide in ways we cannot understand because "we had told them so clearly . . .". Greater insight is needed into the mechanisms of educational policy making, not in general, but for very particular cases, such as technology education. This requires a very different type of study than we have seen published in our journals to date. It is still a rare type of research, even though the need for it is evident when considering the survival of technology education.

The Epistemic Basis

Another important area for future technology education research is the epistemic basis for the subject. Recently, in the UK, the subject Design and Technology was critiqued for lacking such a basis, and as a result the position of Design and Technology in the curriculum was questioned. This poses a challenge for technology education research world-wide. In the first instance, we need to identify the epistemic basis of the subject; in other words, we have to find an agreed answer to the question: What are the fundamental concepts, laws and principles, in technology, that put the subject on an equal level with science and mathematics education? Some work has already been done on this and we are fortunate to have several studies that resulted in more or less the same list of basic concepts (Custer et al. 2010; Rossouw et al. 2011).

More is needed, though, than this list. We also need to know how the theory plays out in education. How can these concepts be taught and learnt? The suggestion has been taken from developments in science education that contexts should play a vital role in the learning process. Contexts, then, ought to be more than occasional examples to illustrate theory, but social practices that make sense to pupils and can only be participated in meaningfully with a proper mastery of certain concepts. Design activities are a candidate for such practices, but we still have little insight into how they stimulate conceptual learning. Some studies suggest they do, but other studies show no effect. No doubt, the problem is not in the individual studies, but in the fact that they are not easily comparable and therefore do not yet 'add up'. Additionally, they are generally not of a design-based research methodology so that the knowledge gained about the effect of design or other classroom interventions on conceptual learning was not based on a systematically optimised situation, but on a random existing one. Here, much work is still to be done.

Conceptual learning in design and technology is particularly challenging because of its abstract nature: we never see these concepts in practice. For example, what we see are cars, mobile phones, computers, buildings; not 'systems'. It takes time for us to learn that all the artefacts we see around us have certain characteristics in common that we use to understand a concept called 'system'. Even when we know what a 'system' is, it is sometimes hard to recognise it in a concrete artefact, because in each and every artefact this concept takes a somewhat different shape because the characteristics that are common for all systems are then mixed with characteristics that are specific to the car, the mobile phone, the computer or the building. Learning concepts therefore requires that we learn to separate the common characteristics from the context-specific characteristics. One can illustrate this by thinking about chameleons. The first time we meet one, it sits near the water and is blue. So we develop the idea that the chameleon is a blue animal with a long tongue. The next one we see is in the grass. We do not recognise it as a chameleon as it is not blue—yet it does have the long tongue. Then we see a third one on a red tiled roof and it is red, but has the same long tongue as the previous two had. Gradually we start realising that it is the tongue rather than the color of the body that makes the chameleon a chameleon. Once we know this, we recognise more easily that the grey animal sitting on the asphalt road with the long tongue is again a chameleon. Educational research can investigate how this learning process can be best organised and supported.

Teachers are a crucial aspect in realising high quality technology education. In science education, the Pedagogical Content Knowledge (PCK) of teachers has become a focus for study. Although the concept of PCK is still somewhat fuzzy, it has quickly grown in popularity. Broadly speaking, it is the knowledge that teachers need to have in order to be able to effectively teach specific topics. It is a very personal knowledge that teachers develop in the course of their education and teaching practice. Often it is associated with a European term for knowledge that is specific for one subject—vakdidaktiek in Dutch, Fackdidaktik in German, etc.

Preliminary studies investigating the nature of PCK in technology education have been conducted, but there is still a lot of work to be done. Measuring teachers' PCK is desirable, not in the least for teacher education programmes to evaluate the effects of the programme, but we still do not know how to measure the various components of PCK in technology education—or indeed in science education, where much research has been conducted. While much can no doubt be learnt from science education, technology education has many aspects that differ from science education. Research by Williams and Lockley (2012) indicated that the different nature of science and technological knowledge also rendered elements of PCK inapplicable to technology teachers. For some other elements, insights from science education can probably be transferred to technology education, with modifications regarding specific characteristics of technological concepts (such as normativity).

Research on STEM

Another issue related to the survival of technology education in the curriculum is the relation with other subjects, and in particular with science and mathematics education. In several countries the acronym STEM is used to express the desire to interrelate science, technology, (pre-university) engineering and mathematics education. This can be done at several levels, ranging from accidental shared projects to a fully integrated school subject called STEM. As indicated by Cathy Buntting and Alister Jones in Chap. 10 of this volume, there are numerous hurdles for true integration of the components in STEM. One is that it is not easy to define projects in which knowledge and skills from science, technology, engineering and mathematics are all essential for success. Often the emphasis is on one or two of the STEM disciplines and the involvement of the other subject areas is quickly recognised by pupils as artificial. In addition, the ways in which the methods of the disciplines interact (research, design, mathematical modelling) is a matter that needs further research; in fact, this is almost entirely un-researched territory.

Related to this is the need for research into how various skills should cooperate in STEM. Creativity is definitely one of the skills that features in this spectrum—one that in fact is part not only of technology and engineering, but also science and to some extent mathematics. Studies were carried out decades ago into the way creativity develops in children (Torrence 1972), but little research is available about the way creativity can be developed by 'rich projects' in which design activities are combined with research activities and mathematical modelling (see Chap. 9 of this volume, by David Spendlove, for more on creativity in design). The need for and development of reasoning skills also needs further investigation. Here it is necessary to distinguish between cause-effect reasoning (can I reason back and forth between causes and effects?) and means-ends reasoning (can I reason back and forth between means and ends?). Both are important for science and mathematics as well as for technology and engineering. This is why integrated STEM projects should be a good vehicle for simultaneously developing skills in both reasoning types.

Although I have thus far grouped 'technology and engineering' together, the two components of the term can be distinguished from each other. Technology is the umbrella term for both the development and production of artefacts, systems and processes by engineers and technicians, and the use of such artefacts, systems and processes by engineers, technicians and users in society. Engineering is a narrower term that focuses on design and making by professionals who have been educated for such specialised work (engineers). Engineering is also characterised by certain concepts that can be absent in technology in the broader sense (Katehi et al. 2009). For example, engineering is highly quantitative in nature. A lot of design work in schools is qualitative and does not entail making calculations about constructions. For engineers, however, making calculations is a necessary part of their work. Another difference between technology and engineering is modelling, which tends to be far more prominent in engineering than in technology curriculum. In fact, modelling seems to be almost absent in much of technology education practice. Even if it is present, it remains implicit and the nature of models is not discussed explicitly. One exception is the New Zealand Curriculum, which includes technological modelling as an explicit component of technological knowledge. A third engineering characteristic is the intensive use of knowledge from natural sciences. This, too, is often lacking in current technology education practice. In other words, it can be concluded that the 'E' in STEM is still largely absent in current practice and both research *and* development are needed in the future to strive towards addressing this. This, too, has everything to do with the relevance and survival of technology education. Engineering is socially respected, and if technology education is not related to engineering in a visible way, it will miss this opportunity of being recognised as being socially relevant. As we have currently only begun acknowledging that basic engineering concepts should be taught, we are still some way from knowing how to teach them effectively. Research therefore has the potential of offering important support to developing the E in STEM.

A closer link with science education is not only important in the context of the STEM ideal in teaching practice, but also for research. Science education has a well-established tradition of educational research, from which technology education has a lot to gain. Numerous studies into both pupils' naïve or pre-concepts have been done in science education, while this research topic is still in its infancy in technology education. Instrument development is a crucial issue here. In science education research a lot of expertise has been developed and it would be a waste to start from the beginning in technology education. Additionally, strategies to identify or 'measure' initial ideas in more qualitative ways have been developed in science education research. Often the term misconceptions was used in this context. I would, however, want to argue against the use of that term, in line with current developments in science education. The pre-concepts that we have intuitively developed through practical experiences are often effective as long as their application is restricted to those situations in which we developed them. For example, in practice, we do not encounter situations without friction. Therefore it makes sense to develop the view that objects on which no force is acting will come to a standstill. It is only when we are confronted with frictionless contexts—which will typically happen only in a classroom experiment—that the application of the Aristotelian concept of force fails. The pre-concept then appears to be wrong, and we need to adapt our ideas. Still, for everyday-life situations, our old notion will continue to function satisfactorily and we will fall back on it even after we have learnt the scientifically correct concept. This is what can be called the difference between 'street image' and 'school image'. The phenomenon is well known in science education, but is worthy of further investigation in technology education.

User-Orientation

In the UK, the Design Council has presented 'A new vision for Design & Technology in schools' (see http://www.designcouncil.org.uk/our-work/Insight/Education-and-skills/Design–Technology-in-schools/). Although this new vision has elements that are UK-specific, much of what is in this new view applies to other countries. Therefore, it would be profitable for technology education research to take into account certain elements of this vision in developing an agenda for future research.

Aspects promoted by the Design Council include:

- stimulating design literacy by not only focusing on the designer perspective but also the user perspective,
- enhancing the links between arts, science and business in the design capacity,
- enhancing pupils' understanding of user-centred design approaches,
- including up-to-date design technologies,

- bringing design activities in a higher theoretical level, and
- enhancing relations with industry.

Some of these ‘new directions’ are not as new as they are presented. However, one that is of particular interest because it seems to be undervalued in current technology education practice is the user perspective, both in the design literacy that is aimed for and in the design methods that are used. Research also has a blind spot here. To date, most research has taken for granted that design activities are there to develop design skills. Most pupils, however, will not continue their education to become a designer or engineer. They will, however, all become citizens who will use technologies. Almost no research has been done regarding how design and other activities can be developed and executed in order to stimulate user literacy. The users’ perspective is also often missing in existing design activities in that pupils are mostly challenged to make the design such that it fulfils its ‘technical’ function. For example, the best mousetrap car design is the one that travels the longest distance. Often no user is defined and pupils do not need to bother explicitly about a user’s perspective. Research has reflected this absence of emphasis, and few studies focus on how a user-focused approach in design projects can be developed with pupils. David Spendlove also raises the issue of user-orientation in Chap. 9 of this volume.

The Use of Media

The use of media has long been an area of interest in technology education research. There are, however, currently important reasons for affording this area a more prominent place in technology education. The emergence of gaming and social media have had an enormous impact on the lives of young people, and their interactions with such media have become a substantial part of their daily activities. To date, technology education has been very much bound to school classes, perhaps extended with ad-hoc visits to museums or industrial organisations.

While school continues to be a place where pupils spend much of their time, an increasing part of their lives has become virtual. They love gaming, become inhabitants of virtual worlds such as Second Life, are plugged into various social networking sites, and many write blogs. This has at least two implications for technology education. First, a new dimension should be added to technological literacy, as it has become evident that appropriate use of these media by young people is by no means to be taken for granted. For example, reports have been published that show that pupils perform worse in education because they are too preoccupied with the use of games (e.g., Rehbein et al. 2010). An addictive effect of such media has also been reported. This means that contemporary technological literacy also entails the knowledge, skills and attitudes to give social media an appropriate place in one’s life. Educational research can support the development of new pedagogies and materials that help learners acquire such dimension in technological literacy.

The second implication is the use of such media to teach about technology. While the use of media in education is the domain of educational technology rather than technology education, when we focus on the use of such media to teach specifically about technology, it becomes part of technology education. For this reason it should form part of technology education research when it comes to developing insights into how digital technologies can be used for educational purposes.

Teacher Education

I will be short on research about teacher education, as the research topics addressed above all have implications for research in teacher education. If teachers are to be given a more active role in research, they need to be prepared for this. It is by no means obvious how to do this as programmes are often already overloaded and it is not likely to be possible in the short time available to prepare teachers adequately for doing research—or even to interact intellectually with it. The small research studies student teachers are required to conduct tend to be fairly superficial and don't meet the standards of academic research.

Research is needed to identify feasible ways of acquainting pre-service teachers with research methodologies in ways that fit within the dimensions of a teacher education programme. Two aims seem to be realistic: preparing teachers for being good partners with researchers while still primarily being teachers, and giving teachers some experience in research by having them assist in faculty members' research. In the latter case, they do not need to do a full research study themselves but only be part of a certain phase of a research study, and learn about the other phases by listening to the researchers' stories. In such a master-apprentice situation, future teachers can get a taste of what research is without the burden of a complete mini-research project that they are individually responsible for carrying out. Research in teacher education could show how this can be given shape in an effective way. Those who are already practicing teachers who want to become involved in research will need to be provided with in-service activities to acquaint them with current research methodologies and the way these can be applied in technology education research.

The Effect of Research on Policy and Practice

How can we know the effect of research on teaching practice and policy? This issue is also addressed by Kendall Starkweather in Chap. 13 of this book. Often, the relationship between research and policy making is indirect. What may happen is that teacher educators get acquainted with outcomes of educational research and incorporate the outcomes in their teacher education programmes. They often work alongside researcher colleagues, and in many cases carry out research themselves (refer to my earlier plea for this!). The result of a changed teacher education is a new generation of teachers who have knowledge that has originated from research projects. There is therefore a time gap of at least one generation in this mechanism for research to affect practice. This also makes it difficult to trace back the educational changes to the original research efforts that led to them. A challenge for the future is to make the relation more explicit. This can be done, for instance, by offering the research-based insights taught in teacher education in such a way that the future teachers realise that it was research that produced these insights and not the intuition and experience of the teacher educators. Teachers should also be taught to read research articles so that they are equipped to acquaint themselves with future findings from educational research. It should become 'second nature' for teachers to monitor the research field of their teaching subject. Close cooperation between researchers and the teacher educators can stimulate this.

Another way in which research can impact on the practice of technology education is through the emergence of international contacts. In particular, research-oriented conferences and workshops have contributed to increasing international cooperation in technology education. For example, the meeting of researchers at international research-oriented conferences facilitated the spreading of knowledge about ways in which different countries were approach problems in developing and introducing technology education, providing a source of inspiration for curriculum developers and teacher educators in other countries. The PATT conferences are an example of conferences with such an effect. Although they originally focused exclusively on attitude measurement, the scope soon widened to include other aspects of technology education. The research-oriented nature of the early PATT conferences has been maintained throughout the existence of the series of conferences. Thus, reported and discussed research efforts have had a certain impact on the internationalisation of technology education and made it possible for strengths from different countries to be built on, and experienced weaknesses to be avoided. This is a form of effectiveness that, like the previous mechanism (teacher education influenced by research), is seldom documented, and it is again difficult to assess precise ways in which research has affected practice.

Concluding Remarks

In this chapter I have sketched future directions for technology education research. I have suggested an agenda for technology education research in which design-based studies will become a more prominent type of study. In addition, research questions will be chosen that relate more directly to what interests and is valued by teachers, particularly the effect of new and innovative learning materials. I also made a plea for research into the process of policy making in technology education, the challenges that STEM education poses, the user-dimension of technological literacy, and the use of new media in technology education. Teachers should play a more active role than currently in carrying out this research agenda.

Whether or not this road can be travelled will depend on the investments that are made. In this regard, there is some concern. Several institutes that have been strong in technology education research have given up their efforts. In Germany, for instance, there were several universities with robust technology education research, but many of them are no longer active in this field. In the UK, several institutes have also closed their research programmes. In the former Eastern-European countries almost no research in technology education survived the political changes of the 1980s/1990s. On the other hand, in countries like New Zealand, there has been an increase in research activities in the twenty-first century.

It is important that universities invest in technology education research. Unfortunately, there is a vicious circle here. Technology education research will only be valued when technology education itself is valued—but to provide justification for the appreciation of technology education, relevant research outputs are needed. It is still possible that technology education will go through a phase in which its very survival will depend on the efforts of a few countries that perform extremely well in technology education research and thus provide the ammunition for others to defend both technology education itself and its supporting research to their governments and policy makers. The extent to which researchers will be able to realise a better link with educational practice and enhance their understanding of policy processes will, in my view, determine the future of technology education. There is every reason to work hard on this, as our case is definitely worth it.

References

Broekkamp, H., & van Hout-Wolters, B. H. A. M. (2007). The gap between educational research and practice: A literature review. *Educational Research and Evaluation, 13*, 303–320.

Custer, R. L., Daugherty, J. L., & Meyer, J. P. (2010). Formulating a concept base for secondary level engineering: A review and synthesis. *Journal of Technology Education, 22*(1), 4–21.

de Vries, M. J. (2003). Editorial. *International Journal of Technology and Design Education, 13*, 199–205.

Foster, W. T. (1992). Topics and methods of recent graduate student research in Industrial Education and related fields. *Journal of Industrial Teacher Education, 30*(1), 59–72.

Garmire, E., & Pearson, G. (2006). *Tech tally. Approaches to assessing technological literacy*. Washington, DC: National Academies Press.

Jones, A., & de Vries, M. J. (Eds.). (2009). *International handbook of research and development in technology education*. Rotterdam/Taipei: Sense.

Katehi, L., Pearson, G., & Feder, M. (2009). *Engineering in K–12 education: Understanding the status and improving the prospects*. Washington, DC: National Academies Press.

Kimbell, R., & Stables, K. (2007). *Researching design learning. Issues and findings from two decades of research and development*. Dordrecht: Springer.

Petrina, S. (1998). The politics of research in technology education: A critical content and discourse analysis of the Journal of Technology Education, Volumes 1-8. *Journal of Technology Education, 10*, 27–57.

Rehbein, F., Kleimann, M., & Mößle, T. (2010). Prevalence and risk factors of video game dependency in adolescence: Results of a German nationwide survey. *Cyberpsychology, Behavior and Social Networking, 13*, 269–277.

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, 4*, 409–424.

Sjøberg, S., & Schreiner, C. (2010). *The ROSE project: An overview and key findings*. Oslo: University of Oslo.

Skogh, I.-B., & Gumaelius, L. (2012). Technology teachers as researchers: The TUFF experience. In H. Middleton (Ed.), *Explorations of best practice in Technology, Design & Engineering Education* (Vol. 2, pp. 118–127). Brisbane: Griffith Institute for Educational Research.

The Design-Based Research Collective. (2003). Design-based research: An emerging paradigm for educational inquiry. *Educational Researcher, 32*, 5–8.

Torrence, E. P. (1972). Can we teach children to think creatively. *The Journal of Creative Behavior, 6*, 114–143.

Wicklein, R., & Hill, R. B. (1996). Navigating the straits with research or opinion? Setting the course for technology education. *International Journal of Technology and Design Education, 6*, 31–43.

Williams, P. J., & Lockley, J. (2012, July). *An analysis of PCK to elaborate the difference between scientific and technological knowledge*. Paper presented at the Pupils Attitude Toward Technology (PATT) 26 Conference: Technology Education for the 21st Century. Stockholm.

Zuga, K. F. (1997). An analysis of technology education in the United States based upon an historical overview and review of contemporary curriculum research. *International Journal of Technology and Design Education, 7*, 203–217.