Transfer, Transitions and Transformations of Learning

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Scope
Technology Education has gone through a lot of changes in the past decades. It has developed from a craft oriented school subject to a learning area in which the meaning of technology as an important part of our contemporary culture is explored, both by the learning of theoretical concepts and through practical activities. This development has been accompanied by educational research. The output of research studies is published mostly as articles in scholarly Technology Education and Science Education journals. There is a need, however, for more than that. The field still lacks an international book series that is entirely dedicated to Technology Education. *The International Technology Education Studies* aim at providing the opportunity to publish more extensive texts than in journal articles, or to publish coherent collections of articles/chapters that focus on a certain theme. In this book series monographs and edited volumes will be published. The books will be peer reviewed in order to assure the quality of the texts.

Transfer, Transitions and Transformations of Learning

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1. TRANSFER, TRANSITION, OR TRANSFORMATION?

INTRODUCTION

> Schools are supposed to be stopovers in life, not ends in themselves. The information, skills, and understandings they offer are knowledge-to-go. Not just to use on site. (Perkins & Salomon, 2012, p. 248)

Transfer of learning has been a periodic topic of research during the 20th century and a topic of research and critique in the late 20th and for most of the 21st century so far. The seemingly simple task of examining how learning in one setting affects learning or activity in another setting commenced in modern times with Thorndike and Woodworth's (1901) study. After many studies, Thorndike (1913) concluded that transfer did not actually occur and that the human mind was organised such that it learned things separately and apparently in isolation.

Others (Bransford & Schwartz, 1999; Wenger, 1998) have argued that Thorndike and Woodworth came up with the conclusions they did because they were using the wrong way to identify or measure transfer. Bransford and Schwartz (1999) argue that Thorndike and Woodworth used an experimental method they described as sequestered problem solving (SPS) that was not a valid way to measure transfer. Bransford and Schwartz argued that we should be examining transfer in terms of preparation for future learning (PFL), rather than what is directly seen to be transferred. Perkins and Salomon (2012) argue that motivation is a key to understanding successful and unsuccessful transfer. Stevenson (1986, 1998) explores the related concept of perceptions of ownership of learning by learners and the effect this has on transfer, and particularly, far transfer. Marton (2006) argues we have been looking at the wrong aspect of transfer, concentrating on identifying sameness between learning settings instead of differences.

Schwartz, Chase, and Bransford (2012) argue that particular teaching and learning strategies can impede transfer by inducing a phenomenon they call overzealous transfer (OZT). OZT occurs when people use learned routines on the basis of similarities between new situations and existing knowledge, when the capacity to identify new learning is more appropriate. Theories on boundary crossing (Akkerrman & Bakker, 2011) focus on the values of differences between learning settings and how to create possibilities for learning at the boundaries of diverse practices. Finally, Beach (1999) has argued that transfer is not the appropriate metaphor and we should be thinking of what we currently call transfer as a process of transition where both the learner and the learning materials are transformed.

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We are thus in an exciting period in terms of exploring what these fundamental aspects of learning look like in terms of contemporary research and theorising. This book includes researchers involved in undertaking studies that explore the concept of transfer or more recent conceptualisations that fit within the general terms of transitions and transformations. These three themes are addressed within the overall learning area that is the focus of this book series: technology education.

In this introductory chapter, we attempt to do two things. In the first section, we provide an overview of issues in past and current research on transfer, transitions, and transformations that are addressed in the different chapter in this book. This provides the foundation for the remaining chapters. In the second section we provide an introduction to each of the succeeding chapters.

WHAT IS SUCCESSFUL TRANSFER: SEQUESTERED PROBLEM SOLVING (SPS) VERSUS PREPARATION FOR FUTURE LEARNING (PFL)

The first issue regarding transfer that is often addressed in the chapters of this book is the question: What is successful transfer? The classical definition of successful transfer is that it is a product of the learning process where something learned in one context is used to assist learning in another context (Thorndike & Woodworth, 1901). Thorndike and others were some of the first to examine common assumptions about learning, such as the belief that learning difficult subjects such as Latin increased people's general learning skills (Bransford & Schwartz, 1999). Thorndike's work showed that while people might do well on a test of content they had previously learned, they would not necessarily use that learning in a new situation where it would appear to be applicable. Based on many studies, Thorndike (1913) argued that transfer did not happen and that the human mind was not wired to perform transfer.

Bransford and Swartz (1999), however, argued that most previous research into transfer employed a transfer task that they labelled sequestered problem solving (SPS), alluding to a process that is like that used in courtrooms where juries are sequestered to ensure they are not exposed to contaminating information. In the same way, subjects in transfer tests are kept isolated and have no access to texts, or the ability to try things out, receive feedback, or revise. It is easy to see why SPS would be used from an experimental perspective. However, Bransford and Schwartz argue that direct application of remembered information to the solving of a new problem does not represent an authentic way to measure transfer. They advanced an alternative approach to understanding transfer and argued that it is more appropriate to measure the degree to which particular learning prepared people for future learning (PFL).

SPS and PFL can be thought of as representing general differences between much of the research on transfer. That is, SPS can be seen to represent, in a general way, research that accepts that transfer occurs and the issue of interest for research is in establishing how to facilitate transfer. PFL argues for a more oblique approach to transfer that poses the question of whether the traditional concept espoused by

Thorndike and Woodworth actually exists. The following paragraphs in this first section examine research that is relevant to the chapters that follow.

THE INFLUENCE OF MOTIVATION ON SUCCESSFUL TRANSFER

Perkins and Salomon (2012) have advanced the argument that motivation is a key factor in any explanation of transfer, both in terms of successful and unsuccessful instances of transfer. Similarly, Bransford and Schwarz (1999) mention people's willingness to seek others' ideas and perspectives as an important aspect of the active nature of transfer. Perkins and Salomon's starting point is the observation that transfer occurs easily in many normal life circumstances but failure to transfer learning is a common feature of formal learning settings. They therefore argue that motivation to transfer can be examined using a "detect-elect-connect" model where the three aspects of the model are described as "bridges" where it is possible to identify if the process of transfer is occurring.

In the Perkins and Salomon (2012) model, "detect" is used to describe the action where a person becomes aware that there may be a link between previously learnt information and a current situation. They argue that motivation is a factor determining whether a person will detect the link. Perkins and Salomon argue that motivation is even more critical to the "elect" bridge in their model. They argue that old learned practices and habits often get in the way of using knowledge detected to elect to do something different. The last bridge in Perkins and Salomon's model is "connecting," where, after detecting a possible relationship and electing to explore it, people go on to make the connection between the prior knowledge and the current situation. Perkins and Salomon argue that understanding the role of motivation as the driver to connect each of the three bridges in their model of transfer provides a way to predict whether transfer of learning will be successful.

Using a concept related to motivation, Stevenson (1986, 1998) supports Perkins and Salomon's (2012) argument that motivation is a key to successful transfer. Stevenson undertook studies with automotive apprentices and examined the features that led to successful transfer. Stevenson examined transfer where the learning was similar to the transfer requirements and where there were significant differences between the learning and transfer requirements. Stevenson found that students' sense of ownership of learning is a key motivator of learning that is important for successful transfer, in general, but is particularly important if the goal of learning is to achieve far transfer.

SAMENESS AND DIFFERENCE AS A KEY TO UNDERSTANDING TRANSFER

A second issue addressed in many chapters in this book is the sameness or difference between situations and the influence on whether or not transfer occurs. Marton (2006) argues that we need to widen the focus when examining transfer, from the consideration of how learning one thing helps people to do something that is a bit different, to considering how perceptions of difference and sameness between tasks might help people transfer learning. That is, Marton argues that understanding difference is as important as, and may be more important than, understanding sameness between learning situations. In doing so, Marton argues for the importance of the perceptual aspect of transfer: what people attend to or notice. Similarly, Bransford and Schwarz (1999) argue for perceptual learning and the importance of contrasting cases.

Marton provides a number of examples to show the limitations of the emphasis on similarities between situations. He argues that if we have students learn and practice addition and then we give them the task again, we will not be able to determine whether they learned the tasks by rote or that they understand how to add. If they are given different addition tasks, we can say that they have learned and understand how to add. Marton extends this argument for the importance of perceiving difference to achieve transfer by pointing out that this is how we learn in everyday life:

> We learn to notice differences and to make distinctions. We see everything against the background of our experience. We see someone as tall because we have seen people of different heights. We experience wine as fruity because we have had wine before that was not fruity. (Marton, 2006, p. 512)

Marton argues that the perceiving of difference occurs at two levels. First, learning occurs as a function of perceiving differences within the learning situation, and second, transfer is regarded as a function of the perception of differences between learning and other situations, or put another way, between one context and another context. Bransford and Schwarz (1999) describe how experience with contrasting cases can affect what a learner notices about subsequent events and how the learner interprets them. They add that just contrasting different cases is not enough. It sets the stage for future learning, but learners need an explanation for the patterns of similarities and differences they discover. In their study, analysing and contrasting different cases prepared learners to understand the explanation of an expert in a later lecture.

In this book, this issue is addressed in Chapter 11 by Bjorklund, who draws on Marton's (2006) research to explain the issue of implicit pattern recognition as a key component of his dual memory model of transfer. In a similar way Banks and Plant explore the similarities between science and technology in Chapter 3 as a way of challenging the traditional view of technology as applied science. Kimbell draws on notions of sameness and difference in Chapter 7 as he examines the way teachers use collective judgements to achieve reliable assessment of student performance.

AVOIDING UNPRODUCTIVE TRANSFER STRATEGIES

Building on earlier work by Bransford and Schwartz (1999), Schwartz et al. (2012) examined the phenomena of positive and negative transfer and the role of instruction. They draw on summaries of transfer research by Chi and VanLehn (2012) that conclude that successful transfer is often achieved by using instruction that helps individuals to treat a new problem as being similar to one they have already learned. However, while these instructional strategies work some of the time, Schwartz et al. (2012) argue that the strategies can be overdone and describe a phenomenon they call overzealous transfer (OZT) where learning is overgeneralised and transferred into situations where it is inappropriate.

Schwartz et al. draw on work by Schwartz , Chase, Oppezzo, and Chin (2011) that found that 75% of studies of transfer in science, technology, engineering, and science (STEM) content used tell (teach) and practice routines. Schwartz, Chase & Bransford (2012) argued that one problem with tell and practice routines is they can emphasise efficiency at the expense of finding new ways to look at learning materials (Bonawitz et al., 2011). Stevenson (1986) noted that tell and practice methods were efficient for near transfer but did not encourage far transfer.

Schwartz et al. (2011) found that the negative effects of OZT could be reduced by having students use a technique called inventing with contrasting cases, where they had to, in essence, invent a way to understand the learning material. This is analogous to Perkins and Salomon's (2012) adaptive transfer. That is, students had to engage in a form of far transfer or look for new and purposeful ways to learn. In other words, they had to engage in what is, arguably, creative behaviour. Another strategy for achieving effective transfer is to ensure initial learning involves the learning of concepts and principles within a range of contexts (Schwartz et al., 2012). De Vries explores this strategy as a way for learners to cope with the changing nature of technology in Chapter 2. As such De Vries' chapter also fits within the frame of preparation for future learning (PFL).

CONSEQUENTIAL TRANSITIONS INVOLVING TRANSFORMATION

All of the research and theorising reported so far in this introduction addressed issues concerned with understanding the phenomenon of transfer. What they do not do is question the legitimacy of the concept of transfer. In this section, Beach argues for a different approach to what we call transfer.

A perspective on transfer adopted by a number of chapters in this book is that of transfer as consequential transitions. Beach (1999) and others (for example, Lave & Wenger, 1991) find traditional research on transfer limited in its ability to explain how learning, at its most basic, occurs, and, more generally, how people develop knowledge and understanding. Beach advances an alternative explanation for transfer. Adopting a sociocultural approach, Beach argues that there is a body of research (e.g., Beach, 1995a, 1995b; Cole, 1996; Whitson, 1997; Lemke, 1997; Evans, 1999) to support his conclusion concerning the "centrality of symbols, technologies, and texts, or systems of artifacts, in propagating knowledge across social situations" (Beach, 2003, p. 41). Thus, the idea that people generate knowledge across social activities rather than transfer it from one situation to another is a key feature of Beach's theory.

Beach argues that when looking at the situation where transfer is assumed to have occurred, transfer of knowledge from learning task A represents "a very narrow band of all that potentially goes on in learning task B" (1999, p. 108).

Beach argues further that there is a conceptual isolation between the material assumed to have been transferred from learning activity A and the other learning that is or will occur in learning activity B. Beach argues that while transfer happens in general life situations, intentional transfer, or facilitated transfer, as is assumed to occur as a result of formal learning, does not occur or occurs rarely. This proposition appears to be supported by Detterman (1993), who argues that true transfer only occurs spontaneously. Beach uses this argument to suggest that the metaphor of transfer is best discarded and replaced by the metaphor of transitions. Beach (1999, 2003) argues for a sociocultural approach described as consequential transitions.

A consequential transition is defined as a developmental change in the relation between an individual and one or more social activities. Beach (2003) argues that this developmental change occurs via four types of consequential transitions. The first type Beach calls *lateral transitions*, where an individual moves in a single direction from one activity to another activity that is historically related. An example might be moving from school to work after education finishes. Lateral transitions are regarded as being most closely related to classical transfer in terms of their unidirectionality. That is, there appears to be a developmental link between learning at school and the learning required for work (see Baartman et al., Chapter 5).

The second type of transition Beach (2003) describes as *collateral transitions*, where an individual is simultaneously engaged in two or more historically related activities. An example might be a student moving between different classes in school. Collateral transitions are thus multi-directional, but the issue of development is less clear than with lateral transitions because of the multi-directionality. Collateral transition is often assumed to occur across different subjects in school where, for example, learning of compound ratios in mathematics might transfer to understanding gear ratios in mechanics or engineering classes. The evidence for collateral transfer in schooling, however, is not strong.

The third type of transition is what Beach (2003) calls *encompassing transitions*. Encompassing transitions occur when participants engage in a single social activity and the activity occurs within the boundaries of that activity. Encompassing transitions are a function of the change in the activity. Beach draws on Lave and Wenger's concept of legitimate peripheral participation where: "learners inevitably participate in communities of practitioners and … the mastery of knowledge and skill requires newcomers to move to full participation in the sociocultural practices of a community" (1991, p. 29).

The final kind of transition is what Beach (2003) calls *mediational transitions*. They occur within educational activities that simulate involvement in an activity where the participant has not yet experienced the activity. Beach provides an example of a mediating transition from a study of adults learning to become bartenders in a private vocational school. Students initially memorised drink recipes using written materials, however, the pressure to achieve speed and accuracy meant the students were assisted in moving from written materials to mnemonic materials more closely related to the mixing of the drinks themselves.

The students were highly literate part-time actors, restaurant managers, and graduate students and the vocational activity acted as a bridge between the two other systems of activity; that is, between their role as part-time actors, students, or managers and their role as bartenders. Beach argues that mediated transitions always provide the stimulus to allow the learner to move beyond their current point, to the developmental position they are working towards. In this sense Beach argues that mediated transitions are roughly equivalent to Vygotsky's (1978) concept of a zone of proximal development and always involves the notion of developmental progress.

Beach (2003) also argues that the transition of self and social activity usually involves a struggle and that transition does not occur unproblematically as is sometimes thought to be the case with transfer. Beach argues that consequential transitions involve a struggle and in the process both the learner and what is learnt are transformed. The concept of consequential transitions from competence to expertise is explored in Chapter 8 by Middleton in terms of the activities in which architects engage at various stages of their development. Pavlova examines the idea of transformation of the self through learning activities concerned with sustainable development in Chapter 9. In doing so, Pavlova argues for problem solving-based learning activities to ensure students do not regard the learning material as inert knowledge. MacGregor explores the development of teacher professional development in Chapter 10. Macgregor accomplishes this by analysing the transformations that occur as a group of 10 teachers transition to full participating members of the teaching community.

TRANSFER AS BOUNDARY CROSSING

Akkerman and Bakker (2011) argue that all learning involves boundaries and this is the case whether we are talking about the development of expertise or gaining knowledge of something. At the personal level, boundaries are the distinctions between what is known and what is not yet known. Akkerman and Bakker argue that at the occupational level, boundaries are becoming more explicit as a result of increasing specialisation. In order to avoid fragmentation, people look for ways to connect across work practices. An example of boundaries was identified by Alsup (2006), who found that student teachers encountered pedagogical values at the school level that differed from those found at university, and these represent one form of sociocultural boundary.

Akkerman and Bakker (2011) and others (e.g., Tuomi-Gröhn & Engeström, 2003) argue that developmental learning occurs as a consequence of a process they describe as boundary crossing, where meaning between different sides of the boundary are negotiated across the boundary, hence the term boundary crossing. Evidence of boundary crossing, both explicitly and implicitly, can be found in a number of chapters in this book.

Adapting to new situations (that is, transfer) often involves "letting go" of previously held ideas and behaviours. This requires an attitude to resist making old responses by simply assimilating new information to already existing schemas and mental models. Instead, effective learners need an attitude to look critically at their current knowledge and beliefs (Baartman & De Bruijn, 2011). Learning processes involved in such transfer are accommodation and transformation or expansive learning (Illeris, 2004), which involve not only cognitive but also social and emotional changes. Studies on boundary crossing show that people often try to keep or establish boundaries between different practices (e.g., professions) because of feelings of uncertainty or threat. For example, Timmons and Tanner (2004) discuss how nurses feel threatened in their professional identity by the emergence of a new, slightly similar profession.

The issue of boundary crossing is addressed in three chapters. Bjurulf argues in Chapter 4 that school-based workplace learning that runs parallel with workplace learning is not a simple transfer of school learning to a workplace setting, but an iteration of both forms of learning that can be regarded as a form of boundary crossing. In Chapter 5, Baartman et al. employ the idea of boundary crossing as a way to advance learning between nurses and technicians. In Chapter 6, Kilbrink explores the boundary that is created by the perception of formal learning as theoretical and workplace learning as practical. Kilbrink found that the boundary was artificial and that boundary crossing occurred as a consequence of the need to integrate theory and practice across both sides of the school-workplace boundary.

OVERVIEW OF CHAPTERS IN THIS BOOK

In this next section we introduce each of the remaining chapters and draw connections where appropriate between these chapters and issues raised in the first part of this introduction. In those chapters already discussed the authors theorise about transfer via concept learning (De Vries), the relationship between "useful" technological knowledge and its relation to other knowledge (Banks & Plant), transfer between school and work (Bjurulf; Baartman, Gravemeijer, & De Bruijn; Kilbrink), transfer and assessment (Kimbell), the transition to expertise (Middleton), transformation via sustainable development education (Pavlova), the transitions and transformations from university to school (MacGregor), and transfer between formal learning and learning from practice (Bjorklund).

In Chapter 2, De Vries advances the idea that with the rapid changes in technology that are characteristic of modern life, learning about technology in ways that do not become rapidly redundant could be achieved by employing concept learning to develop learning that is more robust and able to be used in a variety of appropriate contexts.

Banks and Plant explore the distinctions and relationships between science and technology and other knowledge in Chapter 3. Banks and Plant advance the argument that history and practice does not support the technology-as-applied-science belief that is dominant in both society and in the schooling system.

Bjurulf reports in Chapter 4 on research examining the transfer of learning between upper secondary school vocational studies and the workplaces in which students spent half their school time. Bjurulf found that transfer was an interactive process between school learning and workplace learning and not the one-way transfer sometimes thought to be characteristic of such programs.

In Chapter 5, Baartman, Gravemeijer, and De Bruijn present a study from the perspective of boundary crossing as an alternative to traditional transfer. They focus on the communication and collaboration between nurses and technicians, who work on the boundaries of their professions, and the learning opportunities offered by this boundary crossing.

Kilbrink examines the relationship between theoretical and practical learning in a school and workplace collaborative learning in Chapter 6. Kilbrink argues, on the basis of her research, that the dichotomised view of theory and practice is false and that, in reality, there is a necessary integration between theory and practice and that it is this integration that facilitates the transfer of learning.

In Chapter 7, Kimbell addresses the complex issue of the ways by which assessors of national school examinations transfer their judgements across different assessment items. Kimbell explores the cognitive processes that allow assessors to achieve coherence across judgements. That is, he is interested in how the transfer of assessment criteria and standards is achieved.

In Chapter 8, Middleton draws on a study he conducted with architects. The study examined the transition from competence to expertise. Middleton found that expertise in architecture had features in common with expertise generally, as did the transition, but that it was represented through both words and images and that, contrary to earlier views, imaginal data in the form of sketches provided a much fuller account of the transition to expertise in architecture. Middleton argues for the importance of utilising visual data when researching transitions in areas where learning is mediated by more than words, such as in design.

Pavlova employs Mezirow's (1978) work on transformative learning and Habermas's (1971) domains of learning research in Chapter 9 to develop the argument that education for sustainable development is more than students learning about environmental issues. Pavlova argues that for education for sustainable development to be successful it needs to be critically self-reflective and emancipatory.

Transitions and transformations of self are the topic of MacGregor's research in Chapter 10. MacGregor draws on a year-long study of beginning design and technology teachers to argue that the process of professional identity formation involves many transitions and the transformation of self. MacGregor identifies the factors that help and hinder beginning teachers transitions and transformations.

In Chapter 11, Bjorklund explores the discontinuity between formal learning, which is explicit and easily described, and learning in practice, which is often implicit and difficult to describe. Bjorklund argues that for transfer of learning to occur there needs to be a constant interplay between the explicit and implicit memory systems. Bjorklund calls the learning system based on this interplay a dual memory system.

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2. TRANSFER IN TECHNOLOGY THROUGH A CONCEPT-CONTEXT APPROACH

INTRODUCTION

One of the challenges of technology education is to keep the content of the curriculum up to date. This challenge is particular for technology education, as technological developments tend to go increasingly faster. Of course, other disciplines develop as well, but the increase of new subject matter in, for instance, science education, is by no means as great as in technology education. Constantly new devices are developed and implemented in society, with often quite dramatic changes in our daily life. Personal computers, the Internet, mobile phones, GPS, mp4 players, Facebook, and Twitter are all developments that took place in the past few decades. We would not like to have technology education without such new developments being part of the curriculum. But how can we avoid having to reinvent technology education every couple of years? The only way to do that is by seeking more overall concepts that are time-independent and yet give a first understanding of all these new developments. Engineers also use such concepts. The concept of "systems" is an outstanding example of that. Systems offer a basic understanding of many very different devices. Teaching about systems can help pupils get a first understanding of many devices around them, ranging from more traditional devices such as bikes and washing machines, to the newer ones like mobile phones and GPS devices. We know, however, that learning abstract concepts is more difficult than learning about concrete devices. Therefore we have to think about strategies to transfer what pupils learn from the study of one concrete device to other devices. That is what the concept-context approach in education aims at. In this chapter, I will first explain why transfer is a problem in technology education, and in education generally. Then I will describe the concept-context approach as an answer to that problem. Finally, I will draw some conclusions about how the concept-context approach could be used in technology education.

CONCEPT LEARNING AS A PEDAGOGICAL CHALLENGE

Concepts are by definition abstract. When describing reality, we can leave out aspects and details to end up with an abstract concept. The word "abstract" comes from Latin and means "pull off." A physicist looking at a cat that falls out of a window pulls off all aspects of this event except the physical aspect. The physicist is not concerned with the price of the cat, not with the fear the cat experiences

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during the fall, but reduces the event to a point mass making the motion of a linear acceleration. This description of the motion is therefore an abstraction, a concept. The strength of that abstraction is that I can use the same concept to describe other falling objects. I can transfer what I have learnt about the motion of the falling cat to other situations. This transfer, however, is not an automatic one. I first need to recognise what precisely is common in the motions of the falling cat and the other falling objects I can observe. When I am totally new to physics, I may still be distracted by the cat's price, fear, colour, or whatever else the event of the falling cat contains other than the motion of linear acceleration. One can compare this with the problem of recognising a chameleon in different situations. When we see a chameleon near the water, it has taken a blue colour and we may think that a chameleon is a blue animal. When we, however, see the same chameleon on a red roof, it has turned red and if we do not know what characterises the species of chameleons, we may think it is a different animal we see on the roof than the one we saw near the water. The same holds when we see it on a road and it has turned grey, or when we see it in the grass and it has turned green. In each concrete situation the chameleon takes a different shape. This also happens with abstract concepts, like system. In different disciplines, engineers give different concrete content to this concept. A mechanical engineer will use the concept of system to talk about matter, energy and information flows through complex devices. An architect, however, probably will not even use the term "system" to describe how different parts of a building have to work together in order to perform the overall function of a, let us say, railway station. It is difficult for someone who is not acquainted with the abstract concept of system to recognise that what the mechanical engineer talks about is in essence the same as what the architect talks about and can be expressed with the term "system."

STRATEGIES FOR CONCEPT LEARNING

In the past, we held the rather naïve belief that abstract concepts can be taught and learnt at an abstract level right away and then be "applied" to concrete situations. This, however, appeared to be too optimistic. It was one of the causes for the continuing existence of incorrect conceptions in the learners' minds. The only effect was that these learners, who already had certain ways of dealing with the various concrete situations, now learnt an additional strategy for that next to the intuitive ones they already had. What then happened is that the way they approached the concrete situation depended on the question of whether or not it had to be dealt with in an educational situation. In a classroom situation, the learners would deal with the situation as told by the teacher, that is, by using the learnt abstract concepts and principles, but once returned to daily life, they would fall back on their own intuitive ideas. Someone expressed this as the persistent coexistence of a "school image" and a "street image." In fact, it means that the concept is not understood, nor is its connection to concrete objects. It is only seen as an artificial way of dealing with certain situations without practical relevance.

Having seen this, educationalist took a next step and started working with the idea of “transfer.” Learners would then be confronted with a practical situation, be taught how to separate out the abstract concept from this situation, and then transfer it to another situation. This, too, appeared to be too naïve. The reason for this has been explained above in the chameleon metaphor. Being able to transfer in fact already presupposed the mastery of the abstract concept, which does not take place after having had the opportunity of seeing one and the same concept in different situations. This is needed in order for learners to be able to distinguish what in the whole event is particular for that situation (for instance, the long tongue of the chameleon) and what is situation-specific (the colour it has taken). This is where the concept-context approach comes in.

In the concept-context approach, learners get to see different situations that can be approached by using one and the same abstract concept. They first get to see the green chameleon in the grass. They learn various properties of the beast, including its colour. Then they get to see the chameleon sitting near the water and again they study all the characteristics of that animal. Perhaps some commonalities already strike them as they go. Next, they study the chameleon on the red roof and again learn the various characteristics and the beast, now probably getting already a better feeling for what is common for the three situations having been studied now, and what is particular for them. Gradually, they learn what is constant about the animal for all the different situations in which they study them and thus learn what a chameleon is. Once they have mastered that, they have no difficulties in recognising a chameleon sitting in a bed of purple flowers and having again taken a different colour.

So the concept-context approach claims to be a solution for the problem of transfer in concept learning. By studying the concept in a series of different contexts, learners gradually develop an understanding of the generic properties of the concept (Bulte, Westbroek, De Jong, & Pilot, 2006; Pilot & Bulte, 2006). There is another effect of this approach. By first learning the concept in concrete situations where other concepts also play a role, the leaner will also develop an understanding in relations between one concept and other concepts. Thus, a network of concepts emerges in the learner’s mind rather than a set of isolated concepts. This gives extra versatility to the concept. Not only can it be used in a variety of different concrete situations, but for each of those situations, it can also be linked to other relevant concepts.

This idea matches very well with recent notions such as situated cognition and cognitive apprenticeship (Hennessy, 1993), that also express the notion that knowledge always has a “local” dimension and is never entirely abstract, and that therefore learning can best take place in a concrete situations where a learner learns from a local expert as in an apprentice-master relationship.

There is, however, one obvious disadvantage of this approach. It is more time consuming than the approach in which the concept is taught at an abstract level immediately. It can, however, be questioned if learning takes place at all in that direct approach. The same holds for the more deductive approach in which concepts are taught in only one concrete situation and then taken to an abstract level. Transfer still appears to be difficult then. Probably the extra time spent on learning in various contexts before gradually moving to an abstract level provides its own rewards because learning is more in-depth and lasting. Besides that, it has a better chance of challenging the intuitive notions that the learner held before studying the concept.

CONCEPTS AND CONTEXTS IN TECHNOLOGY AND ENGINEERING

We have now seen that the concept-context approach claims to enable concept learning in a more effective way than "applying" concepts leant at an abstract level first, or than the transfer of concepts learnt in only one concrete situation first. If we want to apply this approach to put together a curriculum for technology education that enables teaching and learning that is not as time-dependent as just studying each and every new gadget that appears on the market, then this concept-context approach seems to be attractive. But to be able to apply it, we have to know what concepts and contexts are relevant for technology education. In order to find that out, some years ago, a Delphi study was done to identify such concepts and contexts. The results of this study were that a set of concepts was found on which experts in the philosophy of technology, in engineering, and in technology education agreed. In addition, a list of contexts suitable for teaching and learning those concepts was identified.

The outcome of the Delphi study was the list of concepts presented in Table 1.

Table 1. Concepts

Main concept	*Sub-concepts*
Designing	Optimising
("design as a verb")	Trade-offs
	Specifications
	Technology Assessment
	Inventing
Modelling	(abstraction, idealisation)
Systems	Artefacts ("design as a noun")
	Structure
	Function
Resources	Materials
	Energy
	Information
Values	Sustainability
	Innovation
	Risk/failure
	Social interaction

This list differentiates between main concepts and sub-concepts. This is something that was added later to the outcomes of the Delphi study, where experts had brought forward concepts that evidently were at different level of generality. The researchers therefore identified some concepts as more "basic" than others and grouped them as can be seen in Table 1. The sub-concepts for modelling were also added later by the researchers, just to get the idea that for modelling, as for the other basic concepts, sub-concepts can be identified, if desired.

Valuable as this list may be as an indication of what experts see as important concepts in engineering, the list was not developed on the basis of systematic analysis, but on the listing of separate, individual concepts. Particularly at the level of sub-concepts, this causes the possibility of missing sub-concepts. This is indeed the case. There are at least two instances of sub-concepts that must be added to the list as in the literature they are seen as part of a systematic analysis of one of the main concepts. In the first place the main concept of "systems" has artefact, function, and structure as sub-concepts. It is clear, however, that function and structure are necessarily connected by working principle. It is the working principle that makes it possible that a certain physical structure can fulfil a certain function. It is the lever principle that makes it possible that a long rod can function as a device with which a small force can be transformed into a large force. In fact, working force was in the total list that was produced by all experts together, but it was ranked too low to get into Table 1. An example like this makes clear that more analytical work is necessary to turn Table 1 into a more coherent set of concepts and sub-concepts.

Another limitation of Table 1 and the way it was developed is that we do not get to see the engineering disciplines underlying the concepts. The concepts are in fact instances of overlap between different engineering disciplines. That makes them valuable for a general education curriculum, but there is a certain danger that in elaborating this list into a curriculum we may choose our example in such a way that certain disciplines will be missing. One can question whether that is a problem. But if, for instance, the whole domain of nanotechnology would be absent in this elaboration, one can question whether that curriculum is an up-to-date representation of technology and engineering as we know it today. In fact, nanotechnology was mentioned by some experts as a possible context, but in the ranking went to the bottom of the list because it was not really a context. That fits with the chosen methodology of focusing on concept and contexts, but it does create a risk of some disciplinary domains not being recognised in the curriculum.

In Table 2 the outcomes of the context part of the Delphi study are presented.

The terms in the table were not always the terms used by the experts. The researchers used them to group contexts under headings that express human and social concerns. The idea for that did emerge from the Delphi study, as several experts expressed as their motives for bringing forward certain contexts that they saw a need for technology education to deal with "what makes the world a better place," as one of them expressed it. In other words, these experts saw the need for technology education to address basic human and social needs as contexts for learning concepts related to technology and engineering.

Table 2. Contexts

Context
Shelter ("construction")
Artefacts for practical purposes ("production")
Mobility ("transportation")
Communication
Health ("biomedical technologies")
Food
Water
Energy
Safety

The contexts in Table 1 are still relatively generic and a transformation to a more practical level is needed. There is still some debate as to what this "lower" level should be. Some see it as mere examples of situations in which we find these human and social concerns. Others (e.g., Bulte et al., 2006) talk about "practices" as the preferred concretisation. Practices then are meaningful sets of activities in which pupils can be engaged in daily life. For the context of health, for instance, a possible practice is going to the dentist every six months. This is something that pupils experience themselves. Through this practice they all get acquainted with waiting rooms, dentists' drills, advice for how to brush one's teeth, etcetera. The notion of practices is taken from ethics. Ethicist Alisdair MacIntyre (1985) came up with the idea that morally good behaviour is learnt in concrete situations and therefore becomes context dependent. One does not learn to become a "good human being" in general, but one learns to become a (morally) good teacher, or a good surgeon, or a good engineer. Here we see the same context-dependence as in concept-learning. For that reason, the notion of practices seems to be a suitable one for concretising our contexts.

AN ELABORATED EXAMPLE: SYSTEMS

I have already mentioned the concept of systems as an obvious example of a concept that is used throughout the various engineering domains, be it not always under that name. Let me now show how the concept-context approach can support the transfer of this concept from one domain to another.

A possible entry to the concept is to do a first project in the context of shelter. This context refers to the human and social need of protection against the elements. The school building can be an example of that. In some countries, learning takes place in the open space, but this means that schooling is weather-dependent. When it rains, no teaching can take place. Therefore, people now construct school buildings. They can range from very simple one-room shelters to the complex and advanced buildings that we see in some countries. But irrespective of the level of complexity and sophistication of the school building, in all cases the various elements of the building all have to work together in order to realise the overall function of shelter in the context of teaching and learning activities. Even in the case of a one-room school building, there is a floor, a roof, and walls that have to come together to protect the teacher and learners. In a multi-room school building, the architect also needs to reflect on the way various rooms have to "cooperate" in order to realise the overall function of the building. Architects do that by using maps and drawings that show the flow of "traffic" between rooms. By emphasising this aspects of "parts working together" in the classroom activity on shelter, the teacher can point the learners' attention specifically to one of the basic characteristics of systems and thus initiate the learning of this concept. In a second project, now in the context of water, a project on clean water at home can be done. Pupils can do activities that make them aware that a whole set of artefacts is used to get clean water into the house, use it for various purposes, and then get rid of the used water. They may note that, contrary to the previous project, experts use the term "system" in this context. By again pointing specifically at the notion of parts working together, the teacher can begin to raise an awareness of this communality between the two projects. But the teacher also has to take into account that this notion of parts working together takes quite different shapes in the two contexts. In the first project, the parts are very stable and fixed. Rooms cannot easily be replaced or transported. In the water situations, some parts of the system, however, do get replaced (like the tap washer or the central heating boiler). A third project then can bring to the fore again the same idea of parts working together, but now in the context of mobility. In this context, there are lots of opportunities to show that the parts working together can be very different and also include humans. The local bus system is a combination of transportation means, infrastructure, organisation, and people all working together to bring other people from A to B. This concretisation of the concept of system is again very different from the previous ones at first sight, but by studying the way elements of it are all entangled somehow in order to realise the transportation function, the learners get to realise that the situation is not 100% different from the previous ones. Next, a project in the context of communication can further enhance the idea that parts working together may look different in different contexts, but in essence is the same for all those situations.

PRECONCEPTIONS

As stated before, in the concept-context approach one can address certain preconceptions that learners may hold. Unfortunately, in technology education we do not yet know much about preconceptions in our domain, in particular when comparing to the domain of science education where research into preconceptions has already become a well-established tradition. Technology education in this respect is still in its infancy, and there is a need for more research here. We do have some examples of studies into pupils' preconceptions. For instance, a recent study has shown that in primary education, both for children and for their teachers the concept of system is by no means an obvious one (Koski & De Vries, 2012). Children have difficulties to realise the boundaries between their own activities and the activities that have been taken over by a device in the function of, for instance, making coffee using a filter coffee machine. Also, they are limited in their awareness of the different types of input and output (in particular, energy and information inputs and outputs are often not recognised as such). Frederik, Sonneveld, and De Vries (2011) studied teachers' preconceptions regarding the relation between structure and function. It appeared that the teachers had difficulties seeing the difference between the two because they tended to call some properties of an artefact functional that were clearly structural and vice versa. If that is already the case for teachers, it can be expected that pupils will have even more difficulties distinguishing between functional and structural properties of artefacts. Frederik et al. are the only ones who dealt with the list of fundamental concepts in Table 1. There are some other studies, but those refer to concepts at a much "deeper" level. Parkinson (2001), for instance, did a study into misconceptions related to the sub-concept (in Table 1) of structures among student-teachers. He found various misconceptions that became evident when the student-teachers were asked to design a bridge. The fact that these misconceptions were revealed in the context of a design challenge shows that design activities can be a vehicle through which preconceptions (some of which can be called misconceptions if compared to scientific theories) can be made visible and hence discussable. That suggests design activities as a possible educational strategy for making pupils willing to bend their intuitive conceptions towards the more scientific ("correct") concepts. In a similar way Ginns, Norton, and McRobbie (2005) found various dubious preconceptions related to material properties among primary school children. They, too, used design activities to bring these preconceptions to the surface. They also found that the design activities helped the pupils to develop a better understanding. They did not yet, however, suggest an explanation for that. In the next section I want to present one that directly relates to the nature of design.

DESIGN ACTIVITIES AS AN OPPORTUNITY FOR CONCEPT-CONTEXT

So, one of the possible practices that can be found in all contexts presented in Table 2 is designing. Although this is not a practice in which learners are normally involved (one of the requirements for a practice as an educational concretisation of contexts), it is well accessible for learners and can directly refer to challenge they experience in daily life. Design activities are particularly attractive because they allow for cognitive conflicts to be realised. Cognitive conflicts are situations in which learners' intuitive and scientifically incorrect notions conflict with reality. For instance, children may have the preconception that bigger objects will sink rather than smaller objects. The design challenge of building a boat that can carry as much weight as possible would then result in a small boat, as they expect this boat to be better in floating than a large boat. But one team could be smart enough to build a big boat and easily win the challenge. Seeing the large boat hold all that weight can cause a cognitive conflict with the other children and make them open for altering their ideas about floating and sinking.

Another advantage of design challenges in the concept-context approach is that design situations always require a combination of insights into different concepts. In the boat challenge example, the notions of sinking and floating have to be combined with ideas about stability of floating objects. As stated before, the concept-context approach stimulates the development of a network of concepts in the learners' minds. This is precisely what a design challenge needs. In literature, we find design mentioned as an activity in which not only existing knowledge is used, but in which also new knowledge is gained (De Vries 2005). Historian of technology Walther Vincenti (1990), for instance, mentions design as one of the sources of "what engineers know."

CONCLUSION

In this chapter, I have shown that certain concepts can be identified that characterise technology and engineering, and that those concept can be taught in contexts that represent the purpose of technology and engineering as "making the world a better place." I have also claimed that design activities can be a suitable context (or practice) to teach those concepts. I have shown that some insights into pupils' and teachers' preconceptions regarding these concepts have been gained, but that these insights are fairly scattered and scarce. Clearly, there is still a challenge here. I would like to suggest that there is a need for research studies that either support or refute my claim that design activities have certain characteristics that allow for cognitive conflicts to occur and hence are suitable for a constructivist teaching of concepts.

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3. TRANSFERRING KNOWLEDGE VERSUS KNOWLEDGE THROUGH TECHNOLOGY EDUCATION

What's the Difference?

INTRODUCTION

In this college,
Useful knowledge
Everywhere one finds,
And already,
Growing steady,
We've enlarged our minds.[1]

These lines come from a Victorian comic opera that lampooned university study generally and women's higher education in particular. A hundred and thirty years later it still points up current distinctions between different types of knowledge and hints at what type of knowledge is more valued. The "Classical" education of the time had little if any technical or scientific tuition, but the author was only mildly satirical realising that "Useful knowledge" was something that the Victorians valued highly. Steam engines and railways, bridges and tunnels were the physical manifestation of a "can-do" ethos of the age which placed practical utility to the fore and often demonstrated that technological knowledge led while scientific explanation followed rather than vice versa. Gaining such practical and technical know-how was recognised as needing more than a reliance on a simple "rule-of thumb" craft-based apprenticeship model, and Mechanics Institutes had been established by the start of Queen Victoria's reign in most of Britain's major industrialised towns to provide more formal adult education in a range of vocational subjects. Many became the forerunner of some famous current Universities such as Herriot-Watt University in Edinburgh, Birkbeck College in London, and University of Manchester Institute of Science and Technology (UMIST), now part of the University of Manchester. But what of today? What is the relationship between the useful knowledge that is particular to technology and situated in the context of learning about technology, and what is its relationship to the knowledge transferred from other domains, particularly science, which is exploited in technology education?

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One often hears people, especially politicians, referring to "science and technology" as if science and technology were a single activity inseparably linked. The aims and processes of science, however, are fundamentally different from those of technology and the links between them are not as formal as many people think. Maybe the confusion is because science is seen, erroneously, as necessarily underpinning technology – providing the foundation to develop "useful knowledge." Disappointingly, the confusion is also present in the school curriculum where, in simple terms, science is often seen as "theory," that is, "know-why," and technology as both practical, that is, "know-how," and in some way dependent on science. To consider knowledge transfer from other subject domains that may be exploited in technology education, particularly science, we must first clarify our understanding of "science" and "technology," and how science knowledge is "exploited" in learning technology; and vice versa how technology is used to advance science.

This chapter considers:

– the distinction between scientific knowledge (knowledge usually gained through studying science) and technological knowledge (knowledge usually gained through studying technology);
– the relationship between science and technology using examples from history. When knowledge transfer has been important and when it has not;
– the common ground between science and technology;
– designing and problem solving as key areas of knowledge used and learnt in technology which have wider application, and technology as a lead subject for learning "affective" knowledge; and
– systems thinking both in science and in technology, and "black boxes" – designing electronic systems as a technological process.

THE DISTICTION BETWEEN SCIENTIFIC AND TECHNOLOGICAL KNOWLEDGE

> Technology is about creating artefacts and solving problems, while science is primarily about describing and explaining phenomena in the world. (Noström, 2011)

Young people want to know *why* something is the way it is or *how* something works; they seem to want answers to two sorts of questions. One type of question seeks knowledge of the "knowing how" variety – how a thing works, how it is used, how it is possible to improve the function of something or the way something is done, or how to create something which has a new purpose. This is technological knowledge. It is the practical knowledge of application, that is, know-how or more formally the *operating precepts*. The other type of question seeks knowledge of the "knowing why" variety – why the world is the way it is, first to help us understand the rules that confirm generally accepted agreement about what we know, and second to help us rationalise the experience of our senses. This type of knowledge is called scientific knowledge. It considers the whys and wherefores of the operating precepts, that is, the science of the know-how, or more formally the *operating aetiology* (Clarke, 1982). Thus the baking of a cake by following a recipe uses operating precepts; mix this with that in these proportions according to these instructions and there you have it – a birthday cake. Understanding the chemistry of why particular ingredients, when mixed in particular proportions, produce the result they do is the operating aetiology – and you do not necessarily need that kind of knowledge to bake a cake!

However, scientific knowledge would be useful in improving the design of the cake. If we consider the birthday cake as a food product, then we could draw on knowledge of food additives to improve the cake's shelf-life or reduce its sugar content. A knowledge of nutrition would enable us to produce similar party food which is just as much fun but healthier to eat.

The press cliché is that we live in a "technological age." Some would say that all should have an understanding of the workings of what we use, yet most of us lead perfectly satisfactory lives on the basis of knowing how rather than knowing why. One can know *how* to drive a car without having much idea of *why* the engine and all its control systems do the job they do. Similarly, a motor mechanic (or a TV engineer and numerous other "serving" people) can mend engines without any knowledge of gas laws, combustion principles, materials properties, or other scientific knowledge of the "knowing why" variety.

The level of "knowing why" needs to be appropriately matched to the needs for the "knowing how" for them together to be useful knowledge for creating appropriate products.

TECHNOLOGY BEFORE SCIENCE?

Science has been in the school curriculum for a long time yet the subject of technology is a relative newcomer. In many countries technology in the curriculum fights for its survival as curriculum designers have perhaps tended cling to the belief that science education provides a more appropriate preparation for students intending to follow careers in industry and that without a thorough understanding of scientific principles there can be little progress in the various fields of application.

The assumption that science knowledge always precedes technology knowledge can be challenged through some wide-ranging examples (see Plant, 1994). How to refine copper has been known since ancient times, millennia before the concept of oxidation was understood. Around 1795 the Paris confectioner Appert devised a method of preserving food by heating it (to kill bacteria) and, without delay, sealing it in a container. The idea caught on, and a cannery using tins was already functioning in Bermondsey in 1814 when Louis Pasteur proposed a "theory of bacterial action." England became the "steam workshop" of the world in the 18th century following the invention of the first commercial steam engine by Thomas Savery and Thomas Newcomen at the end of the 17th century (Bronowski, 1973). Their knowledge of how to design steam engines spread as "know-how" across Europe and to North America. Yet the concept that heat was a form of energy able to do work came later. Later still Sadi Carnot, an officer in the French Army, became preoccupied with the concept of heat engines but it was years before his findings influenced steam engine design. The science of thermodynamics followed from the intellectual challenge to understand the operation of better steam engines. The principal point is that technology is more than the application of fully understood scientific knowledge; a point acknowledge by the economist Nathan Rosenburg:

> It is knowledge of techniques, methods, and designs that work, and that work in certain ways and with certain consequences, even when we cannot explain exactly why. It is […] a form of knowledge which has generated a certain rate of economic progress for thousands of years. Indeed, if the human race had been confined to technologies that were understood in a scientific sense, it would have passed from the scene long ago. (Rosenburg, 1982, p. 143)

Technologists today use a host of ideas and "rules-of thumb" that are helpful but not scientifically sound. Examples include the idea of a centrifugal force, heat flow (like a fluid), and the notion that a vacuum "sucks" (see Noström, 2011). For example, heat flow in science is often conceptualised using the kinetic theory of molecular motion. This is of limited value in technology where heat flow related to conductivity (or even "U values") and temperature difference is usually much more useful in practical situations. In order to use a particular idea for practical action, it is sometimes the case that a full scientific explanation is unnecessary and too abstract to be useful knowledge:

> [Reconstruction of knowledge] involves creating or inventing new "concepts" which are more appropriate than the scientific ones to the practical task being worked upon. … Science frequently advances by the simplification of complex real-life situations; its beams in elementary physics are perfectly rigid; its levers rarely bend; balls rolling down inclined planes are truly spherical and unhampered by air resistance and friction. Decontextualisation, the separation of general knowledge from particular experience, is one of its most successful strategies. Solving technological problems necessitates building back into the situation all the complications of "real life", reversing the process of reductionism by recontextualising knowledge. What results may be applicable in a particular context or set of circumstances only. (Layton, 1993, p. 59)

In technology, if the knowledge is useful then it continues to be exploited until it is no longer of use. In science, a concept that is not "correct" in that it does not match experimental results or related theory is discarded. However, rejection of certain scientific ideas such as phlogiston, the caloric theory of heat, and acceptance of energy as quanta took many years!

It is obviously true that new technologies have arisen from scientific discoveries. Microelectronics is founded on the "blue skies" fundamental science of semiconductors and similar fundamental research has led to

– improved knowledge of the intrinsic properties of materials such as lightweight alloys, carbon fibres, and plastics;
– the development of new types of superconductor, the laser, and other electronic devices; and
– high yielding, disease-resistant crops through an improved understanding of the scientific basis of genetics.

There is a link between scientific discoveries and new or improved technologies, and technology *can* stimulate new directions for science too. Space research is an example of this. Technological developments, for example rockets that can launch the Hubble Space Telescope and the Curiosity Mars Rover – technological achievements in their own right – can promote new challenges for science by revealing new features of the universe.

COMMON GROUND BETWEEN SCIENCE AND TECHNOLOGY

As we have seen, science does not need to precede technology but technology can be stimulated by the findings of science. Indeed, in response to today's economic demands there is pressure to structure scientific research with the specific purpose of stimulating technology, and hence a nation's wealth. Of course, the "laws of nature" as formulated by science set particular constraints within which all technological activity has to take place. For example, the second law of thermodynamics suggests that the building of a perpetual motion machine is futile despite inventors' persistent efforts to "break" the law! Other constraints may be economic, human skill and imagination, cultural influences, resource availability and so on. Furthermore scientific discoveries can suggest new products such as lasers and nuclear magnetic resonance imaging in medicine. Conversely, as illustrated above, technology does make a contribution to science in several ways. Examples include providing the stimulus for science to explain why things work in the way they do. The contribution of technology is especially evident in the way scientific concepts are deployed in technological activities.

It is useful to make a distinction between concepts which are directly related to knowing how (i.e., technological concepts as defined above) and concepts related to knowing why (i.e., scientific concepts). It is very difficult to make hard and fast distinctions between these two types of concepts, but consider the following examples. An electron is a concept, a fundamental atomic particle; science is able to describe its mass, charge, and other properties. In these terms the concept of an electron has no obvious practical application and is an example of a "knowing why" concept. On the other hand a light switch is a technological concept for it has been designed for the particular purpose of switching on and off a flow of electrons. It is a "knowing how" concept.

To see how the concepts are deployed in teaching science and technology, take the concept of *insulation* (a technological concept), which has relevance to understanding *conduction* (a scientific concept) of electricity and of heat. In the context of a science lesson, a teacher might involve children in exploring *electrical* *conduction* through simple experiments, for example, by using an ohmmeter to compare the resistance of a variety of materials, or using a simple circuit and noting the effect on the brightness of a lamp when different materials are placed in series with the lamp. In a study of *heat conduction* students might be encouraged to plot temperature/time graphs that compare the rate of cooling of a beaker of hot water wrapped around with different materials. Very often such a science activity would be placed within an "everyday" context (see Figure 1). The aim, in a scientific sense, is to find out the property of the material. This would lead on to the idea that if there is a lot of trapped air, then that material is a good insulator as it stops convection. However, as Murphy (1991, 2007) notes, some students (particularly girls) are distracted by this technological context. The important first step in this science lesson is to strip away the context to set up a comparison

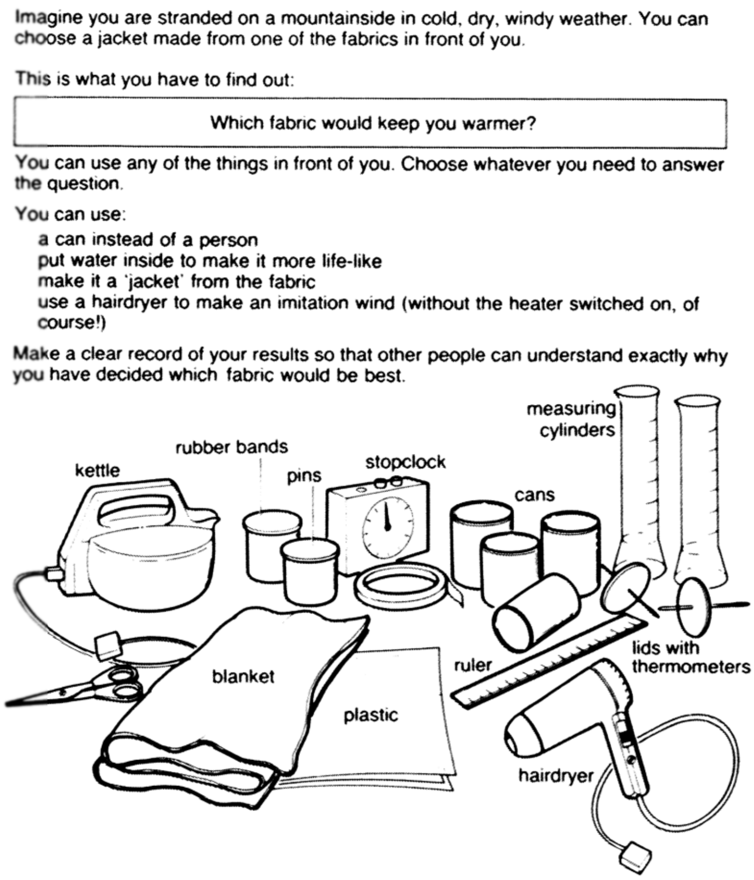

Figure 1. Investigating the "best" material for a mountaineer's jacket.

experiment between differently lagged beakers; yet some students will wish to stick with the real problem presented and make a little "jacket." After all, that is what was asked for, not some abstract experimental method. Rather than making the science lesson "real" and meaningful, the context has provided a serious distraction.

This is an example how knowledge that is important for a science lesson is not the totality of the useful knowledge for a technology lesson. In technology such an understanding of suitable material properties would be an important factor to consider, but it would not be the only criterion. In addition, the students would need to consider non-scientific factors such as cost and availability, water resistance and toxicity, strength and flame-proofness, and colour and density of the insulating materials that might be used. So, whereas scientific knowledge of heat conduction would contribute to the design process, a range of other factors could also influence the choice of insulating material, such as its appropriateness to a given cultural context. Further, suppose scientific experiments in a country with few "advanced" material resources show that the stripped and powdered bark of a local tree, or the cotton-like seed heads of a local plant, would make a suitable low-cost heat insulating material. Why then should the technologists in this country use a hard-to-obtain and costly imported insulating material when the collection and preparation of this indigenous material also provides local employment? These wider considerations that are grounded in know-how and the value systems of the people using the technology are an important aspect of technological design activities.

In summary, science often has a contribution to make to enhancing design and technology projects. However, teachers need to be clear about what that contribution may be, and plan to teach it to students. It is also important to realise that in designing and making, scientific understanding is but one contributory factor among many competing concerns. Although scientific ideas *can* enhance projects, it is possible, in fact usual, for a student to conduct complex technological activity without first exploring and understanding all aspects of the science involved.

OTHER USEFUL KNOWLEDGE DEVELOPED IN TECHNOLOGY CURRICULA

Affective Knowledge and Values

Technology cannot be divorced from other dimensions of human thinking and behaviour since the beliefs and values of individuals and communities are influenced by, and exert pressure on, technology itself. In technological activities it is just as important to involve students in making value judgements about the *human*, or rather *humane*, dimensions of technology as it is to focus solely on technical details about the functioning of the technological product. Given that the *purpose* of technology is to respond to certain sorts of need, students should be expected to find answers to questions such as:

- Whose needs are to be met?
- Who has identified the needs?
- Are proposals for a particular technological development acceptable to the individuals and communities who are to use or be influenced by the development?

Decisions about various technological *processes* are affected by a range of criteria, each of which depends on different kinds of values. For example, materials used may be in short supply or come from environmentally sensitive regions of the globe; new construction projects may disturb or destroy wildlife, and so on. Evaluations of the *products* of technological activities are subject to decisions about fitness for purpose, cost effectiveness, possible health hazards, and so on. People's values affect every stage of the technological process from decisions taken about whether to embark on a particular innovation, through the process of development, to the acceptability of the subsequent product. The clarification of values is a responsibility of all engaged in technological activities and it has a central role to play in the affective dimension of a student's education.

The different *social* meanings attached to technology are nowhere more evident than in the use of the terms *high technology* and *intermediate technology*. The former is used to describe large-scale, capital-intensive technologies such as microelectronics which use a highly skilled workforce; and the latter is used to describe small-scale (Schumacher, 1973), labour-intensive technologies advocated for small communities that capitalise on local skills and resources which are at the community's disposal. It is of course quite possible that relatively high-technology electronics may be *appropriate* in small communities (e.g., those in remote areas), but this leads to issues about control of technology and economic power. It is these influences that make design and technology rich in educational terms. The interpretation of what is needed, how it is to be done, and who is to benefit should be made explicit and debated in order to question the value judgements that underlay any assumptions about a course of action.

Problem Solving

Discussions about technology as a vehicle for the teaching of problem solving sometimes become emotionally charged. Over the years, those proposing different technology curricula have used this argument as a principal way of advocating that technology should have an enhanced status in the school curriculum because a general ability to solve problems is central to satisfying human needs. Glaser (1984), Hennessy and McCormick (2002), and Layton (1993) all suggest that learning is heavily influenced by the context in which it occurs. McCormick (2006) in particular suggests that this is to be expected if one takes a sociocultural view of learning, where knowledge is the result of the social interactions in which it occurs and is inseparable from them.

Students do not easily transfer their ability in a particular activity from one learning "domain" to another. Technology teachers have assumed that if students are taught to investigate the factors influencing the design decisions for making one product, for example a moisture sensor, then they will be able to transfer those techniques to consider the different design decisions for, say, batch food production. The evidence is that students do not easily transfer their understanding across these different contexts and require considerable support from their teacher to help them do so (McCormick, 2006). Barak (2007) agrees that no all-purpose problem-solving method exists, but has set out a set of series of what he calls "strategies, schemes and heuristics" that would help teachers and their students to start with a framework for considering various possible problem-solving techniques. Murphy and McCormick (1997), however, caution that such strategies become an "algorithm" which sometimes teachers and students follow rather slavishly. Problem solving within a specific context is not confined to learning in technology; many people are able to add up effectively when shopping in a supermarket but find a similar sum set in a maths lesson very difficult (Lave, 1988).

There is a close association in a particular context between the conceptual knowledge associated with the particular problem and an understanding of what action needs to be done to tackle that problem (procedural knowledge). People think within the context in which they find themselves – "situated-cognition." Murphy (2006) and Murphy and McCormick (1997) suggest that when students are presented with problems in unfamiliar contexts they tend to use everyday knowledge to tackle them.

Designing

Although problem solving is seen as central to the teaching of technology, "designing" is sometimes considered as so important that it is separated out – as in "technology and design" – perhaps for extra emphasis, as in most of the school technology curricula around the world students engage in designing to some extent. Mawson (2003), working in New Zealand, sets out the particular emphasis on the "design-make-evaluate" process there and in many other countries. He also notes the widespread criticism of how such an artificially linear "design process" is taught in schools, drawing on a wide range of research studies in Australia, Canada, and England and going back very many years. For example, Archer (1973) advocated design to be developed to a level which merited scholarly consideration, and Eggleston (1992) agreed about its importance:

> At the heart of the matter is the design process. This is the process of problem-solving which begins with a detailed preliminary identification of a problem and a diagnosis of needs that have to be met by a solution, and goes through a series of stages in which various solutions are conceived, explored and evaluated until an optimum answer is found that appears to satisfy the necessary criteria as fully as possible within the limits and opportunities available. (p. 18)

Eggleston, therefore, sees design as a special form of problem solving, and just as is the case with problem solving discussed above, many have criticised the simplistic models that were promoted when technology (or *design* and technology!) was first introduced into schools as a more scholarly activity than the former craft-based subjects. Initially such criticisms manifested themselves in the search for alternative models which better described what people engaged in a design activity actually did. This search for the "holy grail" of a supposedly correct description of the design process might have been seen as imposing order on what is necessarily a complicated and iterative process. That some countries wish to do this is to be able to assess and give students credit for the *process* of technology rather than just the end product that they make. However, this desire to assess builds in a level of unfortunate artificiality – even game playing – that is unacceptable to many learners. For example, when evidence of ideas is judged through a portfolio of drawings and notes, it is not unheard of for a student to be advised (after they have completed their final made artefact) to go back and invent some more "initial ideas"!

Mawson (2003) advocates that prior to any introduction of a perceived need, students need to be exposed to the context within which the task will be based:

> During this exploration of the general knowledge, relevant information, and social attitudes relating to the particular context, children should also be given an opportunity to explore the range of materials available to them when working towards their solution. (p. 123)

As was plain from Murphy's (1991, 2007) example of the mountaineer's jacket above, not only does the context shape students' ideas and thoughts about their emerging design, so does the opportunity to engage in their work alongside others. The opportunities for such collaborative work, however, are often not offered to students in the individualistic common "design-and-make" technology education paradigm common in many countries.

Systems Thinking

"Systems thinking" is a process of considering interacting elements in terms of overall function rather than a concentration on the individual component parts; looking at the whole building, as it were, rather than the individual bricks. Systems thinking is important in both science (particularly biology) and technology. In biology, examples of organs working together to perform a certain task include the digestive system, blood circulation system, and nervous system. Such systems are present in all mammals and in all cases they can be considered as a functional block that does a job – but with component parts. For the blood example, components are the heart, blood, and blood vessels; for the nervous system, the brain, spinal cord, and peripheral nerves. The approach to first aid is also systemic, as is triage, the process of determining the priority of patients' treatments based on the severity of their condition, dealing with bleeding and breathing problems before taking action on broken bones. In technology, the design and use of electronics systems is an example of the value of using know-how rather than know-why in technological activities in the classroom (see Banks & Barlex, forthcoming). In technological activities, students are expected to have a clear idea of what they want the electronics systems to do; it is a goal-oriented approach that is an essential ingredient of the successful use of electronics in designing and making activities. Rather than focusing on any scientific understanding of the way in which the individual devices and circuits work, the emphasis is on the functional aspects of the electronic devices and circuits that the students are to use. Students should be expected to ask questions such as:

– What do I want my electronics system to do?
– What operating conditions, for example, power supply requirements, does it need to work?
– Will the device stand up to rigours of use in its intended environment?
– How much will it cost to make and run?
– What characteristics of this device are better for this design than other similar devices?
– Will it be safe and easy to use?
– Can the components needed be obtained easily?
– Will it be acceptable, culturally and economically, to the people in the community in which it is to be used?

To a technologist, meeting these functional and contextual criteria are as important a consideration as knowing why the electronic devices used work in the way they do. The emphasis on *function* and *context* rather than *theory* and *fundamentals* may be misleading, seeming to lack opportunities for rigorous thought. However, the design and assembly of circuits and systems for specific purposes requires knowledge and understanding at the operational level. These operating precepts are just as demanding intellectually as the operating aetiology used by science to explain concepts such as electrical conductivity and potential. An example or two will make these points clearer.

An *electronics system* can be represented by three linked building blocks as shown in Figure 2. It is an assembly of functional electronic *building blocks* that are connected together to achieve a *particular purpose*, for example, sounding an alarm when smoke is in the air. Examples of *input* building blocks include switches, for example, mechanical and semiconductor types, microphones, and light-dependent resistors. *Processor* building blocks include amplifiers, comparators, oscillators, and counters. *Output* building blocks include light-emitting diodes, seven-segment displays, loudspeakers, and meters. Thus, the *input* building block of a smoke detector would be a smoke sensor. Its *processor* building block might comprise a comparator to switch on an audio frequency oscillator when the smoke level detected by the sensor has reached a pre-set danger point, followed, perhaps, by an amplifier. The detector's *output* building block would be a small loudspeaker or piezoelectric device to generate an audio

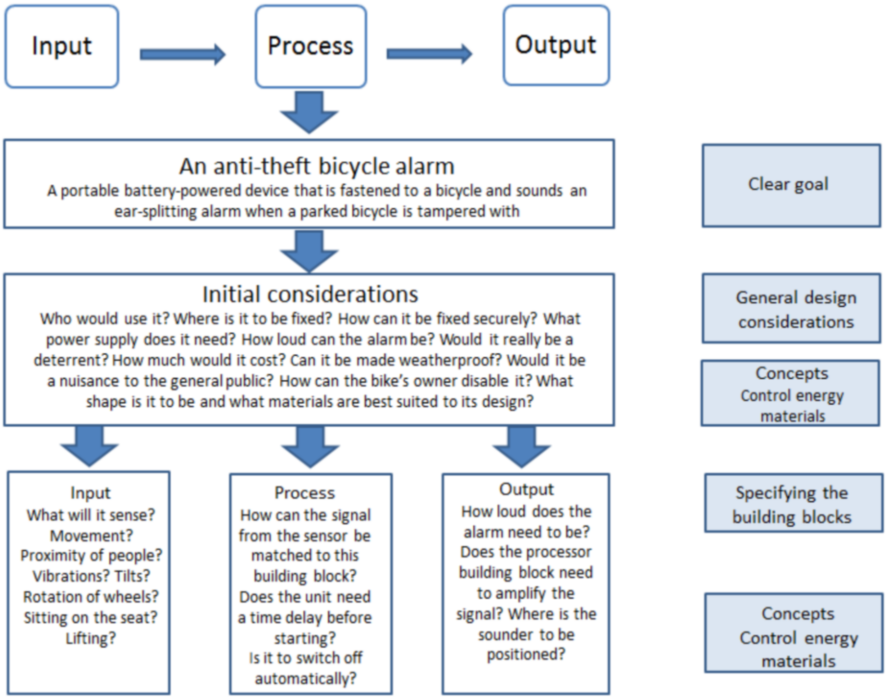

Figure 2.The linked building blocks of an electronic system and some of the technological criteria and concepts to be considered.

frequency sound when signals are received from the oscillator. Students quickly learn to associate a circuit board with a particular "job." For example, a 14-year-old student would easily solve the problem of making a "rain alarm" by linking a moisture detector (*input*) to a buzzer (*output*) by using a transistor switch (*process*).

Such black boxes can also be used to make more complex devices. Design decisions are based on how the product is to be used and students are constrained by their specification criteria, not by a lack of understanding of why the circuit functions. A *detailed* knowledge at the component level is unnecessary. Let us assume that a student is aiming to design and make an anti-theft warning device to clip onto a bicycle and provide an ear-piercing sound if the bicycle is about to be stolen, that is, it is a portable device to be used by an individual. First and foremost, there needs to be a clear specification of what the system is to do (see Figure 2). Second, there needs to be a consideration of the environment in which it is to be used, not just the physical environment (e.g., wet, dusty, hot, cold, or dry), but the human environment, too:

- who is to use it;
- what is it to look like – its shape, colour, size and so on;
- how it is to be used, for example, whether fixed to the wheels, handlebars, or forks;
- how much it is to cost to make and to sell; and
- whether the user needs to have any technical skills to use it.

Only after these criteria are established through appropriate research is it possible for the student to select the functional building blocks that will enable a prototype system to be made which meets the criteria. There are several concepts which arise in this analysis of need. For example, in terms of *energy* there is a consideration of the power supply requirements. In terms of the *process*, a student will need to consider how the device can control the sound long and loud enough to alert attention. Is it to have an automatic cut-out? What is to be the operating principle of the sensor which first detects the movement of the bicycle? In terms of *materials*, cost, ruggedness, waterproofness, and design of the casing for the unit and similar considerations for the components need to be tackled.

When it comes to the manufacture of the anti-theft bicycle alarm, however, the technical factors to be considered are more than simply selecting appropriate input, process, and output devices; plugging them together; and expecting the system to work. What is most often missed in designing electronic systems is the need to consider the requirements that enable each building block to respond to the signal it receives and send an appropriate signal to the building block that follows it. The concept being highlighted here is called *matching*. This is more complex, but at a basic level, students are able to use computer software which will give the design for a printed circuit board combining the contributory functional blocks.

Systems thinking can sometimes make simple ideas more complex. Consider the example of a flush cistern in a toilet where the ballcock regulates the level of the tank. If a variety of technologists are asked to draw a systems diagram of a cistern, they will probably produce very different diagrams. Similarly, when asked to identify the input to a simple burglar alarm as shown above, students sometimes identify the input as “electricity” or “the battery” (McCormick & Banks, 1994). However, when building up complicated electronic devices, considering them as a collection of functional blocks in terms of input, process, and output functions can very much simplify the learning of electronics. Just as a first aider does not need to know about the chemical triggers needed for the beating of the heart, a technologist does not need to know about the detailed working of an integrated circuit, or even a transistor, in terms of the physics involved, just how to use it in a range of circumstances. A systems thinking approach in both cases gives the necessary overview and provides the necessary useful knowledge for the task in hand.

CONCLUSION

When we consider transferring knowledge from other domains versus knowledge acquired through technology education, we have seen that we need to keep in mind the important differences in terms of purpose and intent. Technology has often been considered a portfolio subject which just transfers useful knowledge from other areas, and indeed sometimes technology is merely seen as "applied science." In this chapter, however, we have seen that whereas technology is founded in human need to change the environment, science is in understanding the whys and wherefores of the world around us. The *know-why* of science is a fundamentally different goal from the *know-how* of technology. Science knowledge and understanding will often contribute to project work in schools, but it is necessary to keep in mind the sometimes limited extent of such knowledge which is actually required and the other useful knowledge such as designing and systems thinking that is also required. The contribution of science needs to be set against the other dominant factors such as *sustainability*, *aesthetics*, and *appropriateness*. But as Plant (1994, p. 29) reminds us:

> it is also important to recognise that science has a part to play in stimulating technological activities. First, by revealing new frontiers to spur technological inventiveness. Second, by using the vocabulary of science for providing convincing explanations of the behaviour of technological devices. Third, in the provision of convincing explanations of the behaviour of technological devices. Lastly, in the provision of resources for the constraints on technological processes.

Even though technology often resorts to the language of science to describe how the technology works, technological practice is steeped in the culture and social values of the society which uses it. It is indeed very much more than applied science. Not only has technology education its own subject-specific knowledge in design processes, problem-solving techniques, and systems thinking, such useful knowledge can be transferred, used, and applied elsewhere. The goal-directed nature of technology in leading to an appropriate product makes it a first-rate vehicle for using and creating knowledge. The knowledge transfer is a two-way street.

NOTES

[1] Gilbert and Sullivan's *Princess Ida* Act 2 – first performed 5 January 1884.

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4. TRANSFER AS AN ITERATIVE PROCESS BETWEEN SCHOOL AND WORK

The LISA-Project

INTRODUCTION

This chapter explores the nature of transfer between school and work, based on results from a three-year project called the *LISA*-project (*Learning in Several Arenas*) conducted between 2009-2012. The *LISA*-project focused on teaching and learning at a vocational school and at different workplaces, especially in the Energy Program and the Industry Program at the upper secondary school level in Sweden. The aim of the project was to contribute to knowledge about teaching and learning within and between different arenas, in this case school and workplaces.

Working life is in a state of rapid change, by development of technical equipment and materials that affect working tasks and working conditions. Due to this rapid change, no one can predict the kinds of knowledge professionals within different occupations will need in the future, when new tools, machines, and materials are used, once students enter the labour market. Taking this aspect into account is an important part of the learning environment for students choosing vocational education when vocational education is expected to prepare students for challenging work environments. The students must learn to learn, that includes to be able to transfer knowledge between different situations. This is what Bransford and Schwartz (1999) talk about as preparation for future learning. Previous research shows that students experience problems translating what they learn in school and to make the knowledge useful in complex workplace settings (Caravaglia, 1993; Meijers, 2008; Tanggaard, 2007), which motivates empirical studies about transfer, in order to improve teaching and learning so students are prepared to meet the ever changing future employment demands. The importance of this knowledge can be understood in the light of the need for well-educated engineers, researchers, and technicians, in order to allow Sweden to maintain a strong competitive position as an industrial nation (SOU, 2010, p. 28).

In the autumn of 2008, the Swedish government launched an apprenticeship training pilot, where students spent half their time (about 60 weeks) at a workplace. In the regular education, the students spend 15 weeks at a workplace (Sveriges Riksdag, 2009). The aim was to enhance the students' possibilities to get a basic vocational education, increase job experience and advanced skills in a related career field (Sveriges Riksdag, 2009, section 7). One of the schools that were part of the government's investment in the apprenticeship training pilot was also part of

H.E. Middleton & L.K.J. Baartman (eds.), Transfer, Transitions and Transformations of Learning, 39-48.

the three-year research project called the *LISA*-project (*Learning in Several Arenas*). The *LISA*-project focused on teaching and learning at the vocational school and at different workplaces, especially in the Energy Program and the Industry Program at upper secondary school in Sweden.

The purpose of this chapter is to explore the nature of transfer emerging in interviews with teachers and supervisors in vocational education. Accordingly, the chapter is a contribution to knowledge about how the two arenas, school and workplaces, can interplay to enhance students' possibilities to transfer knowledge between different situations.

PROJECT DESCRIPTION

The upper secondary school in the *LISA*-project was part of the government pilot project, mentioned above, which meant that the students had half their teaching at school and the other half as workplace learning. The *LISA*-project ran from Fall 2009, when the students started their education at upper secondary school, and ended in Spring 2012, when the students graduated.

The theoretical framework of the *LISA*-project is grounded in the phenomenology of the life world (Bengtsson, 2005). According to the phenomenology of the life world we all live in a pluralistic world, the life world, but depending on our positions, perspectives and earlier experiences we conceive phenomena in this world differently (Bengtsson, 2005). From the phenomenology of the life world follows that empirical studies are needed in order to obtain knowledge about teaching and learning at different arenas. Another assumption in the project is that people can convey experiences through narratives (Hydén, 2007). In the *LISA*-project we assumed that the narratives were created jointly by the informants and ourselves as researchers (Chase, 2005). This means that we as researchers did not "catch" or find the narratives or that the informants only should give answers to our questions. Instead, the narratives were created together, on the basis of the research questions and the informants' experiences.

The informants in the *LISA*-project were associated through their involvement in the Energy Program and the Industry Program at upper secondary school. Those programs were in-school programs, and not workplace programs. The supervisors in the project were plumbers and industrial workers at workplaces, who supervised the pupils during their workplace training. One of the teachers at the school had worked as a plumber and the other as an industrial worker, before they retrained as teachers. Even before the *LISA*-project was launched, there was an established cooperation between the teachers and the supervisors in the project, which was an advantage in terms of their participation in the three-year project. In total there were two teachers, four supervisors, three students, and four graduate students involved in the project (see Figure 1). There were a few more students interviewed for Kilbrink's study (Chapter 7), however, the three students in Figure 1 were involved in the whole project.

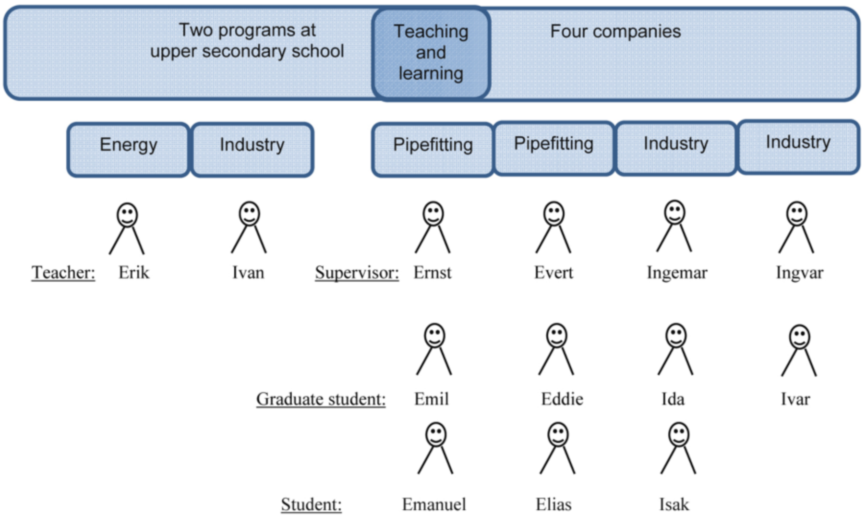

Figure 1. The informants in the LISA-project.

Qualitative methods have been used throughout the project in order to provide a rich and detailed source of narrative data about teaching and learning within the different arenas. We conducted semi-structured interviews, both individually and group interviews. Each of these interviews was audio-taped and transcribed verbatim. The interview method allowed modification of the questions during the interviews and also for exploration of the responses (Cohen, Manion, & Morrison, 2007). Since the narratives were framed by the questions from us as interviewers, we see the narratives that unfolded in the interviews as co-productions in the interview situations (De Fina, 2009). This means that the informants provided details about their experiences, in this project concerning teaching and learning in different arenas, framed by the research questions and framed by the context in which they were told. In this study the informants knew, at some level, what the researchers running the *LISA*-project were interested in and our impression was that they really wanted us to understand what they were telling us about, since they knew that we had no direct, personal experiences from either their education or pipefitting or industrial work. In addition to the interviews, we also observed the teaching at school and at the workplaces and documented the observations by video camera. The observations were necessary to be able to follow closely how the teaching was carried out in order to investigate teaching and learning in the different arenas (Kullberg, 1996). The data was analysed by analysis of narratives and narrative analyses (Polkinghorne, 1995). Polkinghorne (1995) distinguishes between *analysis of narratives* and *narrative analysis* in this way: “analysis of narratives moves from stories to common elements, and narrative analysis moves from elements to stories” (p. 12). We used the concept of narrative for what the informants told in the interviews and then we merged their narratives into a common narrative in our presentation of the results for publications (see Table 1).

Table 1. Publications within the LISA-project

Research question	*Publication*
What factors do influence plumbers and industrial workers to start working within their respective trade? What advantages and disadvantages do plumbers and industrial workers experience in their trades?	Bjurulf, V. (2010). Reasons for choosing a technically oriented education: An interview study within the field of pipefitting and industry. *International Journal of Technology and Design Education.* DOI: 10.1007/s10798-010-9141-5.
What themes of transfer appear in teachers' and supervisors' narratives about technical vocational education? What factors in the narratives are crucial for providing transfer possibilities in technical vocational education?	Kilbrink, N., & Bjurulf, V. (2012). Transfer of knowledge in technical vocational education: A narrative study in Swedish upper secondary school. *International Journal of Technology and Design Education.* DOI: 10.1007/s10798-012-9201-0.
What characterises teaching in school and workplaces, respectively?	Bjurulf, V. (2012). "You'll just have to practice until you find your own way to do it!": A narrative study about how teaching is carried out in Technical Vocational Education. *NorDiNa, 12*(1), 17-25.
Which identities are emerging in narratives of people who are either entering or are established within pipefitting and industrial work?	Bjurulf, V. (2012). Yrkesidentiteter: Berättelser av personer på väg in i och etablerade inom rörmokeri- och industribranschen. In M. Karlsson & H. Pérez Prieto (Ed.), *Livsberättelser – mening och identitet i tid och rum.* (s. 21-41). Karlstad: Karlstad University Studies, nr. 2012:8.
What stories about theory and practice are emerging in the informants' narratives? What differences are made between theory and practice in the narratives? How do the concepts of theory and practice relate to each other in the narratives?	Kilbrink, N. (2012). Skillnaden mellan de oskiljbara: Berättelser om teori och praktik. I M. Karlsson & H. Pérez Prieto (Ed.), *Livsberättelser – mening och identitet i tid och rum. (*s. 85-99). Karlstad: Karlstad University Studies, nr. 2012:8.
What educational content is important to teach and learn during the vocational education according to teachers' and supervisors' narratives about technical vocational education?	Kilbrink, N., & Bjurulf, V. (submitted). Vocational education and employability: A narrative study on educational content in technical vocational education.
How do students, teachers, and supervisors experience theory and practice in relation to teaching and learning in a technical vocational education?	Kilbrink, N. Chapter 12 in this book.

THE NATURE OF TRANSFER

In a dual school system, where half the students' time is allocated to the workplace and the other half to school, the question of transfer is central. How do the two arenas facilitate students' possibilities to be prepared for a labour market state in rapid change, according to new tools, machines, and materials? Do the students experience the vocational education as a continuum or the teaching at school and at the workplaces as separated parts dealing with different kinds of stuff? With students learning at school and at work there should be transfer in both directions as a strength of the dual arrangement. Those questions underlie the following discussion, based on the results from the *LISA*-project, focusing on the nature of the transfer.

Employability

Concerning the question about how the two arenas facilitate students' possibilities to be prepared for the labour market, previous research shows that there often is a discrepancy between the syllabi and the teachers' actual teaching, since the teachers generally have a background as professional workers and know about the expectations from the workplaces (Baartman & de Bruijn, 2011; Berglund, 2009; Lindberg, 2003). Rather, the *LISA*-project underlines this observation, since there is a clear focus on employability. In order to be employable there are some acquired "foundation stones" to be aware of and fulfil, according to the informants in the *LISA*-project. One of those is to be punctual. Maybe it is more of a consistent demand from both arenas, rather than transfer, but to prepare the students for employment as a plumber or industrial worker the teachers are particular about punctuality. They are also particular about the students wearing appropriate clothes.

An example of the foundation stone of punctuality and evidence that it is also related to implied rules for behaviour is evidenced by "be in time and behave!" – a quotation that characterises the results from an employability perspective. An example from school that illustrates how the teachers are handling punctuality is that they are not waiting for students if they are going somewhere together and the students are not on time. If the students know that they are leaving 7 a.m., "the car is leaving," even if there is someone missing. The informants experience a discrepancy between the syllabi and "real life," since the content in the syllabi does not relate to what they know is important for the students in order to become employable, for example, to be punctual.

Another behavioural norm was the requirement for students to be active and show interest and "help themselves" at the workplaces. There are no employers who are interested in a potential employee who "picks up the cell phone" or who "keeps the hands in the pockets." Rather, the students should ask questions such as "what did you do now?" The emphasis during the vocational education is thus to foster the students to become future workmates who "fit into the group of fellow workers." One of the students expressed this as: "I was placed here [at an industrial workshop] to get experience in how it is to have a real job." To have "a real job" includes being one in the team.

The teachers and supervisors in the *LISA*-project agreed about the importance of those "social" skills. That is, they agreed that these were important skills for the students to develop during their education in order to be attractive in the labour market. From that follows that the students recognise the expectations from both arenas and may thereby be able to transfer the skills to additional situations and arenas. The nature of transfer in this respect is to adjust the behaviour in order to fit into a group of people generally, and into a group of plumbers and industrial workers specifically in our project.

Basic Knowledge

When it comes to how the two arenas, school and workplaces, facilitate students' possibilities to be prepared for an ever-changing labour market, both teachers and supervisors emphasise the importance of "basic knowledge" or "foundation stones." As stated in the introduction of this chapter we are living in a world where technical equipment and materials are developed continuously and quickly, which may influence technical-oriented education to prepare the students for a challenging work environment. The students must be prepared to handle new situations. In this respect, the concept of transfer is of high importance. According to the informants in the *LISA*-project, there is a need for basic knowledge acquired from school before students participate in workplace training. The basic knowledge is specific for the actual profession, which presupposes communication between teachers and supervisors, so the teaching in school meets the needs at the workplaces. However, the basic knowledge is also more general, which the informants exemplify in terms of their comments about the importance of being skilled in, for example, mathematics, measuring, and three-dimensional thinking as preparation for employment.

When the students have acquired the basic knowledge in school, they need to apply this knowledge at the workplace training. This view of transfer tends to cement the criticised view of transfer as applying knowledge learnt in one situation and using it in another similar situation (Beach, 1999; Bransford & Schwartz, 1999; Lobato, 2003; Marton, 2006). On the other hand are the examples in the narratives where the informants express a different view of transfer as a preparation for future learning and the importance of variation in teaching in order for the students to be prepared for unknown situations (compare Bransford & Schwartz, 1999; Marton & Pang, 2006). Drawing on Marton's (2006) paper on the importance of discerning differences (as well as similarities) across learning activities as a way of improving transfer, one could suggest that the students need to learn by looking at the batwing and listening at the sound from the welding apparatus in order to be skilled in, for example, welding. Material may differ and also the way you weld, but the senses can be used similarly in different situations.

Beyond basic knowledge acquired from school, the project found that branch-specific content-related basic knowledge is also needed. Therefore, a continuous and close cooperation between the teachers at the school and the supervisors at the workplaces is of importance in order to make sure that the students are offered an up-to-date education. The close cooperation presupposes communication, a factor that both the teachers and the supervisors in the project emphasised as important. Sufficient communication enables the teaching to take as point of departure from the students' previous experiences and knowledge, that is, what the students have learned in *both* arenas, and build further on these and make use of them in different situations. From this point of view, it is important to emphasise both arenas as learning arenas, offering the students possibilities to build further on previous knowledge. Thus, the results indicate that good communication between learning providers is a factor that promotes transfer. By sufficient cooperation and by taking transfer in consideration the students are offered an education that is branch specific *and* general, since the students will be prepared for an unexpected ever-changing future.

The importance of transfer is expressed by one of the teachers in the *LISA*-project, who says that vocational education per se cannot be specific; it cannot be "an exact education," because then the schools would "need to have all the steering systems in the world at the school, and that is impossible." The education must rather prepare the students for future learning (Bransford & Schwartz, 1999). Due to the continuous development of technical equipment and materials a lot of occupations presuppose continuous learning: "you need to keep yourself updated." One of the supervisors in the *LISA*-project says that it impossible to learn everything, which is one of the attractive parts within the technical-oriented trades such as pipefitting and industrial work – you will always have new things to learn.

In order to be able to learn new things, our project points to the importance of basic knowledge that can be used and adjusted in new situations. When new machines or materials are introduced, the basic knowledge constitutes the experiences needed in order to discern critical similarities and/or differences between the well-known machines or materials and the new ones (compare Marton, 2006). According to Marton, "transfer effects may increase with time, experience, and differences" (p. 512). The experience-factor is expressed by one of the students in the *LISA*-project, who says that he "learns the basics at school" and during the workplace training experience he just "learns more and more." This indicates that the students experience the vocational education as a continuum, rather than teaching in school and at the workplaces as separated parts.

The nature of transfer that is connected to being prepared for an ever-changing labour market echoes Bransford and Schwartz's (1999) view of transfer as a preparation for future learning. From the *LISA*-project it is obvious that the preparation for future learning presupposes basic knowledge as a starting point and also as the basis for future learning.

Theory and Practice

Unlike previous research the results from the *LISA*-project suggest that students experience vocational education as a continuum and do not experience problems translating what they learn in school to workplace settings (compare, for example, Caravaglia, 1993; Meijers, 2008; Tanggaard, 2007). Instead, both arenas contribute to the students' development of the professions they have chosen to study for, but it is the individual students who fill the personal "boxes" with the tools that fits themselves in their future professions. In a dual educational system there are possibilities for the students to continuously fill the personal boxes with tools from both arenas, thanks to the fact that teaching occurs in parallel in both school and the workplace. The range of tools from the two arenas may differ in terms of focus on theory and practice. In this project, the informants referred to theory as school-related activities, such as to think and read and also to prepare for workplace training. In a similar way they referred to practice as workplace activities, such as physical work, that is, to use the body and the hands, and to make use of the knowledge learnt in school. Thus, theory is seen as preparation for workplace training, whereas practice is seen as the application of the theory. However, this dichotomised, and criticised, way of dividing theory and practice is nuanced in the informants' narratives. They mean, for example, that theory and practice occurs both in school and at the workplace training. Sometimes the students do have better possibilities to develop some skills of a practical nature in school, since some tasks are time consuming and therefore hard to practice at the workplaces because of financial constraints.

The project also shows that there is a combination of theory and practice in the teaching. Mathematics is, for example, embedded in both pipefitting and industrial work and when the study program is organised with half time workplace training, the students are given the opportunity to see the importance of being skilled in mathematics. When the education is organised with students learning both at school and at workplaces they may realise the meaning of the "theoretical" knowledge taught in school and thereby be motivated to learn. One of the supervisors in the *LISA*-project reports that he sometimes gives the students homework, for example, to make a drawing and figure out the amount of tubes needed for an installation. In this way theory *and* practice are interwoven, as argued by Bjurulf and Kilbrink (2008). The nature of transfer emerging when working with theory and practice is a holistic view of knowledge.

CONCLUDING WORDS

This chapter contributes to empirically based knowledge of the nature of transfer between school and work, and especially the nature of transfer in vocational education. The nature of transfer viewed as a preparation for future learning proposed by Bransford and Schwartz (1999) is supported, but also nuanced regarding the need for basic knowledge as a base for the preparation. It was also found that students were expected to behave in certain ways in order to be considered seriously as potential workmates. The nature of transfer in this respect is to adjust behaviour in order to fit into the norms of the actual group of people. Furthermore, the nature of transfer has emerged as iterative in the sense of theory and practice as interwoven. Since the students must be prepared to handle new situations, in an ever-changing world and in ever-changing trades, preparation for future learning must be viewed as the goal of vocational education. If students learn to learn they will be able to become skilled professionals where transfer of knowledge is a prerequisite for keeping updated in the actual profession.

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5. NURSES' AND TECHNICIANS' COMMUNICATION AND LEARNING AT THE BOUNDARY

INTRODUCTION

Our society is deeply influenced and shaped by artefacts, ideas and values of technology. Technological developments sometimes replace human work, but can also inform human work by making information more accessible and usable (Levy & Murnane, 2005; Kent, Noss, Guile, Hoyles, & Bakker, 2007). As a consequence, "non-technical jobs" such as nursing increasingly require an understanding of technology. For example, nurses are confronted with new instruments and machines such as infusion pumps, but also remote monitoring and alarm systems which enable the elderly to live independently for a longer time. The Dutch Health Care Inspectorate reports incidents which can be attributed to human errors due to lack of competence in working with new technology and poor maintenance (Health Care Inspectorate, 2008). An understanding of technology is thus not only important for employees in science-related jobs, but for all jobs (Rodrigues et al., 2007). Besides this, work is increasingly heterogeneous and interdisciplinary in that it involves actors from different vocations, requiring communication and collaboration across the boundaries of vocations (Engeström, Engeström, & Karkkainen, 1995).

However, vocational education often regards boundaries as problematic instead of opportunities for learning (Akkerman & Bakker, 2011). This becomes apparent in the recurrent debate about the "skills gap" of graduates entering the workplace and the nontransferability of, for example, mathematics from school to the future workplace (Kent et al., 2007). Much of this discussion started from a comparative approach, focusing on the differences between school and work and the idea that similarity between school and work sites is most preferable for successful transitions from school to work. Instead, a relational approach uses the idea of boundary crossing as an alternative to transfer (Akkerman & Bakker, 2011; Tuomi-Gröhn, Engeström, & Young, 2003). Boundary crossing focuses on the values of differences between sites or vocations and considers how relations can be established to achieve productive interactions (Guile & Griffiths, 2001; Poortman, Illeris, & Nieuwenhuis, 2011). In this view, the challenge for education is not to deny the existence of boundaries, but to create possibilities for learning at the boundary by letting students participate and collaborate at the boundaries of their

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vocation and act at a diversity of sites during, for example, apprenticeships. Work and learning are about becoming an expert in a bounded vocational domain, including communication and adaption across boundaries.

This study focuses on boundaries at work between two vocations: nurses and technicians. It aims to shed light on the learning opportunities offered by working at the boundaries of one's vocation. A review study on boundaries and boundary crossing (Akkerman & Bakker, 2011) concludes that studies on boundary crossing present appealing claims about the possible learning benefits of working at the boundary. These claims remain very general, however, and hardly explicate how or what kind of learning is taking place. This study therefore focuses on these learning processes at the individual or micro level. For education, the results of this study may indicate the values of boundary crossing and point out examples in the workplace that students might use to improve their learning, for exercising their vocation in a heterogeneous and interdisciplinary work environment.

The goal of this research is to explore how employees from different vocations work at the boundary and to identify what learning opportunities this offers. This study focuses on the communication and collaboration between nurses and technicians who work together around several technological innovations to organise patient care, for example video communication and domotics (home automation). The research questions are: (1) How can the boundaries at work experienced by nurses and technicians be characterised? (2) How do nurses and technicians communicate and what learning potentials can be observed here? and (3) What do nurses and technicians learn from their work at the boundary? Below, we first present the (sensitising) concepts used in this research, as they are used in the literature. In the methods section, we describe how we used these sensitising concepts to analyse the communication and learning in our cases.

BOUNDARIES AND BOUNDARY CROSSING

The first research question focuses on the nature of delineation of vocations. In sociocultural and cultural-historical theories, challenges in communication between communities of practice are often conceptualised in terms of boundaries (Engeström, 2001; Wenger, 1998). A boundary can be defined as a sociocultural difference leading to discontinuity in action or interaction (Akkerman & Bakker, 2011). Boundaries can be identified by looking at whether people express or encounter such a discontinuity, for example related to difficulties in communication or by referring to another vocation as a different group in terms of "we" and "they" (Kerosuo, 2001). Akkerman and Bakker (2011) distinguished different forms of boundaries, focusing on boundaries between school and work or between work and private life. This study focuses on boundaries within work: how groups and individual professionals with different expertise, different tasks, and different cultural backgrounds collaborate during work.

Boundary crossing refers to a person's transitions and interactions across different sites or communities of practice. When crossing a boundary, a professional enters into "a territory in which we are unfamiliar and, to some significant extent therefore unqualified" (Suchman, 1994, p. 25). In this study, boundary crossing is used as an alternative approach to transfer. As opposed to theories on transfer, boundary-crossing theories refer to an ongoing, two-sided interaction between different contexts. The traditional concept of transfer is used to refer to how people apply what they learn in one task to another future task (Gick & Holyoak, 1983; Salomon & Perkins, 1989). Traditional notions of transfer are limited in that they mainly focus on knowledge, and studies were carried out in school settings or laboratory experiments only. The situated approach to learning and social-cultural theories view transfer not as passing on knowledge to a new unchanging task, but as learning in a continuously changing everyday world (Tuomi-Gröhn et al., 2003). Beach (1999) describes this as transition, which always involves the continuous construction of knowledge rather than the mere application of knowledge acquired previously. Similarly, Van Oers (1998) starts from an activity approach to context and describes contextualising as a process of context making depending on an interpretation of the situation in terms of activity, which is (re)constructed every time an agent gets actively involved in a setting. Because contextualising is a necessary condition for any action and learning, Van Oers argues that the notion of de-contextualising (as in traditional transfer) should be replaced by the idea of a continuous process of re-contextualising. This also fits with the view of both "vertical" and "horizontal" expertise, implying that experts not only possess a large amount of bounded and vocation-specific knowledge, but also need to engage in multiple different tasks and communities of practice in which they enact their expertise.

LEARNING DURING COMMUNICATION AND COLLABORATION AT THE BOUNDARY

Boundary crossing offers opportunities for learning and can even be used as a tool for promoting learning (Tuomi-Grohn et al., 2003). Knowledge and skills are reconstructed due to the confrontation with and sharing between different practices. The ideas and needs from different cultures meet, collide, and form new meaning. In their review of the boundary-crossing literature, Akkerman and Bakker (2011) identified four learning mechanisms that might occur during communication and collaboration at the boundary. These mechanisms are used as a starting point for answering the second research question of this study. It needs to be noted that the learning mechanisms described by Akkerman and Bakker are very general in nature and focus on the organisational level, group level, and individual level. This study focuses on the individual level specifically. Therefore, some of the mechanisms described by Akkerman and Bakker were not used for this study or were adapted to fit the individual level of this study. Also, the learning mechanisms are conceived as "learning potentials," meaning that they might lead to learning but – in our view – do not necessarily do so.

The first learning mechanism is *identification*, the establishment or (re)construction of boundaries in which the discontinuity continues to exist. Identification occurs when existing demarcations between vocations are destabilised or changed and employees feel threatened in their current identity of their own vocation. It is a process whereby people try to establish the boundary by indicating how one practice differs from the other and what belongs to which vocation. The second learning mechanism, *coordination*, describes the establishment of procedures or tools to facilitate the communication between different practices or vocations. Again, boundaries often remain and the dialogue between vocations has the goal to reassure a smooth flow of work. For example, boundary objects are developed which are communication devices, such as a checklist, scheme, or work tools that have meaning in different practices and as such translate between these practices (Zitter, de Bruijn, Simons, & ten Cate, 2012). The third learning mechanism is *reflection*, in which employees realise and explicate similarities and differences between vocations. This occurs by means of perspective making and perspective taking, in which employees explicate their own perspective on a certain issue, but also try to take the perspective of the other practice. In contrast to identification, reflection leads to an expanded perspective on one's own vocation and a renewed construction of professional identity. The fourth and last learning mechanism is *transformation*, which refers to more profound changes in practice in which new in-between practices develop. Related to the context of the current study, Hasu and Engeström (2000) describe how the breakdown of a patient measurement system led to frustration, but also to the opportunity to redevelop the technological design together with the developers. Transformation can result in the development of new routines or procedures that are shared by both practices, or the creation of a new in-between discipline or task (Konkala, 2001, in Tuomi-Gröhn et al., 2003).

WHAT IS LEARNED AT THE BOUNDARY

The third research question of this study focuses on what is learned during the communication and collaboration of nurses and technicians at the boundaries of their vocations. Here, we mainly focus on what is learned with regard to an understanding of technology, as the starting point of this study was the technological developments that impact on diverse job practices.

When it comes to developing an understanding of technology, problems arise as the amount of new technical information is doubling every two years (Binkley et al., 2012). Much of the knowledge and skills that are now taught in school will have become obsolete by the time these students enter the workplace. There is no guarantee that today's students can directly translate what they learn today to what they need in their future jobs. Next to this, a gap appears to exist between what and how science and technology are typically taught at school and how they are used in practice (e.g., Bakker, Kent, Hoyles, & Noss, 2011; Forman & Steen, 1994; Millar & Osborne, 1998). It appears to be difficult to transfer the general concepts of science and technology taught at school to very context-specific situations in the workplace (Wynne, 1991). Forman and Steen (2000), for example, write that in practice people need simple mathematics to solve complex problems, whereas at school complex mathematics is taught in conjunction with simple problems. This transfer problem starts from a more traditional view of transfer, as opposed to the boundary approach taken in this study. In the discussion around the supposed skills gap between what is taught in school and what is needed in the workplace, and the nontransferability of, for example, school mathematics to the workplace, the focus has been on theoretical knowledge such as numeracy. The issue was conceived in pure cognitive terms, as a problem of transfer of school knowledge to work. However, the essential characteristics of knowledge required in technology-mediated work are quite different. Work is not about pen-and-paper calculations, but about using and interpreting technological systems. This knowledge serves to inform workplace judgements and decision making in concrete daily practice. Kent and colleagues (Kent et al., 2007) therefore use the term "techno-mathematical literacies" to denote how mathematical knowledge is mediated by technology in practice and grounded in the context of specific work situations. The prefix "techno-" refers to the mediation by technology, and the plural form "literacies" points to the breadth of knowledge required in the context of contemporary work. In this study, to characterise knowledge used in the workplace, we follow the line of reasoning proposed by Kent and colleagues. Instead of focusing on mathematics, we focus on technological literacies grounded in the context of specific work situations. Workplaces are contexts that can be characterised by a specific division of labour, rules, discourse, and communities using and understanding tools and artefacts in different ways. The knowledge required for effective use of technology can thus not be understood in term of a list of generic, context-independent facts or competencies.

When it comes to working with technology, Zuboff (1991) already described the difference between technology that "automates" jobs and technology that "informates" by making information more accessible and usable (see also Levy & Murnane, 2005). Employees therefore need a capacity for "system thinking," that is, the ability to identify what a technological system is doing and what follows from it. The use of technology does not imply that professional knowledge (in this case, knowledge about nursing) is useless, but requires an additional kind of knowledge. Zuboff mentions skills such as abstract thinking, problem solving, analysis, the ability to perceive patterns and relationships, and the procedural and functional appreciation of technological systems. Similar skills were mentioned in reports about 21st-century skills (e.g., Binkley et al., 2012; Dede, 2009; Voogt & Pareja Roblin, 2010), although these skills are usually formulated in very general terms such as ICT literacy and communication skills. Based on an analysis of 21st-century skills and studies into mathematics in the workplace, Baartman and Gravemeijer (2011) distinguished thinking skills that are necessary to work with technology in practice. These skills include similar skills like recognising (ir)regularities, structures and patterns, interpreting data, problem solving, and modelling. In this study, we adopt the idea of system thinking, which includes a basic understanding of technological systems, from the perspective of a user (instead of a developer or designer). Banks and Plant (Chapter 3) also discuss the idea of system thinking as knowledge and understanding at the operational level, in which the focus is on function and context (know-how) rather than on theory and fundamentals (knowing why). The advantage of the concept of "systems" is that it is more time-independent and offers a first understanding of many devices, ranging from bikes to mobile phones, instead of an understanding of learning to work with one particular device (De Vries, Chapter 2).

Finally, working with technology in practice – like all work – entails a broad "web of reasons," in which employees based their action on a broad range of reasons, derived from all components that are relevant for their vocation, for example, nursing practice, formal knowledge, technology, practical reasons, or past experiences, etcetera. For example, Wynne (1991) showed that employees use considerations other than just science as bases for their decisions and actions when working with machines. From its sociocultural background, boundary crossing tends to focus on communities of practice or activity systems, which does not necessarily suffice to understand an individual's understanding and reasoning in specific situations at the workplace. Therefore, Bakker, Van Mierlo, and Akkerman (2012) used the concept of a web of reasons, originally developed by Brandom (1994, in Bakker & Derry, 2011). A web of reasons is a complex web of interconnected reasons, motives for actions, causes and effects, premises, and implications of actions that a person uses to guide and justify actions in practice. The idea of a web of reasons originates in inferentialism. Bakker and Derry (2011) describe the implications of inferentialism for education, for example, that concepts should be primarily understood in terms of their role in reasoning within a social practice (and not primarily in representational terms related to conceptual content). A knowledgeable person bases his or her decisions on a broad web of reasons that might be very different but are all relevant due to their inferential connections.

Viewed from the perspective of a web of reasons, nurses could introduce elements of an understanding of technology, system thinking, and their attitude towards technology in their web of reasons. This could change their thinking and choices about care and organising care facilities to best help their clients. In this way, their web of reasons to guide and justify their actions expands beyond reasons that are directly related to the conceptual content of their vocation.

METHOD

The context of this study is vocational education, preparing students for a job at levels ranging from assistant worker to middle management. As described by Levy and Murnane (2005), this middle-level type of job is likely to be most affected by technological changes. For the current study, one case in the field of nursing was selected from a broader study into the influence of technology on diverse branches and jobs.

General Case Description

This case study includes two health care organisations that are part of a larger network of health organisations working together in a project around care and technology. In both organisations nurses and technicians mainly work around two technological innovations: video communication and domotics (home automation). Both are used to provide care to elderly and ill people who live independently and would otherwise get home support from a nurse or would require institutional care. The reasons for introducing these technologies in the health care organisation were (partly) economical: It is more efficient to provide care by means of video communication and domotics, than to send a nurse to all homes.

Video communication is mainly used in the care centre, a central office from which the nurses contact their clients by means of a computer and from which they can control the domotics installed in the homes. The nurses working in the care centre generally have a several years of experience in the field and have different reasons for working in the care centre. Some of them cannot carry out the physical work anymore (e.g., bathing and lifting clients); others are specifically interested in video communication. For the video communication system, a computer with a touch screen and camera is installed in the client's house. The client can contact the care centre using the touch screen or the nurse can contact the client from the care centre, working from a computer station (see Figure 1). Examples of services provided by the care centre are a morning/afternoon service, in which the nurse contacts the client on a daily basis. This helps clients to start their day, while the nurse can ask questions and check their general health. Other clients use insulin and are capable of injecting themselves, but need support and a check by the nurse. The nurse observes the client via the video communication system and can intervene when necessary (e.g., when the client is afraid or makes a mistake).

Figure 1. Nurse's work station at the care centre.

Next to the video communication system, domotics are used to adapt the houses of the clients so they can live independently for a longer time. Some simple examples of domotics provided in all houses are the automatic opening of doors and an alarm system. Other more specific examples are a bed mattress to monitor whether (erratic or demented) elderly leave their bed at night, and a watch with a sensor developed for an erratic client to automatically lock the door.

Data Collection

Interviews were conducted with project leaders, nurses, and technicians. In total, five project leaders/team leaders were interviewed, mostly nurses or people with a nursing background. In addition, five nurses working directly with the video communication system and domotics were interviewed and a one-day observation was carried out at the workplace (the care centre). As part of this visit, the failure reports communicated between the nurses and the technical department were studied and explained by one of the nurses. Also, two visits of the clients' homes were carried out to see the working of the systems, explained by one of the nurses. One technician who collaborated most with the nurses was interviewed and two presentations/information meetings were attended, in which one of the technicians explained the working of (new parts of) the system to the nurses.

The interviews and observations guidelines were developed in analogy to the Anglo-Saxon studies into the use of mathematics in the workplace (e.g., Pozzi, Noss, & Hoyles, 1998). First, more easy questions were asked in relation to a person's personal work experience, followed by more difficult questions about the thinking processes underlying concrete actions. The interview questions were partly dependent on the interviewee's function in the organisation. Some examples of questions are:

– What new technologies do you work with? (I.e., the nurse was asked to explain the working of the system he/she worked with. This could be the video communication system, a computer program, etc.)
– How did this new technology change your work? Do you think your work will continue to change in the future?
– What is your opinion of new technologies in your work? What are the advantages and disadvantages?
– What do you find difficult in working with new technologies? And what was no problem for you?
– How did you learn to work with this new technology?
– Which problems do you encounter with working with this new technology? What do you do when you encounter a problem? What problems can you solve yourself and how do you do that? When do you ask for help and what do you ask?
– Do you always trust this new technology? Do unexpected things happen?
– Did you learn new things when working with this technology? What do need to know and be able to do?

Almost all interviews were audio-taped. When this was not possible because of privacy issues (e.g., when a nurse was communicating with clients in the care centre), notes were taken. Audio-tapes and notes were worked out into a report of each interview/observation and interviewees were asked to check the correctness (member check). If necessary, additional questions were asked by email.

Data Analysis

The data were analysed using a combination of a more grounded approach (inductive analysis) and an approach in which the codes are formulated beforehand and imposed on the data. We used the idea of sensitising concepts (Bowen, 2006) to guide the analyses. Sensitising concepts provide directions along which to look at the data, as opposed to definitive concepts that exactly prescribe what to see. The research questions provided three focus points for the analysis, for which sensitising concepts were formulated using the literature (see literature sections above).

The first focus point relates to the boundaries experienced by the nurses and technicians in our case study. Sensitising concepts were boundaries and boundary crossing: sociocultural differences that give rise to discontinuities in interaction or action, and the movement of people across these boundaries (Akkerman & Bakker, 2011). Using these sensitising concepts as guiding principles to look at the data, we looked for instances in which the nurses or technicians expressed discontinuities or problems in their collaboration, or referred to themselves as belonging to different occupational groups.

The second focus point related to the processes of communication and collaboration between nurses and technicians. Here, the sensitising concepts were the four learning mechanisms formulated by Akkerman and Bakker (2011): identification, coordination, reflection, and transformation. These sensitising concepts were chosen because they denote "learning potentials" during work at the boundary. We use the term "learning potential" to indicate that learning does not necessarily take place. This is the reason that we do not speak of learning processes, but of processes of communication and collaboration. In the data, we looked for instances in which these four learning potentials became apparent.

The third focus point was related to what nurses and technicians actually learned during their collaboration. Here, the sensitising concepts were technological literacies (Kent et al., 2007), system thinking (Zuboff, 1991), and web of reasons (Bakker & Derry, 2011).

The process of data analysis was as follows. First, the transcribed interviews and reports of the observations were read multiple times (iterative process) and fragments were put under one of the sensitising concepts. Large data fragments were selected in order to preserve the context of the fragment. The sensitising concepts were used to formulate themes that capture the essence of meaning or experience drawn from various situations and contexts (Morse & Field, 1995). This resulted in a first version of the identified themes. Second, these themes were presented in a meeting with fellow researchers, in which they discussed data fragments and were asked to label the fragments under one of the themes. Third, the themes were adapted, based on the input from the meeting and a second check of the literature, in which we compared our themes again to the meaning of the sensitising concepts in the literature. This resulted in a number of changes. The learning potentials "identification" and "transformation" were used as sensitising concepts for our processes of communication and collaboration. However, identification and transformation – at least in our data – are more about the (re)construction of boundaries without overcoming the discontinuity. As Akkerman and Bakker (2011) mention, this could lead to renewed sense making of vocations and a more thorough identity development, but this is not necessarily the case. We therefore chose to use the concepts of identification and transformation to denote the boundaries that exist between the vocations of nurses and technicians. For the processes of communication and collaboration, we preserved the learning potentials "coordination" and "reflection," which were further specified in the themes "translation," "building communicative connections," "perspective taking," and "perspective making." Regarding the third focus point (what was learned at the boundary), the first theme was called "system thinking" and included ideas of both Zuboff (1991) and technological literacies (Kent et al., 2007), as these appeared to be related. A theme related to attitude change was added. The attitude towards technology, both expressed by the nurses and technicians, appeared to be a major theme, while this was not explicitly addressed in studies on system thinking, technological literacies, and web of reasons, as they tended to be more focused on the content of learning (although the idea of a web of reasons involves all possible reasons and argumentations on which to base actions). Finally, this process of data analysis resulted in the themes presented in Table 1, which are further worked out in the next section.

RESULTS

Below, the results of our case study are described in terms of three focus points. The themes identified within each focus point are not always addressed one after another, but examples and citations are used to illustrate the different themes and (inter)relations between them.

Boundaries Between Vocations

In their work around technological innovations, boundaries between nurses and technicians became apparent in various ways. Some boundaries appeared in the language used by the interviewees. For example, nurses often referred to technicians as "boffins" or as a different group: "the argument of 'the technicians' is …." Also, the technician consistently used the term "nursing interventions" whereas the nurses spoke of "clients."

Table 1. Three focus points and underlying themes

Theme	*Description*	*Example*
	Boundaries between vocations	
Identification	Describing how vocations do and do not relate to one another. Establishing the boundary by mentioning discontinuities	"Nurses and technicians are not at the same wavelength"
Transformation	Change of vocations due to technology and collaboration at the boundary	"Originally we are nurses, but now we are the technical ladies"
Language	Vocations use different language. Use of "we" and "they" to denote different groups	Nurses speak of "clients" whereas technicians use "nursing interventions"
	Processes of communication and collaboration	
Translation	Translating between the clients' situations and technology by means of asking questions and analysing problems	"Then I ask questions: What does this patient do at night? Does she go outside? To identify what really happens"
Building communicative connections	Establishing procedures (boundary objects) to facilitate communication as part of daily practice	The development of a standardised report form
Perspective making	Making clear the perspective of one's own vocation on a certain issue	"We as nurses thought that is unethical"
Perspective taking	Taking the perspective of the other vocation on a certain issue	"You can link this to nursing and anamneses"
	What is learned during work at the boundary	
System thinking	Basic understanding of workings of technological systems	"They need to see it has different layers"
Attitude change	Changed perspective resulting in new sense making and enrichment of vocations. Nurses see value and conditions of technology and technicians see implications in practice	"It is just part of the care we provide"
Web of reasons	Using arguments beyond the conceptual content of their vocation	"From practice you notice that you have to consider very carefully what you are doing"

When it comes to communication, two nurses/project leaders reported that "it is difficult to communicate between nurses and technicians; they are not at the same wavelength and talk about different things." Another communication problem is described by this nurse: "we could not push the problems we encountered in working with the system on to the boffins. They kept saying 'yes, it does work, you must have done something wrong.'" These communication problems also included a process of identification, in which the nurses tried to establish their role in the communication process: "As a nurse, I can take the perspective of the client and check whether it is user friendly. Because technicians think everything is easy." Some of the nurses, in particular when they had less experience with technology, expressed the fear of "an erosion of our profession" and were afraid that "technology will replace the direct contact with our clients," establishing a boundary between what belongs to the nursing profession and what does not (identification). This identification process also involved more positive elements about working in the care centre, for example, for nurses who could not carry out the physical nursing work anymore but "could still carry out their nursing profession" and "build up a real connection with clients." Some nurses even reported that they "have more time for social talk" than when visiting clients at home, which they regarded as an important part of their profession.

Next to identification and the establishment of boundaries between vocations, a transformation process became visible, in which both professions changed due to their work at the boundary. The profoundness of this change differed for nurses working in the care centre and the nurses/project leaders who communicated with the technicians on a daily basis to determine what technology is suitable for new clients. The work of the nurses in the care centre changed because they miss the physical contact with the client: "you have to diagnose diseases in a different way. You have to keep asking questions and know even more about triage and different symptoms" and "you have to listen carefully and draw someone out to tell what is wrong." In the daily contact with clients "you cannot put your arm around someone. I try to smile and look friendly." The nurses/project leaders who directly collaborate with the technicians described themselves as "originally we are nurses, but now we are the technical ladies." They describe a more thorough change of their work:

> you have to word very sharply what the problem is. I walk around there every day so the situation is very clear to me. You have to formulate the requirements. This is a matching process between nurses focusing on people and technicians.

One nurse also characterised himself as an intermediary: "I act as a mediator. I understand the clients' questions, but also understand the technicians. I kind of translate." Finally, the technician described how his work "has completely changed. The values you are trying to realise are completely different. It is no longer a supporting process, but part of the primary process of care taking," and stated "I see the impact of technical failures in practice and want technology to maximally contribute to nursing."

Processes of Communication and Collaboration at the Boundary

Four themes related to processes of communication and collaboration were identified in the data. Two themes are related to the learning mechanism "coordination" described by Akkerman and Bakker (2011): (1) translation between the client's situation and technology by means of asking questions, and (2) building communicative connections, that is, establishing procedures that facilitate communication. Two themes are part of "reflection" as described by Akkerman and Bakker: (3) perspective making and (4) perspective taking.

Translation: This happened most often during the discussions between two nurses/project leaders and the technicians. The goal of these discussions was to translate the client's care needs into technical solutions. During these discussions, the technician asked questions "to get clear what the client's needs exactly are." An example described by the technician:

> What does she do at night, does she go to the living room … no no, she never goes to the living room. Then you have to get clear what happens. She goes up at night, goes to the toilet and has to go back to bed. What do you have to monitor then? That she goes out of bed? But do you have to react to every signal? … no no, only when she …. In this case the intervention was the monitoring whether she stayed out of bed longer than 20 minutes. Then you need a signal, but only at night.

Another example is an erratic client living in a home for the elderly with an open-door policy. In a collaboration between the nurses and technicians they tried to find a solution for this client. One nurse noted that:

> Our policy is that clients can go in and out freely, but this was not a good idea for this client. But you cannot keep the door closed for everybody. Our question was "How can we ensure that everybody can go outside, but she cannot?" […] We used a transponder and detectors at the door. If she approaches the door, it closes […] But this transponder was a kind of little cube and the technician thought she could just put it on her arm. We as nurses thought that is unethical, you cannot let someone walk around like a prisoner with a cube around the wrist.

Besides translation, these discussions also contained many instances of *perspective making* and *perspective taking*, expressing the perspective of one's own vocation on an issue, or taking the perspective of the other vocation. In the first example above, the process of questioning goes back and forth between the questions/perspective of the technician and the answers/perspective of the nurse. In the second example, the nurse describes his perspective on the issue (i.e., it is unethical) and also the technician's perspective (i.e., you can put a cube around the wrist).

The *building of communicative connections* becomes most apparent in the failure reports used to communicate technical failures from the nurses to the technical department. The problem with these failure reports was that they were very general ("it goes all black") whereas the technical department needed more specific information to start their search for solutions. A number of things happened around this failure reporting. One nurse described how he learned in practice "The technical department wants us to report very specifically, for example that the sound is wavering or that the client can hear me, but not the other way around. They kind of educated us to do this." The team leader described how they are working on a standardised report form with often occurring failures, which "helps the nurses to best report failures, so the technicians can act more quickly." The technician spoke about this same report form: "it has to be a kind of protocol or procedure, comparable to the analysis of a problem. Maybe a kind of questionnaire 'check this, check that … if it is this, than do that.'" This report form thus has to act as a boundary object to facilitate the communication between nurses and the technical department.

In the discussions around these communicative connections, *perspective making* and *perspective taking* again occurred. The team manager, for example, reported that "the nurses in the care centre have to know how complicated some failures can be. Sometimes it takes very long to solve a failure because it is so complex. Then the nurses get annoyed." Here, she takes both the perspective of the nurses who are annoyed and the technical department, who have to solve complex problems. The technician also often takes the perspective of the nurses when talking about the report of failures:

> You can link this to nursing and anamnesis. You have to describe what is wrong as good as you can […] A nurse also analyses the problem of a patient, what does he look like, pale or ill, what is the home situation, which interventions are necessary, etcetera.

What Is Learned During Collaboration at the Boundary

Within this last focus point for the analyses, three themes were identified: system thinking, attitude change, and web of reasons. With regard to *system thinking*, the ability to identify what a technological system is doing and what follows from it, the technician mainly indicated that a basic insight in technology is needed to be able to prevent frustrations and miscommunication. For example, he wanted the nurses to understand all questions in the new failure report form: "I want them to understand why this is an important question in such a procedure. This requires an understanding of technology. Because a list of questions like this becomes motivating then." A nurse/team leader said: "I want to understand a bit more of the technology, to understand why it takes so long for some problems to be solved. Now, I don't know when I can call them [i.e., the technical department] to account." Another example that initially led to frustrations was the introduction of a new alarm system working with IP-technology (instead of the old analog system). The technician said:

> it seemed as if the analog alarm devices always worked, but actually you could not see if they were working. So you didn't know. With IP-technology, you can easily see whether it works or not, but this gave the impression that it is less good […] People get angry, but they cannot tell what is the difference [between analog and IP].

Besides these general mentions of the need for an understanding of technology, more specific "technological literacies" were mentioned. One example is related to the interpretation of data and the judgement of (ir)regularities. As part of their services, a new system was being tested in which the activity in each room of a client's home is monitored. This creates an impression of the "regular" activity. Then, activity is monitored constantly and the nurse gets an sms-message generated by the system in case of an "irregular pattern." One of the nurses said that:

> There are different sms-messages. A red one means I have to take action immediately, for example if someone has been in the bathroom for two hours. Almost all messages are yellow, which means a noticeable change in activity. I have to interpret what this might mean. Sometimes you know it is logical, because the children are visiting.

In another occasion, two nurses/project leaders were talking about nursing students who do their internships in their organisation. They were referring to technological literacies or elements of system thinking, like the perception of patterns and relationships: "All ICT systems work differently, for example the electronic client files. Students have to be able to work with all systems […] but they don't understand the protocols or principles" and "They have to understand that all systems work in layers, like a tree diagram. If they understand that, that is the basis." The other nurse added "They do not see that a [technological/ICT] system has many relationships, like first you do this, than this happens, etcetera."

The theme "*attitude change*" is partly related to the previous theme. This theme first relates to the nurses who come to see the value of technology in taking care of their client. Also, they increasingly see the use of technology as part of the normal care-taking process. This is a clear goal of the technician:

> I constantly try to knock technology off its pedestal […] This is what is happening now. It is just part of the care we provide. Sometimes you use technology, sometimes not […] like you use an infusion pump as a medical instrument.

A topic that constantly appeared in conversations about technology is that you have to count in that it will fail sometimes. Many nurses were very keen on the "reliability of the system" as already became apparent in their reactions to the new digital alarm system that they thought less reliable: "clients who really need it, get the old system." Part of the attitude towards technology thus includes the realisation that it might fail. As a consequence, you need to think about risks and conditions. As one nurse put it:

> For example when taking medications. A client is sitting in front of the camera, but you cannot see whether he dropped one […]. This is an assessment of the risks. Is it very dangerous if he forgets one pill? If that is the case, you have to conclude that you cannot monitor this from a distance.

Finally, in some instances the nurses and technicians seemed to have broadened their *web of reasons*, in the sense that they used reasons and arguments beyond the direct conceptual content of their vocation. The technician very often talked about the entire care-taking process and how technology is part of this process, instead of "just a supporting process." He often used arguments grounded in the practical care-taking process like "It sharpened my thinking. From practice you notice that you have to consider very carefully what you are doing, because you might choose the wrong technology or it does not work optimally." The nurses and especially the nurses closely collaborating with the technicians also introduced elements of an understanding of technology in their reasoning. For example, the two nurses/project leaders who determined the technological implementations for the diverse clients in collaboration with the technician used the idea of asking questions to analyse a client's problem in their communication with the other nurses. Also, they looked at the home of their clients in a different way, from the point of view of possible technological interventions: "when someone has animals, a sensor detecting movement will not work. Therefore we made a list of things you have to check, for example if someone has a pet."

CONCLUSIONS AND DICUSSION

The goal of this study was to explore how employees of different vocations – in this case nurses and technicians – work together at the boundary and to study what learning opportunities this offers. Three research questions were formulated: (1) How can the boundaries between vocations be characterised? (2) What are the processes of communication and collaboration at the boundary? and (3) What do the employees from the different vocations learn during their work at the boundary? Nine sensitising concepts guided the data analysis: boundaries and boundary crossing (research question 1), the four learning potentials: identification, coordination, reflection, and transformation (research question 2), and technological literacies, system thinking, and web of reasons (research question 3).

Some general remarks need to be made about this study. Because of the in-depth nature of this case study, a rich picture could be obtained about the collaboration between nurses and technicians. However, the results might not be generalisable to other organisations and other vocations. Also, only one technician was interviewed in this study. He was the most important technician in this organisation in that he was present most of the time and collaborated very closely with the nurses. This technician might not be representative of other technicians. It is interesting to see, though, how close collaboration at the boundary influences his understanding of his job and the arguments he presented for his actions. Such changes might be less apparent for people who cooperate less with people from other vocations, or, put differently, close collaboration might be necessary for processes like transformation, perspective taking, and an expansion on one's web of reasons to occur. Finally, this study monitored the collaboration and communication between nurses and technicians who had been collaborating for some time. The communication processes may be different at the very start of such a collaboration.

Related to the three research questions, we can conclude that boundaries between the vocations of nurses and technicians indeed became apparent. Nurses and technicians both established the boundary between them by expressing what belongs to nursing and what belongs to technology as two different vocations. On the other hand, processes of the transformation of both vocations also became apparent, in which both vocations grew closer to one another. As described by Akkerman and Bakker (2011), transformation requires continued collaborative work at the boundary. The two processes of identification and transformation at the same time seem to confirm this idea: Vocations change, but the boundary – and the work at the boundary – remains distinguishable.

Regarding the second research question about the processes of communication and collaboration and the learning opportunities this offers, a number of aspects regarding coordination and reflection as distinguished by Akkerman and Bakker (2011) became apparent. Translation between the client's needs and possible technological solutions is an important mechanism. Remarkable is that analysing problems by means of asking questions seemed to be a habitual way of acting for the technician, but new to the nurses. To facilitate communication (building communicative connections) a boundary object was developed, in the form of a standardised report form for technical failures. This is comparable to the boundary object described in Engeström's boundary crossing laboratory in which a patient record form was developed for a city health care system (1999, 2001, in Kent et al., 2007). Finally, perspective making and perspective taking took place as processes of reflection on one's own vocation and that of others.

The third research question related to what is learned during this collaboration. It needs to be noted that these "outcomes" of learning often already became apparent during the processes of collaboration and communication described for research question 2. Also, it is interesting to note that Zuboff (1991) already indicated that technology is often introduced to reduce personnel: "the more technology I have, the fewer workers I need." This is what indeed seemed to be the case here, as technology was introduced to reduce the time needed by nurses to visit their clients' homes. Also, comparable to Zuboff's analysis of other work practices, the nurses in this case did not receive any formal training to work with technology. The use of technology changes the nature and content of the professional knowledge. It also demands more knowledge of the constituting discipline, as was seen in the nurses who reported that they actually needed more knowledge about triage and different diseases. In a sense, this is comparable to what Zuboff describes in factories in which employees used to feel and smell substances, but now have to use data from a computer as a basis for their judgements.

To conclude, working on the boundary indeed seems to offer learning opportunities and people indeed learn from working at the boundary. This strengthens the plea for education to look at boundaries as learning opportunities instead of problematic "walls" to overcome. For technology education specifically, this study shows that non-technology students will have to develop a certain level of technological literacy and system thinking, while future technicians will have to develop their ability to investigate problems where technology is the best solution. Education could create opportunities to learn at the boundary by deliberately letting students participate and collaborate at the boundaries of their own vocation. The idea of letting students ask questions at their workplaces and take them back to school is a promising one in this respect (Bakker et al., 2012). In general, the ability to ask questions in the workplace seems very important (Fillietaz, 2011), as this is a way of getting acquainted with the tasks, values, and expertise of other vocations. Finally, as students will enter a workplace that is intrinsically heterogeneous and interdisciplinary, students need experience in working at the boundary and boundary-crossing skills.

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6. TRANSFER OF LEARNING THROUGH INTEGRATION OF THEORY AND PRACTICE IN TECHNICAL VOCATIONAL EDUCATION

INTRODUCTION

This chapter is an empirical contribution to the discussion about theory and practice in technical vocational education. The concepts of theory and practice are often used and discussed in relation to teaching and learning technology (compare, e.g., Bjurulf & Kilbrink, 2008; Gibson, 2009; Hansen, 2000), but also in relation to learning a vocation (e.g., Bengtsson, 2010; Berglund, 2009; Göransson, 2004). In previous research, different ways of handling the concepts of theory and practice are suggested, and how to handle them in relation to education is discussed. The concepts can be handled on different levels and are often used concretely, meaning: school versus workplace, reading versus doing, or language and thinking versus physical work (Berglund, 2009). Berglund (2009) has summarised these dichotomised conceptions about theory and practice as follows (Table 1):

Table .1 Dichotomised conceptions about theory and practice (Berglund, 2009)

	Theory	*Practice*
Content	Verbalised knowledge Science Abstract thinking (ideas)	Manual, physical work Application of science Empirics/real life
Tools	Text/models	Body/hands Physical tools
Humans	Theoretical Intelligent	Practical Unintelligent
Arena	School	Workplace
Hierarchy	Superior	Subordinate

However, this dualistic and dichotomised divide between theory and practice is often criticised (Allan, 2007; Bengtsson, 1995; Berglund, 2009; Goodson, 1996; Keirl, 2010), and different suggestions on methods for bridging the gap between theory and practice in learning technology and vocational learning have been suggested in different studies (Allan, 2007; Berglund, 2009; Gibson, 2009;

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Tempelman & Pilot, 2010). In relation to vocational education, theory is often experienced as being connected to school, whereas practice is often connected to vocational learning in workplaces (Berglund, 2009). When different learning arenas are involved within one educational program, transfer of knowledge between those different arenas – school and workplace – can be put into focus. In an earlier study of transfer in technical vocational education, we found four kinds of transfer: (1) transfer of basic knowledge, (2) transfer of principles and skills, (3) transfer of written materials and real life, and (4) transfer of experiences (Kilbrink & Bjurulf, 2012). In order to create possibilities for transfer, close cooperation between the teachers and supervisors during the students' vocational education was necessary. These kinds of transfer also relate to transfer between different kinds of arenas, such as schools and workplaces and also written materials and real life. Those arenas could be related to different, dichotomised views of theory and practice mentioned by Berglund (2009), if cooperation between teachers and supervisors does not exist to interweave the learning content between those arenas.

There are also arguments for a holistic view of the concepts of theory and practice and for handling them as interwoven, in order to learn wholeness, that is, the totality of what has to be learned with the focus on understanding, rather than remembering isolated units (Bjurulf & Kilbrink, 2008; Kilbrink, 2008). Furthermore, theory and practice needs to be handed as interwoven in order to avoid the dualism, where theory and practice are referred to and thought of as mutually exclusive (Bengtsson, 2010; Keirl, 2010). Nevertheless, there can be arguments for separating theory and practice in an analytic perspective (e.g., Svensson, 2011), which can be done without using the concepts as mutually exclusive. One way to handle theory and practice as part of wholeness in relation to vocational education is to see theory as *knowledge about* and practice as *knowledge in* something (Bengtsson, 1995). Similarly, theory has been seen as *knowing that*, and practice has been seen as *knowing how*, in previous research. The discussion about theory and practice often refers back to Ryle's (1949) ideas about dividing knowledge into what (knowing that) and how (knowing how) and to Aristotle's demarcation between the concepts of theory and practice, where theory referred to contemplation and practice to action (Liedman, 2002). As becomes apparent, the concepts of theory and practice often appear in the context of learning technology and learning a concrete vocation. Therefore, there is a need for empirical studies on how these concepts are actually used in relation to technical and vocational education.

AIM AND RESEARCH QUESTION

In this chapter, the focus is on students', supervisors', and teachers' experiences of theory and practice in relation to teaching and learning in technical vocational education. The aim is to deepen the knowledge about how theory and practice are experienced by people being in a technical vocational education, by studying what the informants tell about when they talk about theory and practice, and what narratives appear in relation to these concepts. Therefore, the purpose is to reveal experiences of theory and practice, with the point of departure in the following research question: *How do students, teachers, and supervisors experience theory and practice in relation to teaching and learning in a technical vocational education?* Hence, this study does not aim to find generally applicable definitions of the concepts, but to describe how theory and practice appear in the informants' narratives about technical vocational education. Furthermore, this study is an empirical contribution to the discussion about theory and practice in technical vocational education.

THEORETICAL POINTS OF DEPARTURE

This study takes the ontological departure in the phenomenology of the life world, which states that we all live in a pluralistic world – the life world – but depending on perspectives, positions and previous experiences, we each experience it differently (Bengtsson, 2005). In the life world phenomenology, the human body is important in relation to learning. In his concept of being-to-the-world, Merleau-Ponty (1962/2002) emphasised that we experience the world through our bodies. Learning is therefore about a change in how the life word is experienced (Alerby, Johansson, Kansanen, & Kroksmark, 2000; Marton & Booth, 1997) and how experiences are incorporated in the human body (Alerby, 2009). When technical artefacts, like machines, tools, or measuring instruments are involved when experiencing the life world, they influence the experience differently, depending on how incorporated the artefact is within the human body (Ihde, 2001). When working with tools, for example, Idhe (2001) argues that the more skilled the worker is, the more incorporated the tool is with the human, and the less visible is the tool itself.

Dreyfus and Dreyfus (1986) have suggested a five-step model for how individuals develop knowledge in relation to practical work. The model is inspired by Merleau-Ponty's philosophy of being-to-the-world (Dreyfus & Dreyfus, 1986; Merleau-Ponty, 1962/2002). Furthermore, the model relates to knowledge content, and not to an individual's cognitive development. The five steps are *novice*, *advanced beginner*, *competent*, *proficient*, and *expert*. Dreyfus and Dreyfus write that this knowledge development is similar between different areas, and that the learner passes through similar stages independent of the content. In the first stage, knowledge is contextualised, and the learner learns by instruction. Throughout the five steps, the learning gets more and more holistic and less contextualised. Finally, in the expert stage knowledge is incorporated within the expert. However, the steps are partly overlapping and not everyone has the aptitude for becoming an expert. Björklund (2008) writes that in his later work, Dreyfus added the knowledge of being able to talk about the knowledge to the model, which happens when an expert works as a teacher. The more the knowledge is developed and the learner moves towards expert, the more intuitive the actions are and the expert does not have to think about how to perform the action (Dreyfus & Dreyfus, 1986).

Bengtsson (2010) criticises Dreyfus and Dreyfus's model for leaving out the theoretical part of knowledge – the knowledge about something – and only focusing on the practical experience of knowing in. According to Bengtsson (2010), both kinds of knowledge need to be taken into account, and theory and practice cannot be handled separately. In the phenomenology of the life world ontology, theory and practice are seen as interwoven entities that interact in teaching and learning. Just like body and soul are not divided into two dichotomised entities, neither are theory and practice. Language teaching has been criticised for simply teaching grammar and vocabulary, and leaving out the use of the language, where it would be incorporated within the learner (Bengtsson, 1993). Technology teaching, on the other hand, has been criticised for focusing on the practical part (knowing in) and leaving out the theoretical part (knowing about) (Bjurulf & Kilbrink, 2008). Lived experiences are neither theoretical nor practical; they are an integration of different kinds of interwoven experiences of perception, action, and reflection (Ferm Thorgersen, 2009).

This study aims to deepen the knowledge about how the concepts of theory and practice are experienced – interwoven or not – by those who teach and learn in technical vocational education.

METHOD

With a phenomenology of the life world perspective, the lived and experienced world is the focus of the research. Consequently, meeting with the people involved with the part of the life world we want to study is necessary, in order to say something about phenomenon in the life world.

In this study, a qualitative method was chosen in order to study students', teachers', and supervisors' experiences of theory and practice in technical vocational education. Semi-structured group interviews, as well as individual interviews (Cohen, Manion, & Morrison, 2000; Kvale, Brinkmann, & Torhell, 2009) with informants teaching and learning in technical vocational education were conducted, in order to reach the informants' experiences of theory and practice in technical vocational education. The empirical material for this chapter is based on sections of 21 interviews (see Table 2), where experiences of theory and practice are brought into focus. The told experiences emerging in the interviews are seen as narratives. The narratives were analysed thematically, with a focus on the content concerning theory and practice (Lieblich, Tuval-Mashiach, & Zilber, 1998; Polkinghorne, 1995). The audio files were transcribed verbatim and the transcripts were read multiple times (Kvale et al., 2009). While analysing the transcripts and listening to the audio files from the interviews, common themes in the narratives appeared. Hence, the themes were not predefined, but have emerged from the data. Therefore, the themes are sometimes overlapping, and do not occur separately.

Table 2. Overview of interviews and informants

Interviews and Informants	*Length (min)*
One group interview with Energy Program teacher Erik and plumber Ernst	87
One group interview with Industry Program teacher Ivan, industrial workers Ingemar and Ingvar	54
One group interview with teachers (Erik at the Energy Program and Ivan at the Industry Program)	60
One group interview with supervisors (plumber Ernst, industrial workers Ingemar and Ingvar)	64
Eleven individual interviews with students: Ebbe (22 min), Edvin (22 min), Edward (22 min), Ellioth (29 min), Emanuel (x2: 17 min and 20 min), Ibbe (30 min), Ibrahim (28 min), Isak (x3: 26 min, 31 min, and 45 min)	292
Two individual interviews with teachers: Erik (52 min) and Ivan (27 min)	79
Four individual interviews with supervisors: Ernst (40 min), Evert (68 min), Ingemar (31 min), and Ingvar (20 min)	159

The informants in this study are students, teachers, and supervisors in an Energy Program and an Industry Program at a Swedish upper secondary school. The school in question was part of an experimental project in Sweden, where the students spent at least half the time of their education at workplaces (about 50 weeks, instead of the ordinary 15 weeks) (Sveriges Riksdag, 2009). All informants were involved with the *LISA*-project (see Bjurulf, Chapter 4). Participating in this project was voluntary. All informants gave their written consent to participate in this study, and the research ethics defined by the Swedish Research Council were followed in the project (Swedish Research Council [SFS], 2003:460, section 16; Vetenskapsrådet, 2002). When quoting the informants in the presentation of the results, fictive names are used. Furthermore, in order to allow traceability of the study and to emphasise the voices of the informants, the results are presented close to the empirical material, with many quotations from the interviews. Informants with pseudonyms starting with an *E* were from the Energy Program and informants with pseudonyms starting with an *I* were from the Industry Program. The interviews were conducted within the *LISA*-project with more research questions than presented in this chapter. Therefore, the interviews also concerned other areas.

In conducting a narrative study like this, an awareness of how the results are dependent on the interpretations of the researcher is also important during the whole process. I am also aware that, as a researcher, I influence a qualitative study like this, which makes the results a co-production between the researcher and the informants in the interview situation (De Fina, 2009). The results from this study also do not claim to answer what really happened in the technical vocational education, but to reflect the informants' told experiences about theory and practice, in accordance with the theoretical points of departure for this study and the research method chosen.

RESULTS

In the presentation of the results, the informants' narratives about theory and practice are synthesised into common narratives in relation to the different themes. Quotations from the interviews are interwoven in the description of the themes below, in order to keep the presentation close to the empirical material and to raise the informants' voices. The interwoven quotations are marked with quotation marks.[1] Comments or clarifications that I have added into the quotations are marked with square brackets. The themes that have emerged from the data aim to reveal the informants' experiences, as they are expressed in their narratives about theory and practice. Every theme is introduced with a longer quotation from the interviews.

The themes are theory and practice in different arenas, theory and practice as different parts of the body, practice as an application of theory, and theory as understanding practice and vice versa.

Theory and Practice in Different Arenas

Teacher Ivan reports that the students:

> get the basics at school. They get a basic education, with different industrial courses, in order to be able to further develop at their workplace learning [and the basics can be] if they for example should be able to run a CNC-machine. So I take the theory at school, how a program looks and why it looks the way it looks, that there are cycles and that there are a lot of tools, computer based, that you can get when you are programming. But then, when they are at the company, then there are a lot of students that get to program, but then you maybe have to adjust or troubleshoot if there is something that does not work out as it is supposed to, when they control measure it. And then you have to be able to read a program.

Hence, theory in this quotation is related to school. Also, in Swedish vocational school, the word practice can be used as a common word for workplace training. Student Ellioth states that "theory means school" and "practice means [workplace] practice." The division of theory and practice often refers to what is done in the different arenas, that is, school and workplace, where the theory is connected to school and practice to the workplace. Supervisor Ingvar says that "at school, there is more theory" and at our workplace it is "just practice." Supervisor Ingemar says that "many times, theory is what you do first." The theory is the fundamental thing, and that is what "you learn in the first semesters at school." Also, teacher Ivan says that the students "get the basics at school." Ivan continues, this basic education is what the students need in order to "develop further at their workplace learning." Teacher Erik tells that the students "can go out to workplace practice directly, without knowing anything, but at the same time it is good to have some knowledge before."

Student Isak refers to welding at school as theory. Isak says that he is not allowed to weld during workplace "practice," but is allowed to at school; "on the workplace practice I don't do that" and "here at school in the beginning, we had a lot of theory, and then I was able to weld a lot." Accordingly, theory is often experienced as what is done at school, but it differs in the experiences of what theory at school means. Isak says that theory is when you learn more about what you do at the workplace, by studying, for example, more about the tools you are working with, and how different materials and their properties influence the tools, like if "the heat differs when you turn different materials, you need to have different shear steel" and that you learn "from theory, by studying at school." Student Ibrahim, however, says that he wants to study more theory at school in order to get "broad knowledge" and the [workplace] practice is more "for learning for the adult life." Ibrahim says that knowledge about, for example, history and math is important, and this is included in theory. Ibrahim also says that he would have liked to have more time at school, in order to "study more subjects" so that "you have better possibilities for studying further later on." He tells that the "disadvantage with all the practice" is that you only know one workplace, and that he wants to have more possibilities for the future.

Theory and Practice as Different Parts of the Body

The advantage with this kind of vocational education, where the students have a large part of their education at a workplace, according to supervisor Ingemar is:

> that they [the students] can learn theory, or practicality, that is really helpful, at least for the vocation, because it is still a lot of handicraft in the vocation, even if it is a lot of data driven, it is a lot of craftsmanship. Handicraft means that you are able to work with your hands. It is really hard to read in order to learn that. You need to practise yourself with your hands and do. You can read about it, and understand it 100%, but then it needs to be translated into practice. A lot of people have problems with that.

This theme concerns theory and practice as relating to different parts of the body. Practice is often related to the hands and physical work, while theory is related to the head and thinking. For teacher Erik, there are no obvious definitions of theory and practice. At first, Erik says that it is really easy to define the concepts, but then he changes his mind and says that it can be complicated. For him it is not a simple matter to separate them in his teaching, but still he tries to define theory as "when you don't get sweaty." Supervisor Ernst reports that some students do not handle the physical work properly and that those students "probably are better suited for theory" and could work as a consultant who read drawings, rather than working with bending pipes. One theme in the narratives, therefore, concerns theory and practice as relating to different parts of the body or using different senses.

In this study, there are many examples of experiences of practice as using the body and different senses. It can be about watching, touching and seizing. By working practically, you are able to get a feeling for how to do, "that, you cannot get from a theory book," supervisor Ernst says. Furthermore, practice is often related to working with the hands. Student Emanuel tells that practice for him is to work "with the hands" and that practice at school is related to "being able to keep on building with pipes, weld and things like that." Supervisor Ingemar says that practice is "what they do with the hands, starting the machines."

Some of the informants also talk about practice as something that is physically heavy. This is a theme that has emerged as important in the narratives from the supervisors at the Energy Program, those who work as plumbers. Supervisor Ernst says that it is important to be strong when working practically. He contrasts this practical work to a theoretical person, "who will fail" and says that it is not possible to carry a heavy furnace, with the weight of 400 kilograms, down a stair "if you don't have a body for it." Supervisor Evert tells that you often need to "be two people" when you do these kinds of jobs. Furthermore, Evert tells that the students are not always prepared for these heavy tasks.

When you get practical experience from working, "the more confident you get, but you also have to keep going," student Isak reports about welding. When you practice it a lot, "it sort of stays in your wrists" he continues, and later Isak also says that "it should probably also stay in your head." Student Edward says that "practice is to do something with the body yourself when you work" and "theory is when you sit and read". When you have theory at the workplace it concerns "reading manuals" and similar, in order to "see where everything should go," student Edvin says. Teacher Ivan says that theory exists foremost in books, "or in my mouth." The student Ebbe tells that "practice is when you get to fiddle around and try to do stuff, in theory you get to read about it." He also tells that they do not have much theory: "it is rather the teacher who tells and shows," which is not theory since the students then "do not sit and read about how to bend pipes in a booklet."

Practice as an Application of Theory

Emanuel says that he likes to:

> prepare himself with some kind of theory, sort of. If I would do a four week long job, then it probably would be nice with a week at school first and thereafter do the four-week job at the workplace if you were able to get to know what it could be about. Then you could be prepared and know what is going to happen, so that you can follow. Sometimes it can be stressful. I have been, sometimes it is a bit too stressful, like for example my last vocational practice. Then maybe they do not always have time like those guys [his current supervisors]. They have time, they can stop in order to help me, but it is not always like this at vocational workplaces.

One theme in the narratives is about practice as an application of theory. Theory is the starting point and a way to prepare for the practice. Practice can be experienced as using what you have learned; to apply what you have learned theoretically about something. Student Isak tells that "theory, that's what you learn for work, what you do at school is theory, I suppose, what you learn and read. And practice is when you use the theory." Student Ibrahim reports that "in theory you learn, in practice you do it." Supervisor Ingvar, however, says, in relation to theory and practice, that it is not obvious that you know something, just because you have read about it; "but if I have done it a couple of times, then at least I know better, than if you have just read about it."

This theme also pertains to experiencing theory as something you have to read, or understand, before you are able to perform actions in a certain way. How much theoretical knowledge you have gained also influences how you learn. Supervisor Ingemar tells that theory "goes more in depth, in reading drawings and things like that" and that depending on how much theory the students have studied before they go to practice, they learn differently. Student Emanuel tells that theory is about preparing and that theory takes time. Furthermore, he tells that you prepare at school, before going to the workplace, and that "theory, yes it is, just sitting at school reading about heating and sanitation."

Theory as Understanding Practice and Vice Versa

Teacher Erik reports that at school there are:

> lessons, then we have, you have the possibility to do in several different ways, we have theory. And also practical work. And in order to get a complete course, I have to have some practical work at school. It would, if you are supposed to explain something difficult to the students, then you can either start with theory, or you do the opposite way, you start with the practical part. Nevertheless, it is good to have two entry keys.

Hence, learning content can be introduced from different angles. Either you can start in theory, or you can start in practice. One theme concerning theory and practice is that they are both needed in order to understand wholeness: In order to understand theory, practical experiences are needed, and in order to understand practice, theory is needed. For example, supervisor Ingemar says that theory has to be experienced. When some things are studied at school, "it gets a bit abstract for them [the students] at the beginning, they need to get out to see and to hear the differences" says teacher Ivan. Supervisor Ingemar agrees that "it must be experienced" in order to be memorable, if the students just study something "in theory" and "are not able to use it quickly enough" they will forget it. Furthermore, theory is also about talking, showing, and explaining to the students. Teacher Erik reports that there is theory in the workshop hall in the school, because he "always talks to them [the students]" and tells the students "look; now I do like this." Erik also tells that theory is "when I draw on the blackboard." Student Emanuel tells that if there is time, they also have theory at the workplace, because he "asks a lot" and that theory is about "things we point at, and talk about."

Sometimes wholeness can motivate the students to try to understand what the supervisor Ingemar calls "theory." In order to understand theory, the students have to read, and sometimes theory is hard to present in formal education in a suitable way. Ingemar tells that "it depends on sure instinct how to fit it [the theory] into education, because in some way they [the students] need to study theory and the best way is when they get stuck so that they have to read." "It comes naturally" when the students themselves discover the need for understanding, Ingemar continues.

Commonly, theory in the narratives is experienced as knowledge about something, that you understand something, or that you learn something new. Student Isak says that theory at the workplace concerns learning something new; "they have a lot of courses here [at the workplace] sometimes too, then all are gathered together and learn something new, and if it is new, then it is a bit of theory, I suppose." Furthermore, supervisor Ingemar tells that there is some theory at the workplace, even if he thinks that theory mostly is connected to school. At the workplace "we read drawings, following the whole process when you receive a product, that's things you do." If something happens, if there is a problem, an alarm for example, the students have to know what to do, and this knowledge is in the books, according to teacher Ivan.

When student Isak talks about his entire education in retrospect, he says that he would have liked to spend more time at school, in order to learn more about the tasks and tools he works with on the workplace practice. Isak says that he would like to "be a bit more skilled on the workplace practice" and that he would be, if he could "learn more at school," and have a bit less workplace practice, because "there is a lot of [workplace] practice." He also says that he likes the practice, but wishes anyway that he had studied "more theory" during the education. His suggestion about how to improve the education is to "remove the core subjects and study more theory." Hence, the core subjects (like history and Swedish) are not theory for him, but deeper knowledge about what he needs to do at the workplaces is.

Furthermore, this theme relates to theory and practice as a whole. In order to understand wholeness, both theory and practice are needed. Student Emanuel says that "at school, we can use paper and try to check the drawings and how it should be done, but firstly, when you are out here [at the workplace], you can understand how it works." Supervisor Ingemar reports that financial reasons can be an obstacle for conducting the education as you wish. Often theory and practice are alternated in the vocational education in this study, and supervisor Ingemar says that "we would like to have a machine" for practising programming at the company, but "unfortunately it is not possible in reality" and then "we have to do the practice and theory in relation to that we run [the machine] with a product that we will have to get paid for."

Student Edvin reports that that "theory is that you sit and read about how stuff works" and that in "practice you are able to see for yourself" and to "do, so that you learn." Theory and practice exist both at school and the workplace training, and "as far as they concern the same topics," theory and practice are connected, Edvin says.

DISCUSSION

The results from this study show that theory is often experienced as something related to school, to think and to read and to prepare for workplace training. In contrast, practice is related to the workplace, to physical work, to using the body and the hands, and it is also related to using what you have learned. This corresponds to how the concepts often are experienced in relation to technical and vocational education (compare, e.g., Bengtsson, 2010; Berglund, 2009; Bjurulf & Kilbrink, 2008; Gibson, 2009; Hansen, 2000). This indicates that an educational benefit of interweaving theory and practice (compare, e.g., Bjurulf & Kilbrink, 2008) is not fully visible in the educational practice – or even seen as an emergency solution (compare the quotation from Ingemar above in the theme *Theory as understanding practice and vice versa*).

However, the experiences of the concepts are also more complicated. When deepening the discussion about theory and practice in technical vocational education, it is not obvious how to divide or define the concepts of theory and practice. Hence, there are two levels of experiencing theory and practice in this study. In the first level, theory and practice corresponds to the dualistic division presented in earlier studies (compare, e.g., Berglund, 2009), but on another level, when there is a deeper discussion about the concepts, theory and practice become more interwoven in the informants' narratives. In the second level, the experiences can be related to how theory and practice are handled holistically in the phenomenology of the life world theory (compare Bengtsson, 1998, 2010) and that lived experiences are neither theoretical nor practical, but an integration of different kinds of interwoven experiences of perception, action and reflection (Ferm Thorgersen, 2009).

As noted in the results section, the four themes that emerged from the data in the study are theory and practice in different arenas, theory and practice as different parts of the body, practice as an application of theory, and theory as understanding practice and vice versa. Some of the themes emerging in the narratives correspond to the dualistic division of theory and practice, presented by Berglund (2009), which can be seen in Table 1 above. For example, the learning arenas serve as the basis for the difference between the concepts, as in the theme *theory and practice in different arenas*. The dualistic experiences can also be related to the concepts as referring to different parts of the body in the theme *theory and practice as different parts of the body*. Moreover, there is a division on the individual level, concerning which parts of the body are used for the different concepts, where practice relates to using the body and different senses and something physically heavy, that is, using the whole body in a way that is in opposition to theory as non-perspiring work. The third theme in the study, *practice as an application of theory*, can also refer to a dualistic view, if the application only goes one way – from the theory, to the practice. The first three themes in the results can therefore represent a dualistic view of the concepts, concerning a division in space (*theory and practice in different arenas*), in body (*theory and practice as different parts of the body*), and in time (*practice as an application of theory*). The fourth theme, *theory as* *understanding practice and vice versa*, concerns a more holistic view of the concepts, where a dualistic division is not similarly visible and the concepts are interwoven and related to the aspects of space, body, and time. Therefore, this theme contains more examples in the presentation of the results and is not divided into further themes.

In the narratives, there is a more obvious division between the concepts of theory and practice related to the beginning of the students' education, where theory as the basic knowledge and preparing part is related to school and described as a prerequisite for practice in further education and work for the students. However, the further into the education and the deeper the knowledge that the discussion with the informants goes, the more integrated the concepts of theory and practice appear. The focus on the basics and theory as something that comes first (the theme *practice as an application of theory*) or belongs to what the student needs to study at school (the theme *theory and practice in different arenas*) before they go to their working practice can be related to the novice stage in Dreyfus and Dreyfus's (1986) model of knowledge development. This division is not that obvious when the students have had more practical experience. Hence, there are themes where the concepts of theory and practice are experienced as more complicated. A more holistic view of the concepts theory and practice can be seen in the theme *theory as understanding practice and vice versa*, but also in the *practice as an application of theory*, if there is an alternation between the learning arenas, and the experiences from both arenas are used and further developed during the students' learning. The informants present more nuanced experiences, when the discussions about the concepts of theory and practice are deepened. For example, theory and practice can be seen as different "entry keys" to learning, and there is theory at the workplace and practice at school. Some experiences also refer to the students sometimes having better possibilities to participate and try different tasks that are experienced as practical at school, rather than at the workplace training. Compare, for example, the quotation from student Isak in the theme *theory and practice in different arenas*, where he states that he has better possibilities to weld at school. This indicates that time-consuming tasks in which the learner needs to have practical experiences, in order to facilitate learning and develop knowledge as in Dreyfus' and Dreyfus' (1986) model, are not always better learned at the workplace. Financial reasons can be an obstacle for taking the time to explain tasks in the working process, during the working process at the workplaces, since the companies' goal is to earn money – in comparison to the schools, where education is a more obvious goal. Authentic learning at the workplace is argued for in other studies (e.g., Billett, 1994), however, the result from this study suggests that workplace learning needs to be complemented with learning in formal educational settings. This formal learning should include aspects of education that are commonly experienced as practical learning.

The practical experience stressed in Dreyfus and Dreyfus's (1986) model is also emphasised in different themes. Compare, for example, the quotation from student Isak, that the welding "stays in your wrists" when you practice it a lot (in the theme *theory and practice as different parts of the body*), and the quotation from supervisor Ingvar, that you know better how to do something if you "have done it a couple of times," than if you just have read about it (in the theme *practice as an application of theory*). This also relates to how knowledge becomes incorporated within the human body (Alerby, 2009; Merleau-Ponty, 1962/2002). Nevertheless, the students in this study also demand more theory in the education, as well as more time at school (compare, for example, Isak's quote about his education in the theme *theory as understanding practice and vice versa*). Mostly this demand refers to a deeper knowledge about what they do at the workplaces, which is theory, as knowledge about the practice (compare Bengtsson, 2010). In one narrative (student Ibranhim, in the theme *theory and practice in different arenas*), the requested theory also concerned a different theory at school, concerning other school subjects, in order to gain a wider knowledge (compare Lindberg, 2003). The demands are also to learn skills during the education that they are able to use in other contexts, which relates to transfer of knowledge (compare Kilbrink & Bjurulf, 2012), so that they can get different kinds of jobs in the future. One way to do this is to learn more theory, above all in relation to the practical work. The practical experiences need to be complemented with theory in the sense of *knowledge about* (Bengtsson, 2010), in order to be able to transfer the knowledge into new situations in the future (Kilbrink & Bjurulf, 2012). From this point of view, both the practical and the theoretical knowledge need to be emphasised during vocational education. This demand for more knowledge about the practice is what also Bengtsson (2010) emphasises in relation to vocational education. Not only the students, but also the teachers and the supervisors, point out the importance of knowledge about the practical work performed at the workplaces, in order to be able to troubleshoot or to solve new problems. The practical experience emphasised by Dreyfus and Dreyfus (1986) is therefore important, but not enough.

CONCLUDING REMARKS

This study contributes with knowledge about how theory and practice are experienced in technical vocational education. The results show that the concepts are commonly used as a dualistic division, also expressed in other studies. Previous research (e.g., Bjurulf & Kilbrink, 2008; Gibson, 2009) concerning the educational benefit of interweaving theory and practice in education is not very visible in the informants' narratives. The use of the concepts theory and practice to a large extent cements the dualistic view of the concepts as two dichotomised entities.

Students demand more theory, and understand it as meaning *knowledge about* what is performed in the practical parts of the education. Furthermore, deeper knowledge about the practice is one way to create conditions for transfer of knowledge in order to be able to handle future new knowledge demands, at new workplaces with new working tasks. Consequently, when theory and practice are handled separately during the education, there are higher demands on the educational settings. Teachers and supervisors need to create possibilities for students to transfer different kinds of knowledge between different arenas (compare Kilbrink & Bjurulf, 2012), where theory and practice are integrated, and concern the same learning objects (Bjurulf & Kilbrink, 2008).

Another conclusion is that authentic learning is not always preferable in vocational education. The students need to practice the actions they are supposed to perform in the workplaces in an environment where there are possibilities to work in a slower pace as a beginner, without disturbing the production, and also to be able to make mistakes and to learn from them. There can be better conditions for doing this in adjusted learning situations at schools, rather than at workplaces.

Finally, it can be stated that the concepts of theory and practice can be experienced in different ways by different informants, but also in different ways by the same informants in different narratives. This indicates that the demand of integrating the concepts in educational settings includes complicated processes involving aspects concerning space, body, and time in order to reach wholeness.

NOTES

1 All quotations are own translations from Swedish.

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7. TRANSFERRING STANDARDS

Judging "This-Now" by Reference to "That-Then"

INTRODUCTION

Assessment hurdles in schools have proliferated dramatically in the last decade. The US Accounting Office estimates that between 2002 and 2008 assessment spending in the USA rose from $1.9 to $5.3 billion, and in England the Times reported that: "English children are tested longer, harder and younger than anywhere else in the world" (Stewart, 2010).

This chapter is not about the policies driving this growth, nor about the wisdom of it all, nor is it about the reliability of the results of all that assessment. I am interested in what is going on in the mind of the assessor. How does the assessor/examiner/judge make their decision about the quality of this or that piece of work?

This chapter is based in a research project conducted in the Technology Education Research Unit (TERU) at Goldsmiths University of London between 2004 and 2010. As part of that project (funded by the Department of Education and a consortium of Awarding Bodies in England) we developed a quite new methodology for assessment, along with new software tools, and we ran a national pilot in schools in 2009. It worked remarkably successfully, with teachers making assessment judgements (of sophisticated multi-media portfolios) easily and quickly and with quite astounding reliability.

In this chapter I attempt to explain the judgement process from inside the minds of those assessing teachers. This requires us to start with some consideration of the cognitive processes involved and then to examine the processes by which a "standard" is carried across (transferred) from one piece of work to another, and from one assessor to another. Without some effective transference, assessment outcomes would be random, unreliable and not worth doing.

COGNITIVE PROCESSING AND ASSOCIATIVE MEMORY

The journalist and science writer Malcolm Gladwell proposes an interesting idea about thinking. In "Blink" (2007), he describes a thought experiment with a card game. There are four decks of cards (two red and two blue) and with each card you

H.E. Middleton & L.K.J. Baartman (eds.), Transfer, Transitions and Transformations of Learning, 85-107.

either win money or lose it. You have just to turn over cards in such a way as to maximise your winnings. What you do not know is that the red deck is high risk (winning and losing lots), and you can really only win from the blue cards. How long does it take you to work this out?

After about 50 cards most of us start to get a hunch about what is going on. After about 80 cards most of us have worked it out and can identify why the red decks are bad for us. We observe what is happening – we put together a theory – it seems to work and so we adapt our strategy. This "Iowa experiment" (Gladwell, 2007, p. 10) shows us one side of our thinking – the conscious logical strategic side. It works but it takes 80 cards to get there because it takes a lot of information to operate.

But there is a second strategy that starts to operate after only 10 cards. The problem is that it operates below the level of consciousness.

> It sends its messages through weirdly indirect channels, such as the sweat glands in the palms of our hands. It's a system in which our brain reaches conclusions without immediately telling us that it's reaching conclusions…. this is called the adaptive unconscious … a giant computer that quickly and quietly processes a lot of the data we need in order to keep functioning as human beings. (Gladwell, 2007, p. 11)

Gladwell argues that most of our survival strategies – like jumping out of the way of an on-coming car – are based on such thinking. But it also operates in more considered areas of decision making. He describes a psychologist giving students three 10-second videos of teachers in the classroom. Even with the sound off they had no difficulty in coming up with a rating of teachers' effectiveness. Then she cut the tapes to 5 seconds and then 2 seconds and the ratings were largely the same as those awarded by students after a whole semester of teaching. Gladwell recognises that we are innately suspicious of this rapid unconscious cognition and indeed our language is full of warnings about it. "Look before you leap," "don't judge a book by its cover," "stop and think," "haste makes waste."

If Gladwell is more journalist than scholar, Daniel Kahneman is very different. His Nobel prize was awarded in the world of economics – but specifically it was awarded for his paradigm-shifting work on decision making and uncertainty. His has been a career in experimental psychology and he is currently Emeritus Professor of Psychology at Princeton. He introduces us to his leading characters "system 1" and "system 2" thinking.

– system 1 operates automatically and quickly, with little or no sense of voluntary control.
– system 2 allocates attention to the effortful mental activities that demand it, including complex computations … [and is] often associated with … agency, choice and concentration. (Kahneman, 2011, p. 21)

System 2 is the kind of thinking that we all understand as thinking in an everyday sense – we look at the task – we concentrate – we employ strategies – we allocate mental and other resources – we work out a solution – and we check that it works. But if system 2 thinking enables us to concentrate and compute solutions to complex problems, it is system 1 that seems to me to be more remarkable. It is intuitive and is (mostly) beyond our control, even to the extent that we are completely unable to stop it working. It just does what it does.

When driving a car, you do not look for the gear lever because you just “know” where it is and your proprioceptive muscle memory does the work for you. You scan the road ahead – adjust your direction – slow down – signal – turn – accelerate, all completely automatically. Those who have tried programming a computer-controlled buggy to do this job will know how complex it is. But we do it all without (system 2) thinking. We are in automatic pilot – below the level of conscious attention. Until something goes wrong. Then we rapidly engage another kind of thought as we try to compute our way out of the problem. Interestingly – as we engage this deliberate (system 2) form of thought – the world appears to go into slow motion, indicating the phenomenally fast processing speed that we are generating to tackle the difficulty.

Of course, this notion of two kinds of mental processing applies only when we are dealing with *skilled* behaviour. Learner-drivers do have to think deliberately about what they are doing and this makes their driving appear clumsy and uncoordinated. As we develop more skill, the auto-pilot phenomenon progressively smooths our behaviour and gradually we lose conscious awareness of those separate considered actions. They blend into a coherent (system 1) performance.

All skilled performance (e.g., by pianists, mountain-climbers, writers, skiers) is dependent upon the fact that we progressively hand over control from our conscious mind and allow our pre-conscious mind to control things (do the auto-processing) for us. It takes hours and weeks and years of practice, but gradually we embed enough pre-ordered behaviours for the mind to know what to do in almost any given circumstance. It is the weird unexpected things that trigger a return to conscious control. While all is going well (while all the incoming signals conform to expectation), our auto-processing keeps things going smoothly. But (back to the car example) if we hit a bit of unexpected ice, our turn of the steering wheel no longer results in the anticipated course-correction. Help! Panic! It is what happens next that is so revealing about the two modes of thinking.

We know (with our deliberate thinking head) that we should steer into the skid. But our auto-processing (laid down over hundreds of hours of practice) tells us to steer away from the potential hazard. When the two kinds of thinking are in dispute, which one wins? My guess is that most of us would try to steer away – lose control – and skid into the hazard. Auto-processing is SO strong that it overrides our conscious thought. Of course this is differently true for those drivers who have lots of experience of skids. Rally drivers are supreme in this area. For them, skidding is normal and they have loads of auto-processed routines to deal with it. My point is that skilled behaviour is VERY difficult to ignore or to unlearn.

The great power of system 1 is that it automatically builds scenarios for you. It looks at the world (and all the odd things in it) and feeds you with the best available hypothesis to explain what is there. If I showed you three unrelated images, your system 1 thinking will be working overtime and in a nanosecond it will make up a series of scenarios to explain their coexistence.

Figure 1. Sample of apparently unconnected images

The brain does all this for us by using *associative memory*. All the images evoke memories and system 1 is trying to associate these memories and link them into a coherent explanation.

Polo: cheap – crunchy – minty
Polar bear: cold – arctic – icy – fierce
Shop: selling – buying – sweets - papers

Maybe the images are about an advertising campaign for Polo?
Maybe Polo is sponsoring a wildlife event?
Maybe Cosmopolitan is ………… ?

> An idea that has been activated does not merely evoke one other idea. It activates many ideas, which in turn activate others. Furthermore only a few of the activated ideas will register in the consciousness; most of the work of associative thinking is silent, hidden from our conscious selves. The notion that we have limited access to the workings of our minds is difficult to accept, because, naturally, it is alien to our experience, but it is true: you know far less about yourself than you feel you do. (Kahneman, 2011, p. 52)

Kahneman summarises the work of system 1 thinking as follows.

> The main function of system 1 is to maintain and update a model of your personal world, which represents what is normal in it. The model is constructed by associations that link ideas of circumstances, events, actions and outcomes that occur with some regularity. …. As these links are formed ... the pattern of associated ideas comes to represent the structure and events of your life, and it determines your interpretation of the present as well as your expectations of the future. (Kahneman, 2011, p. 71)

Hundreds of thousands of years of evolution have made system 1 VERY good at doing this patterning; monitoring what is going on; continuously making assessments and providing explanations. And all without a specific intention and with little or no effort. When uncertainty becomes problematic, system 2 is engaged to look more systematically at the matter and it does so by looking for confirmatory evidence for the hypotheses thrown up by system 1.

A hundred years ago, Freud (ego/id/repression) noted that conscious attention is the tip of the mental iceberg that projects above the water and that – below this conscious thought – there is limitless unconscious activity buzzing away. But now we recognise that this is to underplay the scale of the difference. In *Strangers to Ourselves*, Wilson (2002) suggests that our conscious, deliberate thinking is such a tiny proportion of our whole mental activity that it is better thought of as a snowball sitting on top of Freud's iceberg.

ASSOCIATIVE MEMORY AND SCHOOL ASSESSMENTS

Inevitably this analysis of cognitive processing has serious consequences for the kinds of assessment that we traditionally conduct in schools. Brooks (2012) makes an absolutely direct connection in order to explain the behaviour of General Certificate of Secondary Education (GCSE) examiners.

> This theory distinguishes "quick and associative" System 1 judgements from "slow and rule-governed" System 2 judgements (Suto and Greatorex, 2008, p. 215). Judgments made using System 1 are "intuitive", "automatic, effortless, skilled actions, comprising opaque thought processes, which occur in parallel and so rapidly that they can be difficult to elucidate" whereas System 2 judgments involve "slow, serial, controlled and effortful rule applications, of which the thinker is self-aware." (Brooks, 2012, pp. 65-66)

The reference to Suto and Greatorex (2008) was in relation to work that they did at Cambridge Assessment, where they combined "think aloud" with semi-structured interviews with examiners in order to track the decision making processes that the examiners were using to arrive at their judgements. Suto and Greatorex identified five distinct cognitive marking strategies. For instance, the "matching" strategy required "a simple judgement of whether a candidate's response matches the mark scheme" (p. 220). This was presented as system 1 judgement because markers could rely on rapid pattern recognition, identifying, for instance, a word, letter, or number that matched the mark scheme. "Scrutinising" (p. 225), in contrast, was used for unexpected responses where a marker needed to determine whether an answer was due to error or represented an acceptable alternative to the mark scheme. Scrutinising was presented as evidence of system 2 judgement because it entailed multiple re-reads of a text, pauses, hesitations, and recourse to the mark scheme as markers tried to resolve their uncertainty.

However, perhaps the most profound finding from Suto and Greatorex (2008) was not that they saw evidence of this or that example of system 1 and system 2 processing, but that they saw evidence of examiners transferring the cognitive load involved in assessment judgements from system 2 (slow and deliberate) to system 1 (quick and associative).

> The two systems are thought to be concurrently active, enabling subjects to switch between them according to the cognitive demands of the task in hand…. Another important feature of the dual-processing theory is that 'complex cognitive operations may migrate from System 2 to System 1' as individuals gain experience. (Suto & Greatorex, 2008, p. 215)

They found that the accumulation of experience inclined markers to speedier, less considered judgements as their expertise developed and enabled them gradually to move from type 2 to type 1 processing.

LOADING THE LEVERS OF JUDGEMENT

Since (at least) the early 1980s, school-based assessment judgements have been seriously shaped by lists of criteria that seek to define the qualities that are sought in any piece of work. Despite their almost universal adoption, there are serious limitations to the value of such criteria in making good judgements. The UK experience of National Curriculum Assessment (NCA) in the early 1990s provided a lesson in their limitations. With just one subject (design & technology) defined through approximately 150 "Statements of Attainment," and with primary teachers having to make such assessments for every student in six or seven subjects (each with their own lists of 150 statements), it was not surprising – except perhaps to the political instigators of this madness – that teachers revolted and simply refused to have anything to do with it. The over-reliance on criteria – that was one of the core difficulties of NCA – has been thoroughly documented in many places (see, e.g., Kimbell, 1997, Chapter 5 "The shambles unravels").

In the midst of the early 90s mayhem in England, Wiliam (1992, p. 19) was cautioning against succumbing to the pressure to criterion-reference all assessments, especially those involving complex skills and performances which are irreducible and cannot be itemised because "the whole is greater than the sum of parts." Later, Wiliam (1996, p. 297) notes that teachers involved in a GCSE English qualification – assessed entirely by coursework – "quite quickly internalized notions of 'levelness', so that in the vast majority of cases different teachers would agree that a particular portfolio of work merited, say, a D."

Morgan (1996) describes this quality in terms of building "individual and social constructs" around communities of markers, enabling them to develop "a general construct of 'level' or 'ability' … without access to any stated criteria" (p. 356). Whilst personal constructs enable individuals to make sense of their world, there is also evidence that where there are opportunities to collaborate, the development of constructs can become a shared undertaking, emerging within a community of practice (Wenger, 1998).

Closely related to the idea of "constructs" is that of "heuristics," that Gilovich and Griffin (2002) describe as "highly efficient mental shortcuts" (p. 4) that offer simpler and quicker ways of judging than the extensive algorithmic processing that is characteristic of rational thought. Brooks (2012) describes a really interesting study of heuristics by Garry, McCool, and O'Neill (2005) in the context of jury decisions about sentencing. She describes the use of an "anchoring" process that locates the judgement in relation to a notional fixed point and then allows that judgement to be adjusted one way or another from that point.

> The anchoring and adjustment heuristic has been observed in various settings, mock jury trials for instance. Thus, when half the jurors in a mock jury trial were instructed by the judge to start their deliberations by considering the harshest verdict possible whilst the other half were instructed to start by considering the most lenient sentence possible, the first jury delivered a much harsher verdict than the second. This is consistent with the theory that the judge's instructions had acted as an anchor which was adjusted to reach a final verdict. (Brooks, 2012, p. 73)

In the context of this paper, the notion of the anchoring and adjustment heuristic is highly significant and I will return to this point later. Before that, however, I want to conclude this review of the cognitive background to assessment by referring to the work by Donald Laming. As an experimental psychologist, he is interested in the cognitive processes involved in making a judgement and in "*The eye of the beholder*" (2004) – through a series of ingenious experiments – he demonstrates his principle of relativity, through which he asserts that "…*there is no such thing as absolute judgement*."

> When someone comes to make a judgement in the everyday world, the point of reference is most often taken from past experience. Different people have different accumulations of past experience and for that reason make different judgements about the same issue. We call this difference "a point of view"… All judgments are comparisons of one thing with another … the judgment depends on what comparator is available. (Laming, 2004, p. 11)

This is very un-nerving for a school-based examiner – who is supposed to be marking work by reference to objective criteria and on an absolute scale: "this piece is worth 55% and that one is worth 45%." Alastair Pollit (2004) describes the problem highlighted by Laming, but he locates it firmly in this world of school examinations.

> When we try to judge a performance against grade descriptors we are imagining or remembering other performances and comparing the new performance to them. But these imagined performances are unlikely to be truly representative of performances of that standard, and very likely to vary in the minds of different judges. (Pollitt, 2004, p. 5)

Given that the "point of view" (Laming, 2004) of the different judges will inevitably be different, it is equally inevitable that the "remembered" standard will be inconsistent. And the equally inevitable result is that:

> … there is considerable concern about the level of disagreement between raters, such that "inter-marker reliability" dominates technical discussions about the quality of the assessments. In general it is accepted that it is

> preferable to average the ratings of two raters, or three raters, or more, but considerations of cost quickly intervene. (Pollitt, 2004, p. 5)

As a conclusion to her analysis of marking as judgement, Brooks acknowledges that the messages of cognitive theory have a long way to go before they make a serious impact on the conduct of school-based assessments:

> Various studies have led to advances in practice …. Yet, the fact remains that only a fraction of the insights that have been yielded by a study of the workings of the mind have been applied to educational assessment. Thus, securing a better understanding of the role of judgment in marking remains the immediate priority and a necessary precursor to the improvement of practice. (Brooks, 2012, p. 78)

PROJECT E-SCAPE; AN EMPIRICAL STUDY

Project e-scape was a "performance" assessment project run from the Technology Education Research Unit (TERU) at Goldsmiths University of London from 2004 to 2010. Within the project, 15-year-old learners constructed digital portfolios of work (in design & technology, science, and geography) in response to extended tasks. In science and geography the tasks ran over a half day (3 hours) and in design & technology over 6 hours (two consecutive mornings). These design & technology assessment tasks were conducted in normal design studios and workshops and learners designed and developed products using PDAs as digital sketchbooks, notebooks, cameras, and voice recorders. Their work was automatically and simultaneously sent through a wi-fi connection to a secure web-space in which their virtual web-portfolio emerged. At the end of the national trials we had 350 design & technology portfolios, 60 in science, and 60 in geography (see Kimbell et al., 2009).

At the outset of the project we had assumed that these portfolios would be assessed using a conventional model of GCSE-style assessment – with scores recorded in relation to a set of criteria. But the web-based nature of the portfolios enabled us to explore a quite different approach. We knew of the judgement literature outlined above and had met Pollitt in Cambridge, so after a series of small experiments to validate the idea we embarked upon an approach to assessment based on *comparative* judgement.

> The essential point will be familiar to anyone grounded in the principles of Rasch models: when a judge compares two performances (using their own personal "standard" or internalized criteria) **the judge's standard cancels out**. … A similar effect occurs in sport: when two contestants or teams meet the "better" team is likely to win, whatever the absolute standard of the competition and irrespective of the expectations of any judge who might be involved. The result of comparisons of this kind is *objective relative measurement*. (Pollitt, 2004, p. 6, my emphasis)

In practice, comparative judgement requires that scripts (portfolios) are sent to judges in pairs, and the judges simply report which one is the "better" in each pair. Whilst current "marking" approaches require only that each portfolio be scored once, comparative judgement needs each portfolio to be seen several times in different pairings. In addition to the reliability benefit of the cancelling out of judges' individual biases, a related benefit was immediately clear. Conventional marking is by one marker of one portfolio (at a time). The whole process is individualised. With comparative judgement – using web technologies – it is possible to have whole teams of judges sharing their judgements about the whole sample of portfolios: a collective process that also contributes to the improvement of inter-rater reliability.

In the final phase of the e-scape project, we automated this paired judgement process by developing the "pairs engine," a Rasch modelling algorithm that identified the portfolio pairs to be judged next, and which judge they should be sent to. It was also an *adaptive* algorithm, that is, it learns about the portfolios as it accumulated judges' responses. So at the outset a judge might be sent two portfolios that are randomly chosen from the sample, and if one was pretty good and one fairly weak it was an easy judgement to decide which was stronger. But gradually the engine works out an approximate rank-order for the portfolios, so it can send judges a pair of portfolios that are much closer together in the rank. This refines the rank very rapidly.

In the 2009 national trial with 350 portfolios and 28 judges we rapidly arrived at a rank order with a reliability statistic of 0.95. This is an astonishing statistic: nearly absolute reliability about a set of multi-media portfolios that portray creative designing activity by 350 learners. Never before has it been possible to produce this level of reliability with such data (Figure 2). And all the conventional paraphernalia of assessment was gone. No extended scoring sheets … no allocation

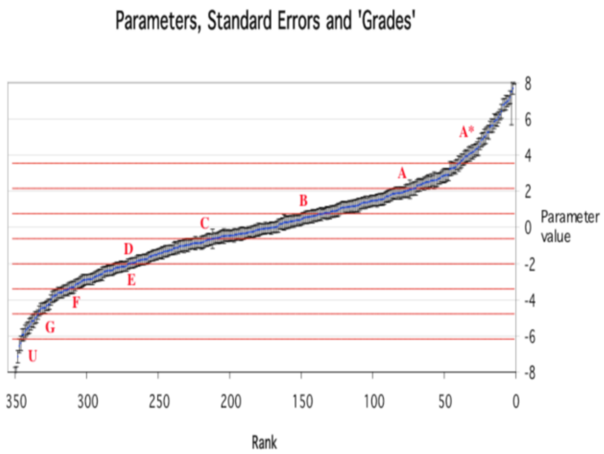

Figure 2. Data from 2009 National trial

of marks and painful calculation of overall scores… no 2nd markers and disagreements ….. no moderation.

All the judges had to do – in relation to each of the pairs of portfolios sent to them – was to say "this one is better than that one." Our teacher/judges thought it was wonderful and were delighted that they had contributed to such an astonishingly reliable outcome.

HOLISTIC JUDGEMENT: A VERY DIFFICULT TASK?

The articulation of system 1 and system 2 thinking (Kahneman, 2011, via Suto & Greatorex, 2008; Brooks, 2012; Laming, 2004 and Pollitt, 2004) in marking students' work rings a lot of bells for me. It fits closely with my own experience of the process of assessment, as teacher, examiner, and senior moderator at various points in my professional life. But there is an additional problem associated with the kinds of judgement that are required in the comparative judgement process that we developed in project e-scape. These judgements are single *holistic* judgements of excellence and – on the face of it – carrying out the judgement presents a very high cognitive load.

Typically – since judges are required to make overall capability judgements - they are NOT looking at a mark scheme. Rather, a broader description of the capability is provided. In England, all National Curriculum subjects have an "importance statement"; a carefully drafted account of the key capabilities to be considered in that subject. Since they describe why the subject is important in the curriculum, we decided that they should be used to articulate the key qualities that judges should bear in mind when reviewing the quality of pieces of work. The geography statement below is typical of these importance statements.

> *The importance of geography in the curriculum*
>
> The study of geography stimulates an interest in and a sense of wonder about places. It helps young people make sense of a complex and dynamically changing world. It explains where places are, how places and landscapes are formed, how people and their environment interact, and how a diverse range of economies, societies and environments are interconnected. It builds on pupils' own experiences to investigate places at all scales, from the personal to the global.
>
> Geographical enquiry encourages questioning, investigation and critical thinking about issues affecting the world and people's lives, now and in the future. Fieldwork is an essential element of this. Pupils learn to think spatially and use maps, visual images and new technologies, including geographical information systems (GIS), to obtain, present and analyse information. Geography inspires pupils to become global citizens by exploring their own place in the world, their values and their responsibilities

to other people, to the environment and to the sustainability of the planet. (Qualifications and Curriculum Development Agency (QCDA), 2011)

When geography teachers were making judgements about their students' portfolios, we asked them to "keep in mind" the key qualities described here but not to try to "score" them. This is not a mark scheme; it is just a global "capture" of excellence. But it is not an obviously simple thing to do because the description of excellence is multi-faceted and complex.

Figure 3. Sample web portfolio

The biggest sample of work in the 2009 national pilot was in design & technology, where we had 350 portfolios. And if the importance statement was multi-faceted and complex, so too were the portfolios that were to be assessed. The portfolios were compiled over a 6-hour designing and modelling activity and involved many data types (drawings, photos, sound files, text, video). The resulting web-portfolio (see Figure 3) is a real-time set of thumbnails laid out in a time line. When clicked on, a photo appears full screen and shows what was captured at that moment in the activity. Clicking on the sound-file it plays gives you the direct voice of the student at that point in the activity. This is a multi-faceted and very complex set of performance data.

So our judges were asked to judge a very complex set of data by reference to a very complex description of excellence. Surely this must be cognitive overload. It is asking too much. And yet the judges reported that it was simple.

– Portfolios displayed in this way have a huge advantage in that the big picture can be seen immediately. It's very easy to get a feel for the project … The

ability to dip in and out of the different sections enabled me to reinforce my holistic mental picture of the project.
– The variety of media used within the portfolio seems to give everyone a fair chance to display their design thinking regardless of their ability. It was fairly easy to see that there was a range of performance evident in the portfolios.
– Much, much faster .. and less scary (than conventional marking). Kimbell et al., 2009) (my insert)

And the reliability statistics emerging from the exercise were quite astonishingly high.

> The value obtained was 0.95, which is very high in GCSE terms. Verbal and Mathematical Reasoning tests were developed for 11+ and similar purposes from about 1926 to 1976. These were designed to achieve very high reliability, by minimising inter-marker variability and maximising the homogeneity of the items that made them up. KR20 statistics for those were always between 0.94 and 0.96. With *escape* in this design & technology task, a level of internal consistency comparable to those reasoning tests has been achieved ***without*** reducing the test to a series of objective items. (Pollitt, in Kimbell et al., 2009)

How on earth were the judges doing it? What was going on that makes such an impossibly difficult task so easy, and the results so reliable?

A THEORETICAL POSITION

The foregoing discussion of type 1 and type 2 thinking (Kahneman, 2011) and their deployment in marking exercises (Brooks, 2012; Suto & Greatorex, 2008; Laming, 2004; Pollitt, 2004) give us some indications of what the judges might be experiencing. To test out these ideas I used the judge-feedback data that was captured in our own 2009 survey (design & technology, geography, and science) and also interviewed judges that were undertaking parallel studies elsewhere using our same "pairs engine." Specifically I undertook four studies:

i) Re-analysed the judgement data from the 2009 e-scape design & technology project (28 judges and 350 portfolios), specifically concerning the comments that judges made during the judgement process.
ii) Joined the maths project run by Dr Ian Jones at Loughborough University exploring "Summative peer assessment of undergraduate calculus using Adaptive Comparative Judgement." Again my interest has been in the comments made by judges (maths undergraduates, maths postgraduates, and maths teachers) as they make their judgements and in their formal feedback.
iii) Joined the awarding body AQA in their experimental use of our adaptive pairs engine in the assessment of geography essay questions. The data here is based on the feedback forms provided to AQA from the judges – who were geography teachers and/or examiners.

iv) Undertaken an experimental judgement session in association with Dr Niall Seery at Limerick University. Two hundred undergraduate engineering students produced portfolios and a sample was judged by 20 of these students. Their judgement processes were observed, videoed, and discussed with them immediately afterwards.

In the light of all these data, I believe that the judgement process operates broadly as follows. Three things (at least) appear to happen and are clearly distinguishable in the data:

i) Surveying and Mapping

As judges scan the whole piece of work for the first time, it presents itself like a navigation screen. Judges look for the clumps of work – the highlights and activity markers. The clarity and layout of the work is important at this point as judges are trying to get an overview of what the work contains. In the maths study (students judging their peers' work on calculus) they were asked what factors might have influenced their judgements. The following comments about layout and presentation were typical of the responses of the group.

– Structured answer that's laid out properly, is written correctly with correct notations and follows smoothly in logical manner.
– Clarity and explanation.
– Subheadings really made the work look more professional and neater and so influenced me more to choose it.
– How easy it was to understand.
– Headings, clearly marked.

Within this mapping process, illustrations appeared to be very important. As the judges dug into the work, they were helped by any drawings, diagrams etcetera that illustrated, punctuated, or otherwise illuminated the activity.

– Clear and labelled diagrams each point being spaced out/easy to see.
– Diagrams, both 2D and 3D, with labels explaining each function's behaviour for a given range of x values …

It is clear that the judges here were desperately trying to work out what the students had done, so *presentational* issues loomed large in their thinking. This is an ordering/sorting/mapping activity that is conscious and considered – typical type 2 thinking. It is responsive to the work that presents itself, but it has consistent qualities to do with answering the questions: "What is going on here"? "Where is the student taking me?"

In the interviews that followed the judging process, the importance of mapping was strongly reinforced. The judges were clearly influenced to some extent by the ease with which they could grasp what was going on.

– There is an instant picture in B, without reading it …. It all falls into place.
– He split it in three parts.
– Well again it was layout. It was easier to read … I think in F the picture was clearer and labelled each section and what it meant.
– I find that order and structure was a big part of that. The ones who did not have a structure I took that to mean it have a less understanding.
– …is easier to understand. A is better ordered. It is easier to read through. You take more of it in.
– First of all, easily C is a lot more organised. [With D] I am not sure what the student is doing …. He's got a chunk here, a chunk there … just looking at D is pretty intimidating. You got to read all that. C looks neater.
– … the layout and how it works out.. The layout in C was better than in D. Content was similar. That is why I chose C. The layout in F was neater than E. Easier on the eye. I can understand it in F.

But in these interviews a further aspect of this mapping process emerged. It seems as though this mapping job is the *first* job being undertaken – and judges appear to start from a neutral position – just trying (even-handedly) to diagnose what is going on. There is much evidence that this then rapidly transforms into a position in which the best organised and most clearly presented work gets the vote. But not always.

– C's layout was a lot nicer. But in terms of content, D had better content.
– I prefer the layout in C … it is easy to read and understand. However the content in D is more accurate

For all judges this mapping process has an overriding *descriptive* function – enabling them to get inside the work and understand what is going on. As the map emerges, its clarity and ease of reading frequently seems to lead the judge beyond description and towards *value judgement*. But this is a separate function, and in several cases this step was not taken. Judgement was suspended and the mapping process was restricted to a descriptive function.

ii) Characterising

Below this level of conscious mapping, judges begin to *characterise* the work. I should admit immediately that there is far less evidence of this process at work. Since it is happening instantaneously – and pre-consciously – there is very little validating data to which we can appeal to illustrate how it works, or even that it exists. But there is some.

In the e-scape study of design & technology portfolios, judges could choose to leave comments about the portfolios in their judging frame. And many did. The comments were just for the judge, and were NOT to be used as part of any other data collection process. So there was no pressure on the judge to bias comments one way or another. Using these informal comments we can see how judges are using associative memory to form impressions of the work; of what the student was trying to do; and occasionally this resolves itself into characterisations of the student him/herself.

Judges typically made characterisations of the objects that students were attempting to develop:

- an egg box
- just a box … nothing really
- crocodile container
- a flying saucer – twister
- a Stanley knife dispenser
- toilet bowl (escape.maps-ict.com/pairs/main/judgementhistory/judgeid/1732)

It is easy to see associative memory at work here. Students are not trying to design egg boxes or flying saucers. They were developing a pill container that would dispense the pill you need when you need to take it. But as the judge scans the work these associations are triggered – primarily I believe in these cases by visual references.

Figure 4. Samples of student work illustrating type 1 thinking

Which of the above comments do you think were triggered by the two pieces of work shown in Figure 4? This is classic type 1 thinking; intuitive and unmanaged.

But there is more to this characterisation than just description of the item. There is also a valuing element as the portfolios align with – or conflict with – those qualities that define "good." Whilst – from an assessment perspective – these judgemental elements of the process would ideally reflect the values embodied in the "importance statement," it seems inevitable (since this processing is pre-conscious) that they *also* reflect the values of the judge. What do they get excited about? What do they value in a task of this kind? All kinds of personal reactions of judges were evident in the data:

- Original and delightful concept.
- wow.

– I really wanted to give it to the mouse trap, but the tiger skin holder was so desirable I couldn't.
– Dummy.
(escape.maps-ict.com/pairs/main/judgementhistory/judgeid/1732)

In the maths study, in which students were tackling a calculus problem, the characterisations were as much to do with presentation style as with the maths, but they begin to form (in the mind of the judge) a characterisation of the student. There is some interesting emotional reaction in the judges.

– This guy D is too verbose … he is writing a lot of things … he was not able to apply what was written here.
– Both E and F made grave errors in terminology and its usage. And this really counts against me, as I have a visceral reaction, almost like a gut reaction when people find the derivative to be 0 and they … go back to the first principle and they should not need to do … the derivative is clearly 0. … they got something that at a moment's thought is complete rubbish.
– I went for C ... the way C has argued the proof… is concise, direct, not waffle. D is waffling a bit, but C is very concise.
– it appears the person knows more than they are talking about …

iii) Validating

As impressions begin to form about the work, judges go "looking" for evidence that might support the emerging impression. In the e-scape design & technology study, this looking frequently takes us beyond the object, such that comments at this point are frequently based on perceptions of the student's progress through the activity. These are teacher-like perceptions – such as:

– changed design for day 2, couldn't make the interesting mechanism..?
– limited idea – but growing – separate model for mechanism
– steady dev of an idea – triangles – not exciting
– metacognitive designing in box 18
– very obvious – mostly – gradually becoming something
(escape.maps-ict.com/pairs/main/judgementhistory/judgeid/1732)

This is – once again – systematic and considered type 2 thinking. It is deliberate and targeted at uncovering evidence to support a half-formed (intuitively formed) view. The fact is that in the e-scape design & technology study these validating comments are from a judging team of *teachers* and their instincts are as much about the students and their progress (or lack of it) as they are about the objects contained in the work. They are in a sense "reading" the student through their interpretation of that student's work:

– interesting water-wheel idea – *growing through lots of material exploration*

– fairly detailed development of circular dispenser, *steady progress OK*
– OK starting point but completely *unable to model any progress*
(escape.maps-ict.com/pairs/main/judgementhistory/judgeid/1732)
(my emphasis)

The second phrases in each of these comments (in my italics) reveal the pedagogic priority of some of our teacher-judges. They appear to have a real desire to see progress being made – and express regret where it is absent.

In the maths judging session, references to mathematical accuracy/correctness typically occurred late in the decision process. It appeared as though the judge was looking for validating evidence, either to support a critical or a generous view of the piece.

– and there is a mistake here
– I don't think this bit is right at all
– this is a very good description of the residuals bit

In the interviews there are several examples of judges talking their way through a decision and (eventually) using the mathematical correctness as a deciding factor:

– The limit of 0 is 0, yes this is true but I think she means the function in some region is 0. So it is not very accurate. So now I am highly confident. I changed my mind.

AN OVERVIEW OF THE JUDGEMENT PROCESS

Initially the judge approaches the work open-mindedly and maps it. Much like a surveyor marking out a field – with a stream – and a hillock – and fences. But this descriptive map is not a paper product like an Ordnance Survey map, it is a mental map – held in the mind – and thereby subject to all the secondary processing that is – quite literally – unstoppable. With pre-conscious associative memory working overtime, triggering emotional as well as intellectual responses, the map mutates from being just a neutral description of the field and rapidly becomes a value-laden depiction. But we are teachers and academics who value reason and argument. So, we need to have evidence to formulate the decision that we know we are about to take. And we therefore seek concrete strengths and weaknesses that can be pointed to as justification for our decision. When we have found enough of these to be confident in our judgement, we declare the decision.

These three aspects of cognitive processing (mapping, characterising, validating) appear to operate concurrently and it is important to remember that this judging process does not require judges to know *everything* that is going on in the portfolio. We are not scoring it, so we do not need to check every detail of what is there that might (in normal assessment circumstances) attract a mark. We simply

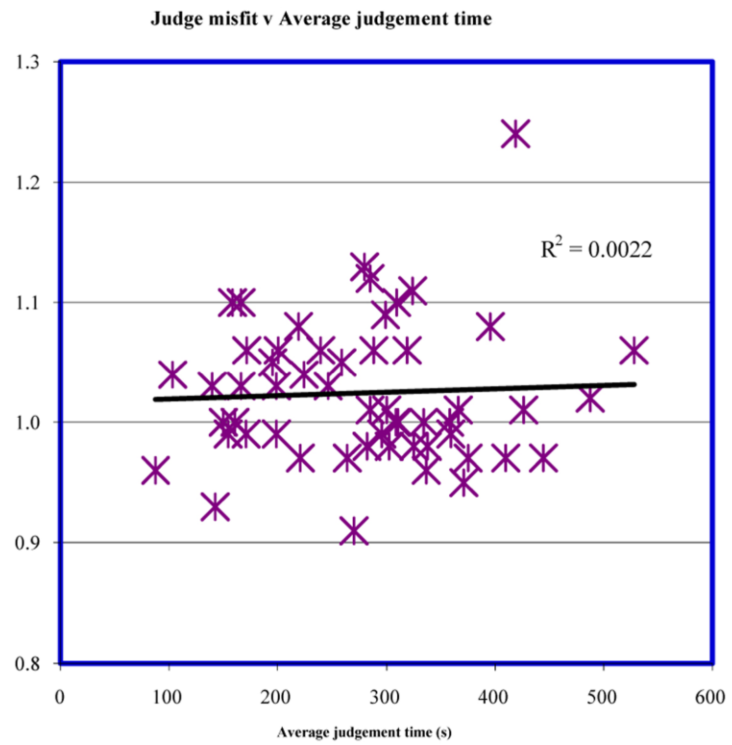

Figure 5. Graph of decision making

need to know enough about it – and the other one of the pair – to say that this one is better than that one (or not). Once we are confident about that decision, the process is concluded and the judgement is made.

HOW LONG DO JUDGEMENTS TAKE?

One of the features of this decision process that has intrigued me since we first developed it is the time that judges take to come to a decision. Why is it so variable, and are slower decisions more reliable?

In 2010, the Qualifications and Curriculum Development Agency (QCDA) commissioned us to conduct an Adaptive Comparative Judgement (ACJ) study of teachers' judging of English writing SATs for 11-year-olds. The data in this case were short (approximately 2 sides of A4) essay-style imaginative stories, and the English importance statement was used for the training. In fact, there was considerable variation in the average time judges spent making their decisions. Some of this reflects differences in the amount that they wrote in their notes about each judgement, but still the range is remarkable. The quickest judge took an average of 88 seconds, or about 1.5 minutes, while the slowest took an average of 588 seconds, or nearly 10 minutes.

If this indicated that some judges were not carrying out the job conscientiously we should find evidence in the misfit statistics, by plotting judges' misfit measure (of inconsistency) against the mean time they took for each judgement.

As Pollitt, Derrick, and Lynch (2010) reported:

> There was no correlation at all in the data, despite the range of speeds observed, from 7 to 41 judgements per hour. We can only conclude that some judges are very good at coming very quickly to the same decisions that other judges arrive at after considerable careful thought. (pp. 35-36)

The mapping process with English imaginative writing will obviously be somewhat different from that with calculus in maths or designing a product in design & technology, but in principle it will be the same. Judges will look for language use – structure – characterisation – story-line. But as the map is being constructed it is also inevitable that their "English teacher" pre-conscious will be characterising the work for them and they will be looking for validating evidence to support their emerging judgement.

My hunch about this is that the time difference is probably attributable to the final – validating – process. Some judges are content to make the decision with one or two items of confirmatory evidence. Most will require more confirming evidence to be confident about the decision, and a few judges will want to be really sure, so they check and check and check again. The difference may be – at least in part – a measure of the confidence of the judge.

But there is a further element to the time it takes for decisions to be made. We might call this the "learning curve." When judges undertake this process there is a lot to get used to. The interface itself is unfamiliar, so judges have to get to know what the buttons do and how to move around the system. And then there is the complexity of the portfolios being displayed. In the design & technology case there were 25 boxes of data in each, and judges soon realise that some of these boxes are more critical than others. So instead of slogging through all the details of every box, they skip to the ones that they know (from their growing experience) hold key elements of the story.

Inevitably, therefore, the judging process gets quicker. The chart in Figure 6 is of the judging times for ten of the judges in the 2009 design & technology sample. Judge C took 20 minutes for each of the 1st 10 judgements, then 15 minutes for the 2nd group of 10, then 8 minutes for the 3rd group, and 5 minutes for the 4th group. The median time for all judges and for all 130 judgements was 4 minutes 6 seconds (see Kimbell et al., 2009).

The learning curve is obvious in these data, but there is more to it than simply the explicit learning of the interface and the portfolio structure. There is also that element of learning that amounts to judges switching their cognitive processes from system 2 to system 1. Recall the observation of Suto and Greatorex: "Another

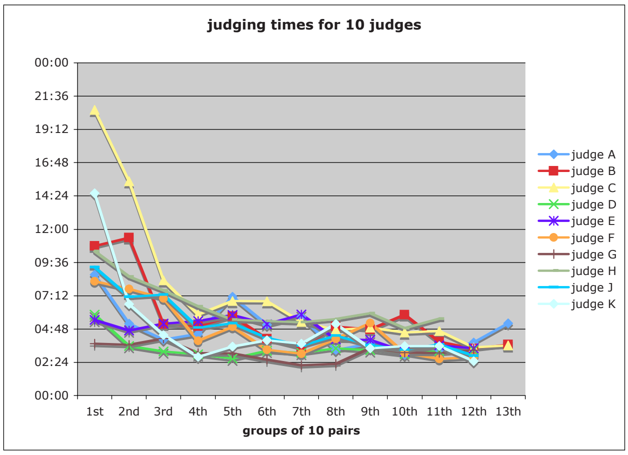

Figure 6. Judgment time over successive judgements

important feature of the dual-processing theory is that 'complex cognitive operations may migrate from System 2 to System 1' as individuals gain experience" (2008, p. 215).

The fact is that the judges of those design & technology portfolios were looking at immensely complex portfolio stories. And they were judging them in relation to a complex and multifaceted importance statement. And they were doing it in 4 minutes! This is astonishingly fast and yet – as the reliability statistics show us – they were also doing it remarkably consistently. The explanation of this – of course – is that our judges were becoming expert in their decision making about these portfolios. As the skilled driver no longer needs to look at all the instruments in the car, so too did their growing expertise free-up our judges from monitoring all the details of the portfolios and the interface. Judging from the chart above, for the first 10 paired judgements it would appear that our judges were working principally with system 2 processing; working their way systematically (and slowly) through the portfolios to arrive at a decision. But after 20-30 such decisions, (as Suto & Greatorex, 2008, suggest) they were behaving increasingly as experts with their processing migrating from system 2 to system 1, and this contributed significantly to being able to arrive at decisions in 4 minutes.

But there is one further element of the "how-long-does-it-take" story that needs to be told.

A REPRISE: THE ANCHORING AND ADJUSTMENT HEURISTIC

I mentioned earlier the value of the "anchoring and adjustment" heuristic as one cognitive strategy to help judges to load the levers of judgement, and in the comparative judgement engine we have built in a feature that explicitly makes use of this heuristic. In each of the early rounds of judging with the engine, judges are faced with two new portfolios (say *A* and *B*). They make their choice and then both disappear from their screen to be replaced by (say) *J* and *K* and so on. But after five rounds of judging (when each of the portfolios in the sample has been compared with five others), an approximate rank is emerging. At this point we have programmed the engine to change the presentation of portfolios. In round 6, two new portfolios are presented (say *P* and *Q*) and the judge makes a choice. But both portfolios do not disappear. One of them remains while the 2nd one disappears to be replaced by a different one, so the choice is now between (say) *P* and *S*. In this case *P* is operating like an anchoring portfolio – we have seen it before and know it – and we now just have to compare it to a different one. After completing this judgement *P* disappears but *S* remains and becomes the anchoring portfolio. This process we call "chaining" and judges report that it dramatically increases the speed of their judgements. Partly, of course, this is because there is only one new portfolio to read and understand, but equally – I believe – it is because the *standard of the anchoring portfolio* is understood and held in working memory for immediate transfer to the new choice.

CONCLUSIONS

In this chapter I have sought to focus the "transfer" debate onto the cognitive processes that operate as teachers make an assessment judgement. How do teachers hold a standard? And how do they transfer it to new work?

I have embedded this debate, first, in Kahneman's (2011) analysis of cognitive processes and, second, in the holistic judging process that teachers used – with great effectiveness – in the e-scape project. And at the core of that judging process is the adaptive comparative judgement (ACJ) engine that we developed as part of that project.

The basis of the judgement process is simple to describe … it is just comparing this portfolio with that one to arrive at a decision about which is better/stronger in relation to the basket of qualities that are represented in the importance statement. But I have sought to flesh out the cognitive process by reference to the comments that judges make as they go through the process and those that they make at the end to describe what they have done.

I believe that there are (at least) three inter-related elements that make up the holistic judging process: *mapping*, *characterising*, and *validating*, and they appear to operate concurrently. That (after a learning curve) judges can do this so rapidly and so reliably is evidence of the development of significant expertise by our judging teams. And this expertise is based on the transference of some of the burden of decision making from slow, itemised judgement (Kahneman's, 2011, system 2 processing), to intuitive, rapid and pre-conscious system 1 judgement. The design of the adaptive comparative judgement software that underpins the operation of judging has also been optimised to make use of the anchoring and adjustment heuristic that further supports speedy judgements.

The statistics speak for themselves. There is no room for any doubt that this process does produce astonishingly accurate assessments, but interestingly it is not yet common practice with Awarding Bodies in England. There are significant developments making use of the system overseas, for example, in Sweden, Singapore, Australia, USA, Ireland, and Israel. And in every case, when we collect feedback data from teachers, they tell us the same things:

1. It is good to have the assessment process as a *collective* process that brings together the judging of many teachers from many schools.
2. The principal benefit of this collective process is that teachers can share and contribute to a *national standard*; seeing work from *many* schools rather than being trapped in the practices and standards of their own school.
3. It is good to have the assessment process based on *holistic* judgements that enable teachers to use an overall balancing judgement about the capability of their learners.
4. It is good to have the assessment process *on-line*, not just for its sharing capability but also for the convenience of undertaking it.
5. It is good to use a *comparative* judgement process that makes the assessments so *easy and quick*.

These are the typical, practical concerns of teachers and schools. But none of them was at the front of our minds as we built the adaptive comparative judgement engine. Our principal concern was reliability. We were attempting to develop an approach that would encourage portfolio-based performance assessment but – at the same time – ensure that the resulting assessments were completely reliable. Having achieved that, it is interesting that teachers value it for other reasons.

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8. REPRESENTATION IN THE TRANSITION FROM NOVICE TO EXPERT ARCHITECT

INTRODUCTION

This chapter draws on a study of the transition from competence to expertise in architectural design to examine key features of the process and how they are represented. The approach taken is based in cognitive psychology and, in particular, the psychology of problem solving. The study is useful for the purposes of this book given there is evidence that the work of designers (in this case architects) displays evidence of near and far transfer, and of creativity. Of equal importance is the reality that we do not yet have a theoretical model to explain the transition from inexperience to design expertise (Dorst & Reyman, 2004). In terms of representations, given that technology education students engage in learning activities that are represented both verbally and visually, the study has implications for how we research technology learning in school settings.

We know quite a lot about expertise in general and what it looks like in a range of areas (Lajoie, 2003). We know that experts have superior memory for the kinds of information relevant to their domain; have a high level of awareness of what they know and do not know; have superior pattern recognition ability; and they produce solutions much quicker, but spend more time analysing problems before starting; and their knowledge is both deeper and more highly structured that non-experts. However, all of these features are specific to a domain. An expert in chess is not able to use that expertise to solve a design problem.

We also know how to describe expertise in a variety of domains, from electronic troubleshooting (Perez, 1991; Gott, Hall, Pokorny, Dibble, & Glaser, 1992); medical diagnosis (Patell & Groen, 1991; Gott, 1989); nursing (Lajoie, Azevedo, & Fleiszer, 1998); and avionics (Lesgold, Lajoie, Logan, & Eggan, 1990), to name only a few of the studies of expertise. Most of these studies work from a knowledge basis with expertise seen as a function of the knowledge base of the domain.

In a study exploring levels of expertise in design, Dorst and Reymen (2004) argue that we do not yet have any developed model of design expertise. They draw on an expanded version (Dreyfus, 2003) of the Dreyfus and Dreyfus (1986) model that argues for descriptors for seven stages. The 1986 model included novice, advanced beginner, competent, proficient, and expert. The 2003 Dreyfus and Dreyfus model adds master and visionary as two higher levels after expert.

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Dorst and Reymen (2004) argue that the revised Dreyfus and Dreyfus (2003) model is more appropriate for design as it is concerned with the development of skills, rather than being a knowledge-based model. However, the Dreyfus and Dreyfus model is limited by not being tested in any significant way. The assumption underlying the model is also contentious, as it accepts the division between knowledge and skills, which ignores concepts from cognitive psychology that argue that both knowledge and skills can be conceptualised as knowledge, with knowledge (information) constituting declarative knowledge (knowledge that) and skills constituting procedural knowledge (knowledge how) (Newell & Simon, 1972; Anderson, 1993).

One of the dominant theories in cognitive psychology over the last 40 years has been that of the problem space, first proposed by Newell and Simon (1972). The problem space is seen to be a way to represent the kinds of problems humans attempt to solve and the processes they engage in to solve them. The Newell and Simon problem space is argued to consist of three components: the problem state, which represents what is known about the problem at the start; the goal state, which is the solution to the problem; and the search space, which constitutes all the knowledge the problem solver has in memory or can access to solve the problem.

Problem solving is regarded as a process of navigating the search space between problem state and goal state. Navigation of the search space is performed by the deployment of procedural knowledge (knowledge how). However, the research used to validate the problem space model consisted of problems where there were clear descriptors of all aspects of the problem state. Studies involved mathematical problem solving (Newell & Simon, 1972; Anderson, 1993) and games such as the Tower of Hanoi (Kotovsky & Fallside, 1989) that are well-defined at all stages of the process and either have one correct answer or a limited range of solutions.

Designing is considered to be a form of problem solving with a requirement for creativity and innovation. However, the Newell and Simon (1972) model does not provide a useful characterisation for design problems. Unlike mathematical problems, design problems are ill-defined in each of the three aspects of the Newell and Simon model. That is, they have: a generally ill-defined starting point ("We want a house that is light and airy and has a relaxed ambience"); a goal state that is also ill-defined (many clients are able to articulate only some aspects of a potentially appropriate solution); and the search space of design problems contains not only the knowledge that may be in memory or accessible by other means, but also the requirement to be creative, that is, it has the requirement to generate something that is new and cannot be found by a process of search.

Middleton (2002) proposed a revised model of the problem space to accommodate design problems. In Middleton's model the problem state was replaced by the problem zone, to acknowledge that the starting point for design problems was often ill-defined and working out what the problem was constituted the first task in designing. The goal state was replaced by the satisficing zone to acknowledge that in design, solutions are as good as is possible at the time, rather than correct. The search space was replaced by the search and construction space, to acknowledge that the solutions to design problems result from a process of identifying known ideas but also involve the creation of new ideas. One aim of the study reported here was to examine how well the model represents the design thinking of architects at different levels of expertise.

One issue explored in the study and in this chapter is the way knowledge in a domain is represented. Interviews and other forms of verbal data are commonly used in social science research, however, many forms of design use both verbal and visual representations of knowledge and activity. For this reason a methodology was used that collected and analysed both verbal and visual data. The study reported here used a modified form of protocol analysis (Ericsson & Simon, 1993). Protocol analysis, or verbal protocol analysis, is a well-used method for collecting data to examine human cognition. Protocol analysis requires the research participant to verbalise whatever comes into their head while they are engaged in an activity requiring thinking. The verbalisations are not regarded as cognitions directly, but as isomorphs that provide indicators of cognitive activity.

A number of studies examining design processes (see Lloyd & Scott, 1994) have assumed that the verbal protocol analysis method can be used for design even though the activity is not represented only by language. The belief underlying these assumptions is that all relevant data would be contained in the verbal data. In fact, Lloyd and Scott noted the prevailing view in 1994 that any data contained in images would constitute only echoes of the verbal data and thus not add any significant data for analysis.

In an important study, Akin and Lin (1995) sought to test the prevailing assumption with a quite simple experiment. They collected video-taped data of a design activity, using normal protocol analysis techniques (Ericsson & Simon, 1993) with the addition of the visual record of the activity. A copy of the visual data (video with sound removed) was given to one researcher to analyse, while a copy of the verbal data (without the video component) was given to another researcher to analyse. Existing assumptions about visual and verbal data would suggest that all relevant data would come from the verbalisations and analysis of the visual data would not add anything new to the analysis. Akin and Lin found that each researcher was able to predict only 20% of the content of the other data source. The conclusion drawn from the study was that to examine design thinking adequately it was necessary to capture both verbal and visual representation of thinking. Thus, for the study reported here, both verbal and visual data were captured and analysed, separately and then in combination.

RESEARCH QUESTIONS

The study reported in this chapter sought to answer three questions. 1. What does design practice look like at various stages of development? 2. How does it compare with general models of expertise? 3. What is the most appropriate way to examine design expertise given the particular nature of design? The study adopted a cognitive psychological approach, drawing on information processing theory (Newell & Simon, 1972; Anderson, 1993; Kosslyn, 1990).

METHOD

The study involved three practising architects with varying lengths of professional experience. The architects were chosen as they represented different levels of experience, and expertise, with the most experienced having won an award in the 12 months prior to the data collection. In addition, each was involved in architectural practice where they worked, to a large extent, on their own, so that solving a design problem as an individual was a normal part of their everyday working practice. Architecture was chosen for the pragmatic reason that it represented an authentic form of design but one where the activity occurs within a constrained timeframe, unlike other possible design professions such as industrial design or related areas such as invention, where the process can occur over extended periods. As a result, most data collection occurred during single sessions of around 20 minutes' duration.

Table 1. Details of architects

Subject	*A1*	*A2*	*A3*
Age	23	29	62
Gender	M	F	M
Architectural design Experience	1 year	7 years	38 years
Level of expertise (Dreyfus & Dreyfus, 1986)	Competent	Proficient	Expert

Each architect was presented with the design brief shown in Figure 1, below. The intention behind the brief was that it would be effortful for both novice and expert designers because it was complex. It also had to be an activity architects considered authentic. The wording of the brief was developed in collaboration with a practising architect who was not otherwise involved in the study and is shown in Figure 1.

The design problem was complex because it contained potentially contradictory requirements. This was done to ensure that all participants would have to engage in an effortful and conscious process of problem solving and not be able to resort to automated processes or tacit knowledge. The potential contradictions were: the requirement to provide privacy while at the same time providing a light and airy atmosphere; the requirement for passive solar energy on a block that faces south in the southern hemisphere; and a block of land that was small and steeply sloping for a client with arthritis, and as a consequence, the inability to use stairs, which would rule out the possibility of having several levels to maximise space or keep costs down. There was also the overarching constraint that the client had a limited budget.

An elderly female client, with limited funds, requires a detached dwelling on a 450m^2 urban Brisbane block. The site measures 15m X 30m with the shortest alignment fronting the street. The site falls away from the street at approximately 30^0, towards the south and is free of established trees. The best views lie to the South, due to the elevated nature of the site. The client suffers from an arthritic condition and has great difficulty negotiating stairs. She values her privacy but would like the house to have a light and airy atmosphere. She also wishes to take best advantage of natural light, breezes and passive solar energy. She is open to suggestions on the general form and character of the house, and despite her age, could not be considered conservative.

Figure 1. The design problem

Collecting the Data

Data were collected using a modified form of protocol analysis (Ericsson & Simon, 1993). Each participant was presented with the design brief and asked to verbalise all and any thoughts that came into their mind while they solved the problem. They were also asked to solve the problem in the normal way they would solve it in professional practice. Using standard protocol analysis processes, if participants stopped verbalising for more than 10 seconds they were prompted with "What are you thinking now?" Participants were video- and audio-recorded. The video-recording was used to capture the development of the visual aspect of the developing design.

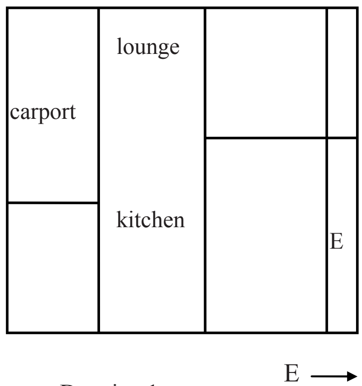
Preparation of Data for Analysis

The data source consisted of a video-tape recording of the problem-solving activity of each subject that included a continuous recording of sketching activity and all verbalisations for each of the subjects. The verbal record of problem solving was transcribed and segmented on the basis of achieving the smallest unit of meaning that constituted an instance of a general process, which often meant segmenting at the level of clauses (Ericsson & Simon, 1993). After segmentation, the verbal and visual protocols were placed in columns as shown in Figure 2. Each sketch corresponded to the section of verbal protocol that was produced while the sketch was being generated. That means the participant in Figure 2 started sketching as they started speaking the phrase in line 028 and stopped at the end of line 049.9.

Analysis of the Data

Because participants were engaged in a problem-solving task, the expectation was that they would generate procedural knowledge data. Thus, the verbal data were analysed to establish, initially, the cognitive procedures employed in solving the

027 now taking best advantage of the site ......
028 um, just looking at it as a block diagram
029 I'd have most living spaces and bedrooms on the northern side, so
030 I'll just indicate that's north for now
031 um ... now with the best views …
032 falls away from the street towards the south
033 the best views towards the south
034 difficult, difficult, difficult …
035 I'll probably still keep the bedrooms on the northern side
036 but make it a very linear plan
037 so we take advantage of the views
038 as well as the northern aspect, um
039 which will also help with cross ventilation
040 so if we could have the carport at one end
041 and then have the lounge and kitchen, um
042 I need to know a bit more about the … client
043 but anyway
044 and then maybe we will spread
045 the ah bedrooms out along one edge
046 there's the bathrooms up…
047 bathrooms and en-suite occupy ... um ....
048 possibly the eastern end of the building
049 so that's east
050 ok, so … let's see



Drawing 1

Figure 2. Illustration of initial representation of problem-solving data

problem. The purpose of this analysis was to examine differences across architects as a function of experience to see how architectural expertise compared with expertise in general. For example, did the expert architect engage in extensive analysis of the problem before attempting to solve it? If so, the data would show significant numbers of exploratory text phrases in the early stage of problem solving.

The purpose of the analysis of the visual data was to identify both the characteristics of the images used in solving the problem, and the function they served in the problem-solving process. In addition, and as with the verbal data, differences across problem solvers of different degrees of expertise were also examined. The following section presents the framework used for coding the verbal protocols that allowed conclusions to be drawn, based on the model of problem solving presented above.

Coding the Verbal Protocols for Cognitive Procedures

Each segment of the verbal protocols of problem-solving activity was coded in terms of cognitive procedures into one of three categories of procedures. The categories were generation, exploration, and executive control. Generation refers to the procedures of retrieval, synthesis, and transformation of knowledge, or, more simply, generating ideas. These procedures have been identified by Finke (1989), Larkin and Simon (1987), and Weber, Moder, and Solie (1990). Exploratory procedures include exploring constraints and exploring attributes. These procedures have been identified by Finke, Ward, and Smith (1992), Gross and Fleisher (1984), and Simon (1973), while executive control includes goal setting, strategy formulation, goal switching, monitoring, and evaluation. Executive control procedures are also referred to as procedures for deciding when to do what. Executive control procedures have been identified by a variety of researchers, including Anderson (1993), Scandura (1981), Chan (1990), Gott (1989), and Perkins (1990).

After coding for cognitive procedures, each protocol was divided into ten equal time segments (tentiles), to allow comparison between subjects at similar stages of the design activity. This made it possible to analyse design activity at any stage of the problem-solving process. For example, experts, in general, spend more time in the initial stages of problem solving analysing the problem before attempting to solve it (Lajoie, 2003). Each tentile was scored in terms of the number of procedures in each category present within each tentile. Figure 3 contains a sample section of verbal protocols from the competent architect.

163	um, she would want a fair bit of space with the laundry	[EC]
164	especially as she may have to use a wheelchair	[EX]
165	one, two, three …	[EC]
166	the bedroom can come back	[GE]
167	it may protrude back again, into the line of the garage	[GE]
168	and can get a window here to the north	[GE]
169	Which will give us some sun in winter	[EX]

Figure 3. Section of verbal data coded for procedures

After coding and separating into tentiles, the data were converted to scatterplots as shown in Figures 4 to 6.

Analysis of Verbal Data

The verbal data provided a useful basis for analysis, particularly when segmented and displayed as scatterplots. Examining the initial plots for all three, important differences appear. The least experienced architect (A1) engaged in rapid generation of solution moves, but quickly slowed down by the fourth tentile where generative procedures were overtaken by exploratory and executive control

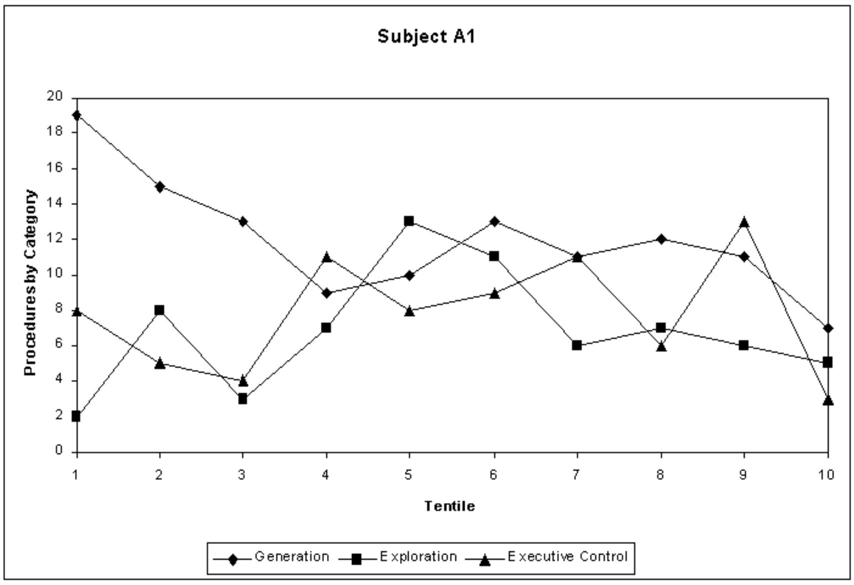


Figure 4. Graph of tentiles for cognitive procedures for the competent architect

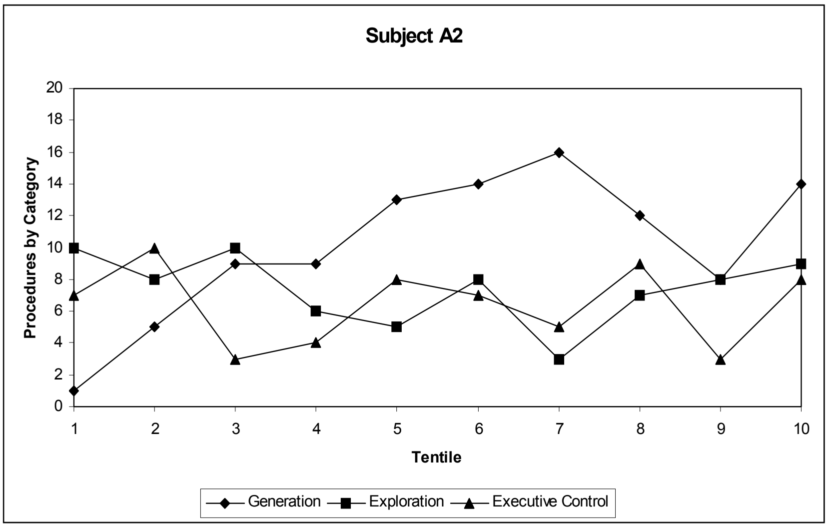


Figure 5. Graph of tentiles for cognitive procedures for the proficient architect

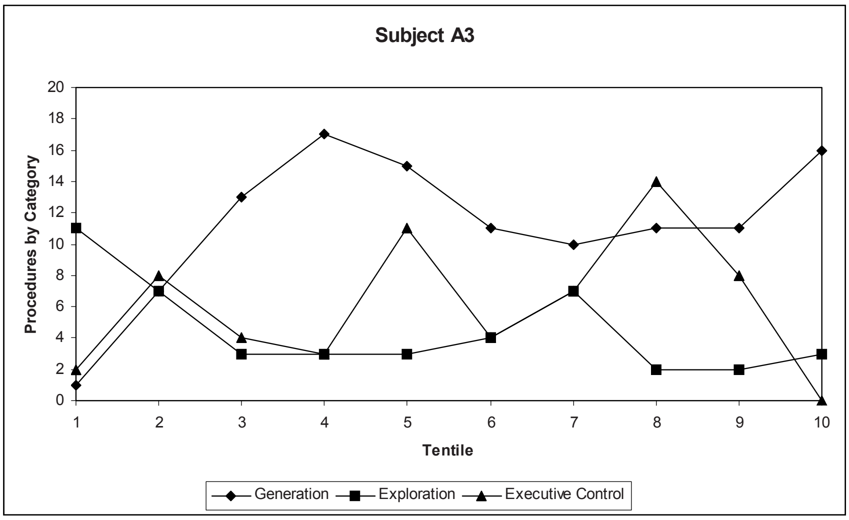


Figure 6. Graph of tentiles for cognitive procedures for the expert architect.

procedures. A1 got into trouble early on and had to spend much subsequent time exploring the problem, trying out ideas, and making decisions. A1 did not produce a solution with which he was happy until tentile 8. Much of A1's activity was consistent with novice-like behaviour in other domains. That is, there was only superficial exploration of the problem before attempting to solve it and much trial and error during the activity, with complexity being discovered as problem solving proceeded. A1 also took the longest to generate a solution.

The behaviour of the proficient architect (A2) indicated a person with more experience. A2 engaged in more exploration of the problem at the beginning, guided by significant executive control procedures. This continued throughout the activity as generative procedures increased to a maximum at tentile 7, at which point A2 had largely completed her solution. Thus, the analysis of A2's cognitive procedures suggests she is more expert that the competent architect (A1) in that she engages in more initial exploration (but less than the expert) before engaging in confident generation of a solution, which occurs sooner in the activity than for A1. Solution generation is largely forward moving, with little of A1's trial and error process.

The expert (A3) displayed a number of expert-like behaviours. A3 engaged in substantial initial exploration of the problem. Much of the exploration was concerned with establishing what aspects of the problem could be solved by his existing architectural knowledge or schemas, and which parts were more complex and required him to generate new ideas. This was followed by confident generation of a solution which appeared by tentile 4. The expert then used the rest of the time to add minor details.

The transition to expertise displayed in the activity of the three architects can be seen in terms of three important features of the analysis of cognitive procedures. The first is the extent of initial exploratory activity, which increased as a function of experience. The second was the manner by which complexity was identified, and the third was the speed of generation of a solution with a consistent speed-up with increasing expertise. The verbal data thus suggest that expertise and the transition to expertise in design has features that appear in studies of expertise in a variety of domains.

Analysis of Visual Data

One aim of the research reported here was to explore how design activity is represented and how visual and verbal data might be used to provide a fuller and more accurate account of design activity and of the transition to expertise than would be the case using verbal data alone. The preceding analysis provided findings from the verbal data. The following section provides an analysis of the visual data generated by the three architects.

In analysing the visual data, a grounded theory approach (Cresswell, 2012) was used. Grounded theory makes no assumptions nor proposes any hypotheses about what will be found in data. Given the scarcity of studies where visual data were the subject of analysis, it was important, first, to identify what might be relevant features of the visual data and, second, to see if there were systematic differences across visual data characteristics or visual data use as a function of level of expertise. This analysis provided seven features of visual data that appeared to be important to any analysis. These were: number of sketches generated; number of sketching episodes; number of sketch types; number of image types; holistic image generation; and time spent sketching. These are summarised in Table 2.

Table 2. Differences in imagery usage

Architects	*Competent*	*Proficient*	*Expert*
Number of sketches	9	5	2
Number of sketch episodes	11	8	5
Number of sketch types	6	3	2
Number of image types	4	2	2
Holistic sketch generated by	mid tentile 9	end tentile 6	Mid-tentile 5
Number of abstract symbols	34	5	3
Time spent sketching as a percentage of total time problem solving	88	75	69

The first important difference across architects was in the number of sketches generated, with a clear progression from nine sketches for A1, five sketches for A2 and two sketches for A3. In reality A3 only generated one main sketch of the solution with one thumb-nail sketch to explore a small detail. The data for number of sketches was interpreted as consistent with features of the transition to expertise.

Sketches were interpreted as expressions of architectural knowledge that became more detailed and integrated as expertise developed.

The second interesting difference across architects was a feature that was labelled sketch episode. It was necessary to create this category because number of sketches did not cover one aspect of the activity which was the switching back and forth between different sketches, which occurred most with A1 and was almost absent with A3. Switching between sketches was interpreted as indicating an architect who did not have detailed architectural knowledge and needed to break the problem down into more manageable parts.

Number of sketch types was included because the least experienced architect (A1) produced the largest number of sketch types and these appeared to be the application of representations learned during university study (A1 was in his first year of professional practice). Each sketch type was used to explore or generate one aspect of the design solution. The proficient architect (A2) used fewer sketch types and the expert (A3) used only one type. However, the expert's sketch was complex and suggested a higher level of integration of architectural knowledge.

Number of image types was a feature of the visual data that was complex to identify but was an observable difference across the architects. To identify differences in imagery types, it was necessary to examine visual and verbal data concurrently as sketches on their own provide evidence of imagery usage but do not necessarily indicate their functional properties, for example, if architects were using sketches to simulate the way a client would move through a house. Analysis of image types indicated that A1 used static, abstract, zoomed (as in zooming in with a camera), and rotated images, while A2 used static and rotated images and A3 used static and dynamic images (images that suggested movement). There was a progression in image type usage with less experience associated with more image type usage, and more experience associated with usage of fewer image types. As with sketch types, usage of greater numbers of image types by A1 is interpreted as indicating both a usage of formally learnt processes and the inability to generate more complex, integrated images.

Another difference across architects was the point in the activity when all significant elements of the design were visible. This point was never the end of the activity but any activity after this point involved completing detail that did not change the basic design. A1 generated what I describe as an holistic design by tentile 8, A2 by tentile 7, and A3 by tentile 4. This result is consistent with existing research that found that experts produce solutions faster than less-experienced practitioners (Lajoie, 2003). It is interesting to note that cross-referencing visual data with the tentiles of cognitive procedures indicates that the point at which each architect generated their holistic sketch was also the tentile with the most generative activity.

Use of abstract symbols was another observable difference across the visual data. These included names, notes, and direction arrows and are interpreted as both aids to memory and cues to the progress of the activity. A1 used 34, A2 used 5, and A3 used 3. The progression in terms of decreasing use also suggests architectural expertise involves more complex and integrated visual data with less need for memory aids (Lajoie, 2003).

The final feature of the visual data was time spent sketching, with A1 spending the most time and A3 the least, with A2 in between. This was an interesting observation as sketching activity was largely associated with generative procedures. This means A1 spent almost all his time (88%) generating, leaving little time for exploration or executive control procedures, that is, engaging in deep thinking about the problem prior to generating a solution. In that sense, A3's time spent sketching was consistent with expertise, with A3 having spent the least time sketching and consequently the most time exploring the problem. The verbal data confirms this interpretation of the visual data.

Combining the Analyses of Verbal and Visual Data

Combining the analyses of verbal and visual data achieved a number of goals. It allowed triangulation of data that confirmed that many features of expertise in general were present in design expertise. As noted earlier, these were time spent exploring the problem, the manner by which complexity was identified, and the speed of production of solutions.

Analysis of the combined data also suggested the problem-solving model proposed by Middleton (2002) was useful in representing ill-structured problems in domains such as design. The data suggested that all architects found the task complex and one where each had to establish their own starting points, their own solution to the problem (there were significant differences between the designs), and each engaged in a process of identifying solution elements from existing knowledge and creating new elements, as predicted by the model.

The study confirmed the central role of visual images in designing and the importance of using visual data in analysing design thinking. With up to 88% of time spent sketching, visual data were central in allowing confident interpretation of the designing activity.

Finally, when undertaking research it is often the case that most results are predicted at the outset, hence the use of hypotheses. However, it is also often the case that some of the most interesting findings are those that were not expected, and this was the case with this study.

During the analysis of the verbal data it was sometimes the case that deciding on the category of cognitive procedure was difficult. In these instances, it was helpful to view the combined data via the video-recording. This was both illuminating and occasionally alarming. For example, on one occasion both A1 and A2 produced identical verbalisations, for example, "we have one bedroom, a second bedroom and a third." However, when one viewed the video it was clear that A1 was sketching the rooms, and thus engaging in a generative activity, while A3 was simply pointing to each room in turn and thus engaging in the executive control activity of monitoring.

This highlights the strength of using combined data but also indicates a potential weakness of some forms of verbal data. This includes verbal data where research participants are verbalising the performing of a task and there is not the opportunity to clarify meaning, as is the case with an interview. People use identical or similar words to indicate various meanings and caution needs to be exercised in analysis unless there are other data that can be used to either support or clarify meaning as was the case in this study.

CONCLUSIONS

The study reported here suggests that design expertise has many features that are found in expertise in general, and the transition to expertise in design is also similar to the transition in other domains. The study did conclude that to produce findings about design thinking and activity confidently it was important to use data that represented the way design activity operated. This involved using both verbalisations and visual imagery data to represent design thinking and action.

The study did support the utility of the problem space model proposed by Middleton (2002) as a way to characterise the particular properties of design problems. This was evident in the way the three architects navigated the search space and in the different ways they identified the problem and the kinds of solutions they proposed. These differences were in addition to the more general differences that were a result of their levels of expertise.

The study has implications for the way we research the learning process in technology education or design and technology education subjects. As with professional design, students involved in designing engage in activities that are both verbally and visually mediated and we can gain meaningful insights into student design processes only if we use methods that acknowledge that reality.

It does need to be said that while the study reported here involved the collection and analysis of rich and detailed data, it did involve only three participants. As such, caution needs to be exercised in making generalisations. However, the study does provide the basis for further research into the thinking processes of both experts and practitioners developing expertise in particular domains. These include domains where the solving of ill-defined problems occurs and creative thinking is required.

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9. EDUCATION FOR SUSTAINABLE DEVELOPMENT AND THE TRANSFORMATION OF SELF

How the World Can Become a Better Place to Live for All

INTRODUCTION

This chapter explores the nature of transformative education within different traditions arguing for a social emancipatory view of transformative education that accommodates both social change and individual transformation (Taylor, 2008) as the most appropriate way of teaching and learning for sustainable development (SD). Mezirow (2000) claims that change to our worldview is a process of learning that occurs in at least one of four ways: by elaborating existing frames of reference, by learning new frames of reference, by transforming points of view, or by transforming habits of mind. It is argued in this chapter that to enable transformative education, learning in technology education classrooms and through teacher training programs needs to employ all four approaches. A transformation of the self through design and problem solving is argued as an active way of developing a particular worldview in accord with the ideals of education for sustainable development (ESD).

TRANSFORMATIVE LEARNING

> Transformative learning is "a deep, structural shift in basic premises of thought, feelings, and actions." (Transformative Learning Centre).[1]

The theory of transformative learning when introduced by Mezirow (1978) was specifically related to adult learning and it helped to explain the ways adults changed their interpretations of the world. The work of Habermas (1971) was among the main factors that influenced the development of Mezirow's theory. Three domains of learning were proposed by Habermas: the technical (specific to a task, governed by rules), the practical (relates to social norms), and the emancipatory (self-reflection and self-knowledge). These helped Mezirow (1985) to formulate three types of learning required for transformative education: instrumental (how to learn), dialogic (when and where to learn), and self-reflective (why to learn). Critical self-reflection is argued by Mezirow (1995) to be the

H.E. Middleton & L.K.J. Baartman (eds.), Transfer, Transitions and Transformations of Learning, 123-132.

central element of transformative learning. However, all three types of learning should be present as they help to transform problematic frames of reference

> sets of fixed assumptions and expectations (habits of mind, meaning perspectives, mindsets) – to make them more inclusive, discriminating, open, reflective, and emotionally able to change. (Mezirow, 2003, p. 58)

Critical reflection on and of assumptions when learners examine their worldview in light of their own particular beliefs is central to the process of learning when "constructing and appropriating new and revised interpretations of the meaning of an experience in the world" (Taylor, 2008, p. 5). This transformation could occur only if the deep feelings that accompanied the original perspective are to be dealt with. A global-oriented view leads to deeper and more complex reflections that involve transforming a series of meaning schemes: "the constellation of concept, belief, judgment, and feeling which shapes a particular interpretation" (Mezirow, 1994, p. 223) that in turn could lead to changes of general frames of references comprising a series of specific meaning schemes.

Since the 1980s, research into fostering transformative learning in the classroom has been based on diverse theoretical interpretations about the process of transformation. As argued by Taylor (2008), at least four main perspectives could be identified: psychocritical, psychoanalytic, psychodevelopmental, and social emancipatory views. Differences in views about transformative teaching and learning relate to the goal of personal transformation (self-actualisation) or emancipatory transformation (planetary consciousness). The first three perspectives give little consideration to the role of context and social change in the transformative experience. The "unit of analysis" therefore is the individual. The fourth perspective is focused on social transformation, so the world can become a better place for all to live in. It is as much about social change as individual transformation; it appreciates the role of social or cultural differences in transformative learning. This social emancipatory view is primarily rooted in the work of Freire (1970) who believes that people as agents should be constantly reflecting on the transformation of their worlds and acting upon these reflections. He criticised the "banking" method of learning when teachers deposit information/knowledge in students. Freire (1970) emphasised the need to develop a consciousness that has the power to transform reality. Further development of this view led to a *planetary view of transformative learning* that takes the totality of life's context beyond the individual and addresses fundamental issues of the whole system (political, social, educational) (O'Sullivan, 1999). This view recognises the interconnectedness between natural and social environments and personal worlds, and therefore requires a vision of preferred futures.

Concern over the need to develop a planetary vision that enables people to see the interconnectivities of the world and the need to address issues holistically goes back to the very beginning of the 20th century, when Vernadsky developed a theory of the nöosphere that presented a philosophically rethought image of our desirable future. Vernadsky's concept of nöosphere or the "sphere of wisdom" (tsarstvo razuma) is grounded in his research in the physical sciences and stages in the evolution of the planet (Vernadsky, 1926, 1945, 1998) from a geological perspective. Although our species represents an insignificant mass of the planet's matter, humankind has emerged as the increasingly dominant "geological force" in the biosphere and its strength relates to human "brain power." Therefore, Vernadsky believed that a planetary vision should frame human actions. However, technological development and an increase in technocratic ideology (particularly in the West) that was linked with the expansion of human power through technical control (Habermas, 1971) has greatly contributed to environmental and social problems that humanity is facing today. These challenges led to the emergence of discourses on sustainable development and on the role of education in achieving desirable futures.

EDUCATION FOR SUSTAINABLE DEVELOPMENT

Since the Rio Declaration on Environment and Development (UN, 1992a) and Agenda 21 (UN, 1992b) Education for Sustainable Development (ESD) discourses highlights the need to create learning experiences that help students to examine personal and social assumptions about development and environment and to understand that frames of references (worldviews) are conditioned. Twenty years later *The Future We Want: Rio+20 Outcome Document* (UN, 2012) confirms the role of education in bringing a meaningful change in people's mind-sets and attitudes in pursuing sustainable consumption and production patterns.

These new directions for education and learning, reflecting the need to increase quality and inclusiveness of education, have been formulated by UNESCO through the UN Decade of Education for Sustainable Development (DESD, 2005-2014). The DESD is an attempt to "integrate the principles, values, and practices of sustainable development into all aspects of education and learning" (UNESCO, 2005, p. 6). More specifically, ESD is about learning to:

- Respect, value, and preserve the achievements of the past;
- Appreciate the wonders and the people of the Earth;
- Live in the a world where all people have sufficient food for a healthy and productive life;
- Assess, care for, and restore the state of our planet;
- Create and enjoy a better, safer, more just world;
- Be caring citizens who exercise their rights and responsibilities locally, nationally, and globally. (UNESCO, 2006)

The Bonn Declaration (UNESCO, 2009), which marks the middle of the decade, emphasises again the role of education in "securing sustainable life chances, aspirations and futures for young people" (p. 2, point 5). Shifting one's worldview is central to education for sustainable development (ESD).

> ESD is far more than teaching knowledge and principles related to sustainability. ESD, in its broadest sense, is education for social

> transformation with the goal of creating more sustainable societies. ESD touches every aspect of education including planning, policy development, programme implementation, finance, curricula, teaching, learning, assessment, administration. (UNESCO, 2012a)

These political discourses on ESD go in parallel with the educational debate about transformative education, the one that can be associated with a planetary view of transformative learning. The transformative nature of education required to address current global challenges has been argued by many (e.g., Bonnett, 2002; Sterling, 2001, 2004, 2007; Stevenson, 2006; Argyris & Schön, 2004; Lundegård & Wickman, 2007; Peters & Gonzalez-Gaudiano, 2008). It requires recognising the interconnectedness among universe, planet, natural environment, human community, and personal world through critical reflection, holistic approaches and positive relationships with others. The emphasis is on *why* we are teaching (compared to *how* or *what* we teach). It is rooted in a particular worldview and based on a particular educational philosophy. The importance of the *why* question supports the argument that ethical development is a core business of education, the ethics that are related to valuing of the other person, moral responsibility, and establishing non-instrumental relationships with nature (Campbell, McMeniman, & Baikaloff, 1992; Parker, Ninomiya, & Cogan, 1999). As argued by Pavlova (2009), *weak anthropocentrism*, the environmental ethics that promotes the mutual flourishing of human and non-human nature, could be used as a basis for transformative education that is a foundation of ESD for technology education. It provides an answer for the *why* question and leads to the need to change our worldviews (or frames of references[2]). A concern for the human condition formulated as the base principle of *Respect and care for the community of life, meaning duty to care for other people and other forms of life now and in the future* (IUCN, UNEP and WWF, 1991) could serve as a guiding value for technology education.

These calls for transformative education, based on the ethics of weak anthropocentrism/a planetary vision, form a specific framework for technology education development.

TECHNOLOGY EDUCATION AS TRANSFORMATIVE EDUCATION

A social emancipatory view of transformative education linked to a planetary vision (framed by ideas of SD) is argued here as the most appropriate way of teaching and learning in technology education. These teaching and learning processes could help students to construct and appropriate new and revised meaning of experiences gained through technology education. The nature of technology education provides a rich context to discuss and visualise desirable futures that could be shaped by technological decisions. A transformative pedagogy applied in technology education classrooms should:

– help students to recognise a situation as being ethically (morally) problematic,

– enable students to have a voice and express their feelings and thoughts, and
– find a solution that serves the best interests of all parties involved and meet characteristics of the planetary vision. (Pavlova, 2012)

Transformative learning is foremost about educating from a particular worldview (a planetary vision) that helps to answer the important question of *why* we are teaching and learning technology in schools. Classroom activities should go beyond a collection of design-briefs for students to solve; all learning in technology education should target students' understandings of preferred futures. Therefore, teaching approaches central to fostering emancipatory transformative learning need to include: *the critical reflection* (to identify the ways learning can transform society and students' own reality); the *liberating approach to teaching* (facilitating cognition through problem posing and discussions); and *equal, horizontal student-teacher relationships* (Freire & Macedo, 1995).

Project-based learning in technology education provides an opportunity to address these different ways of learning in a systematic and holistic manner through addressing SD challenges. As stated in the draft *Australian Curriculum: Technologies*:

> the priority of sustainability provides authentic contexts for creating preferred futures. When identifying and critiquing a need or opportunity, generating ideas and concepts, and producing solutions, students give prime consideration to sustainability by anticipating and balancing economic, environmental and social impacts… The curriculum provides a basis for students to explore their own and competing viewpoints, values and interests. Students work with complexity, uncertainty and risk; make connections between disparate ideas and concepts; self-critique; and propose creative and sustainable solutions. (Australian Curriculum, Assessment and Reporting Authority [ACARA], 2013, p. 17)

Awareness of personal values is a critical component of reflection. One of the approaches that has been shown to be effective in increasing an individual's awareness of personal values and assisting in change behaviour is neuro-linguistic programming (NLP) (O'Connor, 2001). NLP consists of many techniques concerned with individual's understanding of themselves. One of the techniques, "perceptual position," helps individuals to observe situations from different perspectives (O'Connor, 2001), reflect on their values, and challenge their values in respect to that situation. Four key perceptual positions have been described (Hoag, 2005; O'Connor, 2001): (1) your own position where you evaluate your relationship with the object from the perspective of your own reality; (2) the other person's position, you place yourself in place of the other person and then look back at yourself in the first position, and then reflect on how the other feels in response to your feelings in position one; (3) you, in a detached position, observing the dynamics occurring between the first and second positions; new possibilities may arise; and (4) the wholly "objective" detached position, in which you as an independent observer clarify what has been learnt from the first and third positions (the bigger picture). Following this line of discussions and reflections on visual images (e.g., low-cost products for poor in developing countries; green technologies; manufacturing processes that pollute the environment), a teacher can raise a number of issues related to sustainability and preferred futures. Helping students to reflect on their worldviews is an important part of transformative pedagogy as it assists students in understanding their assumptions and the need to change.

Understanding of one's own assumptions and reflections on other people's values are equally important. Real-world learning opportunities that are required for implementing technology education curriculum allow students to recognise and engage in different forms of collaboration and to understand someone's meanings when this person communicates with them. This helps students become more aware of the assumptions, intentions and qualities of the person collaborating. For example, understanding of cultural relativity and power relationships through product analysis could help students to evaluate the same products differently. Students also need to learn how to negotiate and act upon their values and meanings rather than uncritically accept these from others. Culture plays a crucial role in transformative learning.

Mezirow (2000) claims that change to our worldview is a process of learning that occurs in at least one of four ways: by elaborating existing frames of reference, by learning new frames of reference, by transforming points of view, or by transforming habits of mind ("the assumptions we receive and assume from our culture"). These processes are equally important for students and teachers.

Teachers can play an essential role in fostering transformative learning through dynamic, non-hierarchical relationships with students; through knowing students as individuals; through recognising their preferences and life experiences; through engaging them in critical reflections; and through asking critical questions that challenge assumptions and readiness for change. A framework of core competencies in ESD for educators formulated by UNECE highlights the importance of transformation, change and holistic approach (see Table 1). These qualities are very relevant to technology education teachers that use ESD as a framework for teaching and learning to "deliver" transformative education.

To enable transformative pedagogy teachers' prime concern should be with *why* they teach. They also need to be aware of their own frames of reference and how these shape their practices. Teachers need to transform themselves through the process of helping students to transform. To develop a particular worldview, a particular educational philosophy would increase the likelihood of transformative learning of the students in the classes of these teachers. For example, the Draft Australian Curriculum: Technologies uses the frame of "preferred futures" to provide guidance for teachers on *why* to teach the technology education curriculum (ACARA, 2013). Understanding and monitoring the effect of students' transformation on peers in the class, on teachers at school, and on learning in general requires additional qualities for technology education teachers. Tools to understand and interpret the "original" level of students' frames of references,

Table 1. UECE competencies in ESD for educators[3]

	Holistic approach	*Envisioning change*	*Achieving transformation*
The educator understands …	The basics of systems	The root causes of unsustainable development	Why there is a need to transform the education systems that support learning
The educator is able to …	Work with different perspectives on dilemmas, issues, tensions, and conflicts	Facilitate the evaluation of potential consequences of different decisions and actions	Assess learning outcomes in terms of changes and achievement in relation to sustainable development
The educator works with others in ways that …	Actively engage different groups across generations, cultures, places, and disciplines	Encourages notions of alternative futures	Help learners clarify their own and others' worldviews through dialogue, and recognise that alternative frameworks exist
The educator is someone who …	Is inclusive of different disciplines, cultures, and perspectives including indigenous knowledge and worldviews	Is motivated to make a positive contribution to other people and their social and natural environment, locally and globally	Is a crucially reflective practitioner

drawing up a related set of activities (focusing on technology projects and on the issues addressed beyond the technical ones), and tools to observe students' transformation and reflection on these processes should be included in teacher training programs. Specific training is required for how to use NLP in the classroom, how to observe classroom dynamics, monitoring students' responses to classroom activities and projects, and many other issues. So for teachers a strong psychological component is essential for their education together with visionary, design, technical, curriculum, and other aspects.

Saying all this, however, it is important to acknowledge that it is not an easy task to achieve. In the current climate of mainstreaming educational programs to achieve monetary efficiency, it is becoming more and more difficult to teach subject-specific skills and competencies, as more and more often students specialising in different subjects are taught in one classroom.

CONCLUSION

This chapter explores the meaning of transformative education and the main characteristics of transformative learning and teaching. It emphasises the need for reflective learning that challenges students' and teachers' assumptions and leads towards worldview transformations that are shaped by a vision of sustainable development.

Technology education is well positioned to address the challenges of transformative education through linking actions and perspective transformation. This ability to act on preferred futures suggest that teachers need to create opportunities for learners within and outside the classroom. By employing these action- and reflection-based experiences learners will transform. Emphasis on reflection and processes accepted in the classroom help students to become more reflective as they develop. This is a developmental process requiring practice from one learning activity to another. Although rational discourse and critical reflection play a central part in transformative learning, a holistic approach that recognises the importance of feelings and the affective side of learning is very important. To enable this strong psychological component specifically, studies to address issues of transformation should be included in teacher training programs.

The practical orientation of technology education provides a unique opportunity for students and teachers to demonstrate their transformation through practical actions, designing and making products that meet the requirements of "preferred sustainable futures."

NOTES

1. Source: http://tlc.oise.utoronto.ca/About.html
2. These frames are comprised of two elements: a habit of mind (the assumptions we receive and assume from our culture) and a resulting point of view (one's actions) (Mezirow, 2000).
3. Source: http://www.unece.org/fileadmin/DAM/env/esd/6thMeetSC/Learning%20for%20the%20Future_%20Competences%20for%20Educators%20in%20ESD/ECE_CEP_AC13_2011_6%20COMPETENCES%20EN.pdf

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10. TRANSFORMING IDENTITIES

The Process of Becoming a Design and Technology Teacher

INTRODUCTION

Learning to teach can be viewed as a process of becoming, a time of transition and transformation. It involves an examination of what one is doing and who one becomes, that is, one's professional identity (Britzman, 1991, 2003). This chapter presents one aspect of the findings of a longitudinal study of the influences that shape beginning design and technology teachers' professional knowledge and identity. The chapter analyses the stories of 20 teachers to explore the role of and interaction between personal and professional histories, professional knowledge and identity transition and transformation. It is concluded that personal and professional histories emerge as a strong mediating factor in shaping the professional identity and knowledge of beginning design and technology teachers. The chapter argues further that the boundary between professional knowledge and identity is not clear; one appears to be part of the other with neither being viewed as being fixed but as ever-evolving and transforming as a result of past, present, and future interactions and experiences.

The research was conducted in two stages over a 15-month period as the beginning design and technology teachers made the transition from their final year of university into the first year of teaching. The qualitative case study research adopted a narrative inquiry approach (Connelly & Clandinin, 1998, 1999; Clandinin & Connelly, 1995, 1998, 2000; Clandinin, 2007) to examine the influences that shaped the beginning teachers' perceptions of identity and the nature of the perceptions themselves.

The chapter commences with an examination of the literature associated with defining professional identity and, in doing so, provides a framework for investigating the interconnectedness of personal and professional histories and knowledge in shaping beginning design and technology teachers' professional identities.

DEFINING PROFESSIONAL IDENTITY

Understanding teachers' professional identity and the issues related to it can be difficult and complex (Beijaard, Verloop, & Vermunt, 2000; Beijaard, Meijer, &

H.E. Middleton & L.K.J. Baartman (eds.), Transfer, Transitions and Transformations of Learning, 133-147.

Verloop, 2004; Beauchamp & Thomas, 2009). Different meanings are assigned in both the general literature and literature on teaching specifically. For teaching, definitions of professional identity are related to images of how one sees oneself in the roles and responsibilities associated with teaching. It is the knowledge one has of oneself as a teacher (Kelchtermans, 1993). Lasky (2005, p. 900) states more specifically that it is the stories teachers tell to "define themselves to themselves and to others."

This narrative rendering of identity is also reflected in the work of Connelly and Clandinin (1999), who suggest that it is the interconnectedness of our experiences, place, and knowledge that merge to become our professional identity – our narrative or story to live by. This implies that rather than thinking about identity as a stable construct, we can instead think about an ongoing process of identification. It can be argued that from the beginning and during their careers teachers are engaged in creating themselves as teachers (Coldron & Smith, 1999).

Teachers' professional identity has emerged as an important area of research over the last 10 years. The relationship between professional identity and beginning teacher retention has sparked a renewed research interest in the transitionary period for beginning teachers (see, e.g., Ewing & Smith, 2003). For beginning teachers the development of a professional identity appears to be a central element in the transition from pre-service teacher to beginning teacher. Beauchamp and Thomas argue that, for the beginning teacher, this transition can be viewed as "An ongoing and dynamic process which entails making sense of and a (re) interpretation of one's own values and experiences that may be influenced by personal, social and cognitive factors" (Beauchamp & Thomas, 2009 p. 176).

As pre-service teachers commence their careers, their evolving professional identity is open to critique and question as they transition into new and varied contexts. Feiman-Nemser and Parker (1993), Tickle (2000), Flores (2001), and Feiman-Nemser (2001,2003) highlight not only the uniqueness and complexity of the early stages of transition, but also conclude that the way beginning teachers are supported through these early stages has long-term implications for identity formation, continued professional growth and, ultimately, retention in the teaching profession. It can be argued that few experiences in life have such a tremendous impact on the personal and professional life of a teacher as does the first year of teaching.

DEFINING DESIGN AND TECHNOLOGY PROFESSIONAL KNOWLEDGE

In the literature it is argued that teachers derive their professional identity from both the subject matter they teach and their pedagogy (Beijaard, Verloop, & Vermnut, 2000; Staples, 2003). This is also evident in the field of design and technology education where many teachers directly associate their professional identity with the curriculum they deliver (Paechter & Head, 1996; Staples, 2003). Historically, design and technology education in Australia situated itself in the field of boys' craft, manual arts, and, until recently, technical studies.

As a consequence teaching and learning in design and technology education has traditionally been strongly focused on an established body of technical "know-how" or learning specific skills "through doing" (Williams, 2006). However, internationally and nationally design and technology education at a curriculum level has changed dramatically over the last 10 to 20 years, starting with a transition from vocational to general education through a series of curriculum reforms. The culmination of these reforms has witnessed a gradual but continued pedagogical shift from a didactic to a constructivist approach to teaching and learning (Middleton, 2006).

If, as suggested by Beijaard et al. (2000), teachers derive their professional identity from both the subject matter they teach and their pedagogy, then recent changes to the curriculum could be viewed as unsettling for teachers of design and technology. The move away from a transmissive approach to one which sees the teacher adopt a facilitator role has required teachers to question and reshape their professional identity (Staples, 2003). It is the nature of this subject and pedagogical knowledge shift as identified by beginning design and technology teachers that underpins the discussion in this chapter.

For the last two decades there has been considerable research (Grossman, Wilson, & Shulman, 1989; McNamara, 1991; Beijaard et al., 2000, Beijaard et al., 2004) into the forms of knowledge that teachers require to perform their role. This chapter draws on a limited number of studies (e.g., Leach & Banks, 1996; Moon & Banks, 1996; Banks & Barlex, 1999; Banks et al., 2004) that examine research into design and technology teachers' professional knowledge.

When devising a pictorial model of teacher professional knowledge, Banks and Barlex (1999) and Banks et al. (2004) draw on curriculum theory (Shulman, 1986), cognitive theory (Gardner, 1983, 1991) and McNamara's (1991) summary of different forms of teacher knowledge. In their model Banks and Barlex (1999) and Banks et al. (2004) suggest that pre-service and in-service design and technology teachers require the following professional knowledge:

> Subject content knowledge – this can be defined as a working knowledge and an understanding of specific aspects of design and technology education coupled with an understanding and implementation of curriculum documents.
>
> Pedagogical knowledge – this can be defined as subject application, knowing and understanding the ways in which students learn, as well as demonstrating the ability to formulate subject matter so that it can be understood by students.
>
> School subject knowledge – recognising that school-based design and technology education is different to that as practised in the world outside of school; including aspects that may be specific to a site, for example, resource availability, expertise of existing staff, budget constraints.

It is the active intersection of each of these types of knowledge that bring professional knowledge into being. Banks and Barlex (1999) argue further that early career design and technology teachers also need to develop their own personal subject construct, which they suggest is "A complex amalgam of past knowledge, experiences of learning, a personal view of what constitutes 'good 'teaching and a belief in the purposes of the subject" (p. 7).

An adapted version of the Banks and Barlex (1999) pictorial model provided one of the data collection methods for the first phase of this study. While the original framework provided the opportunity for collecting data related to professional knowledge, it did not facilitate the collection of data that related to the influences on the development of that knowledge and how those influences served to shape one's professional identity. As a result, the original framework was amended to address the identified limitations through replacing the school subject knowledge aspect with a question that sought to investigate the influences that had or could shape the development of beginning teachers' professional knowledge.

THE RESEARCH STUDY

The nature of the study was interpretive, in that it was characterised by a concern for the individual, and more specifically the interaction between the individual and their past and present social contexts, including the university and the school in which the beginning teachers commenced their first year of teaching. The paradigms (Lincoln & Guba, 2000), worldviews (Creswell, 2007), or beliefs that guided the research were based on the notion of social constructivism (Neuman, 2000; Lincoln & Guba, 2000; Schwandt, 2007). The beginning teachers were viewed as seeking to understand the world in which they worked and the individually constructed meanings which they made were seen as being subjective. That is, they were related to individual experiences in a particular context and formed through a process of interaction with others as well as "through the historical and social norms that operate in one's life" (Creswell, 2007, p. 8).

The first stage of the research was conducted on the campus of the Australian University in which the 20 pre-service teachers had recently completed four years of undergraduate study in either the design and technology education program or the Bachelor of Education, Primary/Middle (3-9) program. The pre-service teachers had majored in design and technology education and intended to teach design and technology in secondary settings. There were 6 female and 14 male pre-service teachers. They ranged in age from their early 20s to their late 30s. Six of the pre-service teachers had completed a major in design and technology education as part of the Bachelor of Education, Primary/Middle program. The remaining pre-service teachers had completed what equated to a double major in design and technology education as part of the Bachelor of Education Design and Technology Education program. Five of the participants studied courses in food and textile technology with the remaining 15 studying in the areas of advanced technology, electronics, and resistant materials, including wood and metal. All 20 participants studied design as a core teaching methodology. Data for the first stage of the study were collected through a questionnaire that included open-ended, text-response questions, the completion of an adapted teacher professional knowledge framework (Banks & Barlex, 1999), and focus group discussions.

The second stage of the research was conducted in the school settings in which the pre-service teachers commenced teaching. A smaller group consisting of 10 of the 20 pre-service teachers were selected for this phase of the research. The group consisted of one female and nine males. The aim of this reduction in numbers was to keep the data to a manageable scale. Beginning teachers in this phase of the research were selected on the basis that they had all completed their study in the same area of advanced technology, electronics, and resistant materials, including wood and metal. The schools they were teaching in also represented a cross sector of educational systems located in both metropolitan and country locations. Three of the participants had completed a major in design and technology education as part of the Bachelor of Education, Primary/Middle program. The remaining pre-service teachers had completed what equated to a double major in design and technology education. For this stage of the research data were collected via three semi-structured interviews and reflective e-journal entries. Data collection throughout the first year of teaching enabled changes in thoughts and ideas related to the beginning teachers' perceptions of professional identity to be documented, reviewed, and elaborated upon.

The chapter presents data from both stages of the study as collated throughout the beginning teachers' pre-service to in-service transition. For stage one of the study, analysis focused on participants' written and verbal responses to the three open-ended text-response questions and to the teacher knowledge framework. Codes were used to identify broad meanings within the data; these codes were then reduced by merging those of similar meaning. In stage two, effort was taken throughout the analysis to build a portrait of both the individual and the collective (Creswell, 2007). Thus, when analysing the data in this stage, emphasis was placed on individual narratives, and finding meaning in these narratives. What follows is one aspect of this analysis, that is, the significance of personal and professional histories in shaping professional knowledge and identity.

THE SIGNIFICANCE OF PROFESSIONAL AND PERSONAL HISTORIES IN SHAPING PROFESSIONAL KNOWLEDGE AND IDENTITY

The Place of Professional Histories

When pre-service teachers commence their university study, they bring with them varied narratives about who they believe they will become as teachers (Knowles, 1992; Lortie, 1975; Smith, 2007; Groundwater-Smith, Mitchell, & Mockler, 2007). Cohen-Scali (2003) argues further that by the time pre-service teachers commence their study, many have developed a cognitive map of what they think it means to be a teacher. The narratives of professional identity that pre-service teachers hold have been shaped by a range of social, political, and educational constructs that reflect influences of the past, the present, and perhaps a vision for the future (Flores & Day, 2006). The literature suggests that these historical and biographical narratives continue to influence pre-service teachers as they make the transition into teaching (Coldron & Smith, 1999; Kelchtermans, 1993).

Many of the pre-service teachers who commenced their study in the Bachelor of Education, Design and Technology Education undergraduate program brought with them a strong memory of how they were taught. Unlike other professions, it can be argued that people have a strong sense of what the role of a teacher entails through their own experiences as a student. Applebee states that "when we start to teach something new, one of the most powerful influences on what we do is our memory of how we were taught" (Applebee, 1989, p. 217)

It appeared that the opportunity to specifically study design and technology determined many of the pre-service teachers' decision to become a teacher. Many of the pre-service teachers cited the influence of past teachers, often a design and technology teacher, as a reason for their decision to become a teacher in this field. When asked during the first year of their study to provide an image of how they viewed themselves as teachers, the pre-service teachers often drew upon the professional characteristics of a past and well-liked teacher. These past teachers were identified by pre-service teachers as knowing their content, as being highly skilled, and having the ability to communicate well.

Sixty per cent of the pre-service teachers who commenced study in the design and technology undergraduate teacher education program in the year in which this study was situated were mature age or "career switchers" (Richardson & Watt, 2006) and the memories they held of teaching were from some time ago. An implication of this was that a number of pre-service teachers were initially challenged by the changes with which they were confronted during professional experience placements. These challenges centred primarily on issues related to classroom management.

The research also revealed that the narratives of professional identity that pre-service teachers brought to their study were diverse – a result, in many instances, of the changing profile of those entering the field of education. Design and technology teacher education programs attract a high percentage of applicants who have trade or industry background from a field that is directly related to the content knowledge they will be teaching. The trade backgrounds of the design and technology pre-service teachers in this study included patisserie chef, boiler maker, textile designer, prosthetic manufacturer, cabinet maker, electrician, sheet metal worker, dress maker, and car mechanic.

The data revealed that the knowledge gained from professional histories, including past work experiences, provided both a positive and major influence on shaping professional identity. This was evidenced by Issac, who stated "My life experience and previous work does help my professional identity as a design and technology teacher because designing and making prosthetics was a big part of my life for about twenty years" (Stage one, focus group discussion).

The majority of pre-service teachers in the study were able to draw on their life experiences and on the knowledge developed through their technical and trades background to inform their teaching role during professional experience and once they commenced teaching. Neil, a tool maker, and Peter, a builder, both agreed that their work skills had influenced not only their decision to commence teaching in the field, but also their professional identity. They both suggested that their past trade experiences had provided them with a level of confidence in their teaching ability. They felt they already had some of the specific practical content knowledge needed for teaching. Cathy, a textile designer, commented further that her personal and professional identity was shaped by her understanding of the subject-specific knowledge and the technical skills she believed would be required to be successful as a beginning teacher: "I see myself as someone who has in-depth subject knowledge and the skills to be able to impart these into the classroom in a professional manner. I like to work with fabrics; it is what I do" (Stage one, focus group discussion).

As a mechanic, Aaron identified his previous employment and life experiences as having provided him with the ability to manage time and interact with others, and some of the technical skills on which he could draw when teaching. For Damien, having previously completed part of an industrial design degree and having a professional (producing recycled timber furniture) and personal commitment to environmental sustainability enabled him to understand the process of designing and to focus on environmental and social justice issues when planning and teaching.

The Place of Personal Histories

The mature-age pre-service teachers who had children also cited their experience as parents as an influence on their professional knowledge and professional identity. Data from this study would suggest that through the role of parenting, pre-service teachers gained an insight into students' life-worlds or funds of knowledge described as the "historically accumulated and culturally developed bodies of knowledge and skills essential for household or individual functioning and well-being" (Moll, Amanti, Neff, & Gonzalez, 1992, p. 133).

Pre-service teachers who were parents of teenage children indicated that being aware of teenage interests, and knowing the type of behaviour to expect from students of this age, could provide them with an advantage in relationship building once they commenced teaching. Peter cited both his age and role as a parent as being instrumental in:

> Shaping your beliefs about society and how education is shaped by that society. You are hoping that you can set students up for success in life just like you want to do for your own kids. These are the beliefs that inform the sort of person I want to be when I am out there (teaching). (Stage1, focus group discussion)

Peter's comments, as did those of many of the beginning teachers, revealed that by reflecting back on their own histories and life events, teachers were able to deconstruct the influences and beliefs that shaped their identity. Once Peter commenced teaching he continued to draw on the beliefs about teaching that had been shaped by his role as a parent. At the conclusion of his first year of teaching, Peter's final interview responses made strong and continued reference to his personal and professional history. He stated:

> My life experiences still shape who I am and my teaching. My own children, my daughter who is aged 15, the same age of the students I am teaching. I still think about what I want for my own children, the society I want them to live in. I work towards that in my teaching. In my Year 11 home group I talk to them as a former employer of a business, and as a father as well as a teacher. You talk to them about where they are heading in life. (Stage 2, Interview 3)

Peter's journal entries and interview responses revealed a sense of pride in being able to draw on his past experiences as both a parent and builder to inform his teaching practice and in turn to shape his professional identity. More importantly for Peter he felt that the experiences and associated skills that he brought to teaching were valued by both staff and the students he taught and, as such, they positively shaped his professional identity.

SUMMARY OF FINDINGS

It is recognised that teaching is a profession in which who one is as a person is strongly interwoven with how one acts or the role one assumes as a professional, and it is difficult to separate the two (Loughran, 2006). As Loughran (2006, p. 112) argues, "it seems unlikely that the core of the personal will not impact on the core of the professional."

This study provided evidence that the practical content knowledge developed from past personal histories provided a knowledge base from which pre-service teachers drew and on which they continued to build as beginning teachers. Commencing university with a relevant practical knowledge base did not appear to present a barrier to change. In fact, it provided pre-service teachers with a sense of continuity, that is, an aspect of self (or identity) that remained the same over time (Erikson, 1989), and a sense of connectivity with who one is as a person. As a consequence, pre-service teachers whose past histories facilitated the development of deep technical content knowledge demonstrated a heightened level of competence and confidence during professional experience and as they transitioned into their first year of teaching.

Pre-service teachers with this technical knowledge also felt that the expectations of others, particularly mentor teachers during school placements, in regard to their technical ability could be met, thus providing them with the self-confidence to redirect their focus of learning to areas that were new or challenging. This finding is in direct contrast to the research findings of Flores and Day (2006), who found that many beginning teachers are confronted with negative school contexts and cultures that work to destabilise and challenge professional knowledge and positive concepts of identity.

The views on teaching and learning that had been shaped by pre-service teachers' historical and biographical narratives provided a starting point for personal critique and reflection. Consequently, a foundation for connecting learning or making meaning was established as they moved through their teacher education program and into classroom teaching (Bullough & Gitlin, 1995, 2001). For a majority of the pre-service teachers there appeared to be a personal connectedness with the learning area that informed their initial decision to commence study in the design and technology teacher education program. It appears that aspects that shape one's personal identity also influence who one becomes as a design and technology teacher; that is, one's personal interests, one's level of technical skill, and the value that one places on the learning area ultimately shape one's professional identity.

In acknowledging past influences on professional identity, beginning teachers identified elements of their practice that they viewed as being important in shaping their effectiveness as an educator once they commenced teaching. These elements included possessing a body of practical content knowledge and a sufficient level of technical skill related to working with materials and equipment; and the ability to develop professional relationships with students. For many of the beginning teachers in this study the personal and professional dimensions that they brought to teaching were strongly linked to their professional knowledge and identity. What follows are the beginning teachers' responses to their perceptions of design and technology professional knowledge.

PARTICIPANTS' PERCEPTIONS OF PROFESSIONAL KNOWLEDGE – AN AMALGAM OF SUBJECT CONTENT KNOWLEDGE AND PEDAGOGICAL KNOWLEDGE

When identifying the subject content knowledge associated with teaching design and technology education, all beginning teachers stated that ever-increasing changes in technology made specific identification of this knowledge complex and dynamic. For example, Steve, who studied a design and technology major and maths minor, stated:

> I think one of the things that defines us (as design and technology teachers) is the range of topics that are now classed under the design and technology banner. I am not clear what other subjects have to do in regards to curriculum but we have to learn new things every day to keep up with our subject. I know maths changes but it is essentially the same mathematical processes. We have got to understand things like advanced manufacturing, electronics, and new ICT technologies. What we have to teach is continuing to get bigger and bigger and more complex. (Stage1, focus group discussion)

While acknowledging the diversity of subject content knowledge, Sue, who studied a textile and food technology minor, also indicated that beginning teachers need to continually expand their knowledge and in doing so they could facilitate moving the learning area forward. Sue elaborates further:

> Educators are not expected to be an expert in all areas of their subject, nor is it realistic to expect they specialise in knowing each and every piece of

> equipment or material. However a professional teacher does need to strive to understand the curriculum and continuously expand on their content/subject knowledge. This is how we can continually move our learning area forward. (Stage 1, questionnaire response)

These views concur with Barlow (2002), who argues that beginning design and technology teachers are being confronted by a situation where they are required to possess a significantly different and more expansive knowledge than graduates in the past. Additionally, several beginning teachers viewed new and expansive subject content knowledge as providing an opportunity to teach subjects that they wanted to teach in and to teach the content of these subjects in new ways. For example, Neil, who studied a double major in design and technology, stated that "Having the latest learning and knowledge of newer technologies would provide a little bit of political pull, to introduce new ideas and ways of teaching" (Stage1, focus group discussion).

Beginning teachers placed strong emphasis on technical skill development and workplace safety as aspects of professional knowledge. The responses were not unexpected and served to reinforce that this is a unique aspect of subject content knowledge in design and technology education. Steve's comment, as representative of these responses, was that "As design and technology teachers there is a need to understand the fundamental properties of materials and processes and this knowledge is essential to what we do" (Stage 1, focus group discussion).

While previous studies of science and chemistry teachers (see, e.g., Beijaard et al., 2000; Smith, 2007) identify specific subject content knowledge that is theoretically and conceptually based (for example, understanding scientific concepts) few studies have identified the significance of the procedural or practical aspect of subject content knowledge that are central to teaching design and technology. Not unexpectedly, views in regard to identifying the need to understand the nature of a range of materials, be multi-skilled, and work competently with a range of tools and equipment were aspects of subject content knowledge that were also clearly reflected in the majority of responses. These were also the aspects of subject content knowledge that beginning teachers appeared to transfer from their professional histories, as evidenced in the previous section of this chapter. Closely aligned to understanding the properties of materials and processes was the acknowledgement by a number of beginning teachers that possessing a thorough knowledge of safe work practices was a key aspect of design and technology subject content knowledge. For example, Travis stated:

> As D&T teachers we need to have a major understanding of safety, however, I think it is important that we develop ways of delivering that in a way that doesn't bore kids, so they understand it and we can make sure that everyone is safe. (Stage 1, focus group discussion)

The responses concur with Williams's (2006) argument that technology education has traditionally been strongly focused on an established body of learning specific skills through doing. Banks and Barlex (1999) and Staples (2003) also posit that many constructions of professional identity for design and technology teachers focus explicitly on the teachers' functional roles, that is, the transmission of specific subject content know-how. However, the majority of beginning teachers in the study identified that possessing knowledge of design and design processes was an important aspect of their subject content knowledge. These responses represented a shift in thinking about subject content that moved beyond the transmission of subject-specific know-how as identified by Staples (2003) to a more holistic and student-centred approach to knowledge construction. For example, Peter, who studied a double major in design and technology, stated "We need to understand and promote design thinking; this gives us (teachers) the ability to cover the curriculum content in meaningful ways, so we can guide students to think and not just do" (Stage 1, focus group discussion).

This understanding also manifested itself through beginning teachers identifying the need to use different and innovative pedagogical approaches that catered for student diversity and open-ended learning opportunities. For example, Evan, who studied a minor in design and technology, identified the need to cater for a range of learning abilities when teaching:

> You need to know the level of student ability in your class and be able to construct design tasks to cater for a range of students. This could mean, for example, having a large construction project like a model of an energy-efficient house. You then break down the task which could push the most gifted students but support the student who is still developing basic design and technology skills. (Stage 2, Interview 2)

Beijaard et al. (2000) posit that teaching cannot be reduced to a technical or instrumental action, but involves ethical and moral aspects, such as knowing and understanding the ways in which students learn, formulating subject content so that it can be understood by students, and developing effective communications strategies. When asked to identify the pedagogical knowledge that shaped their professional identity, beginning teachers' gave diverse responses. As Sue stated: "Pedagogy is unique to each and every teacher as a result of personal beliefs and ideologies as well as experience and knowledge within a subject and curriculum" (Stage 1, focus group discussion).

Beginning teachers centred their response on the students they were teaching and on meeting their learning needs. Responses were also generic to teaching generally. Data did not reveal aspects of pedagogical knowledge that could be identified as being specific to design and technology education, such as teacher demonstration. Although three beginning teachers identified instilling safe work practices as an aspect of their pedagogy, reference to how this would be achieved appeared to be less transmissive than past research (e.g., Williams, 2006; Staples 2003) would indicate. As Issac, a double major in design and technology suggested, "There is a need to balance student-centred pedagogy with safe work practices in workshop settings without resorting to lock-step processes" (Stage 2, Interview 1).

For Cathy and Carrie, who both studied a double major in food and textile technology, aspects of effective pedagogy included: "Planning a variety of lessons and assessment tasks to enable students with different skill sets to be successful; this could include oral presentations, using ICTs, as well as written assignments: (Cathy, Stage 1, focus group discussion); and "Engaging all students, presenting theory and practical lessons that are interesting, relevant and challenging" (Carrie, Stage1, focus group discussion).

An aspect of pedagogy that was rated highly by beginning teachers was the ability to develop relationships with students. The development of positive professional relationships was identified as a means to ensure relevance to the content of what was being taught. For example, Aaron suggested that:

> The pedagogical knowledge that I will need to become an effective design and technology educator is the ability to develop relationships with my students so that I can produce and negotiate tasks that will motivate and benefit them in meaningful ways. (Stage 1, focus group discussion)

SUMMARY OF FINDINGS

The data revealed that design and technology subject content and pedagogical knowledge continued to be strongly connected to the teaching of technical skills, safety, and safe work practices, coupled with the need to understand the fundamental properties of materials and processes. However, beginning teachers also acknowledged the need to move beyond the transfer of specific skills and knowledge and develop and implement innovative pedagogical approaches that catered for student diversity and open-ended learning opportunities. Teaching through a design-based methodology represented a shift in thinking to a more holistic and student-centred approach to knowledge construction.

Recognition was also given to the ever-expanding range of professional knowledge with which beginning teachers would need to familiarise themselves as they transitioned into teaching. Beginning teachers in this study appeared to embrace and, in some instances, welcome the opportunity to bring new professional knowledge to the field, viewing it as an opportunity to take ownership as well as enabling the learning area to move forward. According to Lamote and Engels (2010), these are the teachers who actively contribute to whole-school development and change, and who seek new challenges for themselves and students. Lamote and Engels apply the term "extended professional" to teachers who associate creativity, innovation, and collaboration as integral aspects of their professional knowledge. In design and technology education, the extended professional could be identified as the teacher who moves beyond teaching familiar content knowledge and skill development and seeks new and relevant directions for the learning area.

CONCLUSION

This research revealed that personal and professional histories are strong mediating factors in shaping the professional identity of beginning design and technology teachers. Through drawing on their personal and professional histories, beginning teachers felt they already possessed some aspects of professional knowledge needed for teaching and, as a consequence, appeared to commence teaching with a heightened level of confidence in their teaching ability. The technical skills, subject content knowledge, beliefs, and values that beginning teachers had previously developed provided them with a sense of identity stability as they transitioned into teaching. This stability was further reinforced through the positive acknowledgment and acceptance of their skills and dispositions from teaching colleagues and school students.

A direct interaction between professional and personal histories, identity, and professional knowledge was evident in the beginning teachers' responses. Issac's response captured this interaction when he stated that:

> The design and technology learning area is quite vast so being an expert across all areas is virtually impossible. To be relatively competent across all areas that you teach is important. Material technology, understanding CAD, electronics and design are all important to me. I think realistically the learning area needs to be somewhat a reflection of who you are as a person so that you are naturally interested in gaining knowledge and skills. (Stage 1, focus group discussion)

In conclusion, the findings suggest that through making the connection between personal and professional histories and what happens in the context of schools, beginning teachers can be better prepared for any disjuncture or tension that they may confront once they commence teaching (Beauchamp & Thomas, 2009). More importantly, the process of "becoming" and time of identity transition and transformation can become a positive and professionally rewarding experience.

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11. WHY DO THEY NOT SEE WHAT I SEE?

The Difference Between Knowing How and Knowing That

INTRODUCTION

It is a cold but sunny September day in a forest in the south of Sweden. A university teacher, Eric, is taking his biology students out on an excursion. During the morning they have taken samples of soil, and identified plants, trees and many other things. At this specific moment the group has arrived at a peat bog. They are going to study the vegetation in this special environment and will soon be drilling deep down into the bog to take samples of partially carbonised mosses. They have been asked to put on their rubber boots and now Eric encourages them to walk out on the quagmire, to make them "feel the grounds tottering beneath their feet." He does not hesitate but walks causally, knowing exactly where to put his feet without getting wet. Hence he is leaving the anxious, struggling, moaning students far behind. Slowly moving themselves out on the peat bog, the students very often fail to establish a "safe" path and some of them begin to sink, getting their boots full of water. Afterwards, at the debriefing, Eric tries to teach them how to walk on a peat bog: "And if you listen, you can feel … hear water oozing between … these floes of moss, or bog, or moss, or peat bog. And one could tell from the vegetation where you could walk or not." Although Eric provides them with several clues about how to walk on the peat bog keeping their feet dry, it is obvious that those rules are of no direct use for the students. This episode was one of many found in a research study on expertise in teaching (Stolpe & Björklund, 2012a). The authors followed two experienced biology teachers when they took their students out on excursions in the nature. Data was collected using video and audio recordings and by taking field notes during the excursions. Afterwards the teachers were interviewed in a stimulated recall setting and were asked to comment on specific situations during the day.

In this episode Eric showed typical expert skills, observing, assessing, and acting in a complex environment almost automatically, and he was asked: How do you know where you could walk or not? He answered: "The vegetation tells you where to put your feet. Sedges indicate that it's dryer. And then one recognises what kind of moisture there is." This illustrates an analytical, conscious answer in which Eric attempted to explain his walking on the bog. However, this type of instruction is more or less useless as guidelines for students, since it would be hard

H.E. Middleton & L.K.J. Baartman (eds.), Transfer, Transitions and Transformations of Learning, 149-167.

to know what was meant by, for example, "the vegetation tells you where to put your feet."

Asked to be more specific, Eric then continued: "It is trial and error. You may probe and you will see. From experience you know where you cannot go because you will sink. It's obvious." Eric has walked on peat bogs many times before, and reliving an earlier experienced situation may have helped him make the correct decisions. He was not able to transfer his own knowledge to the students, partly because his skills were tacit, hidden from himself, and partly because they could not be expressed verbally. This is a general dilemma facing teachers and supervisors everywhere, to transfer their own skills and knowledge to the student or apprentice. Stolpe and Björklund (2012a) used a new psychological model to analyse and explain the behaviour of the teacher and were able to identify two different types of knowledge. There were implicit and explicit memories that explained the expert skills of the teacher, why the skills were tacit, and whether they could be transferred to the students. This chapter presents the model and discusses its usefulness for analysing not only the knowledge of experts, but also other phenomena in the field of transfer research.

The story of Eric was an example of unsuccessful transfer from an expert to his students, illustrating the dilemmas in teaching tacit knowledge or "knowing how." It articulates a difference of two different memory systems and two different kinds of learning. This first paragraph will describe the dual system model, the theories behind it, and some illustrative examples of how it could be used to analyse and understand transfer and its merits and drawbacks. It will be followed by an annotated bibliography of transfer research studies of relevance, using the dual system model as an analytical tool. Summing up, conclusions and implications for training and educational design are then provided.

THEORETICAL MODEL

A Dual Memory System Model

Dual processing is a psychological model implying that humans use two different cognitive systems for reasoning, judgement, and action. The concept of dual processing is more than 40 years old. The two systems have been referred to as system 1 and system 2 (Kahneman, 2003), and the reflexive and the reflective systems (Lieberman, Gaunt, Gilbert, & Trope, 2002) . Evans (2008) compared and linked different researchers' descriptions of these two systems in a comprehensive integrating review. Research in the fields of cognition and neurophysiology eventually confirmed that there really are two biologically distinct memory systems in the human brain, called the *declarative* and the *non-declarative* systems by Squire (2004). By integrating these results from research in psychology, neurophysiology, and pedagogy, Björklund (2007, 2008a) advanced the argument that the dual memory system model also was applicable for learning. He used the terms *implicit* memory system and *explicit* memory system as synonyms for the non-declarative and declarative systems, respectively.

The explicit memory system is characterised by dealing with what is traditionally referred to as facts, events, rules, and labels (Evans, 2008; Squire, 2004). This explicit knowledge can be verbalised and communicated. Associated with the explicit memory system is the working memory, which is our conscious system (Sweller, van Merrienboer, & Paas, 1998). However, the explicit memory system is constrained by the limited capacity of working memory (Lieberman et al., 2002; Marois & Ivanoff, 2005). Working memory may hold about four units at a time and the addition of any further units can lead to cognitive overload (Cowan, 2000; Ross, 1969; Sweller & Chandler, 1991). When used for identification of unknown objects, the explicit system utilises logical rules, searching for characteristics and typical components. Objects are identified through feature-by-feature matching in reference to a generic example (Norman, Young, & Brooks, 2007; Norman & Brooks, 1997). In this procedure, there are many components that need to be processed. Since the working memory is unable to handle many details at the same time (Lieberman et al., 2002) and to process them fast enough, the explicit system has a problem in handling fast real-time events. The retention in time of explicit memory knowledge is rather short: Names and scientific facts may be forgotten in just a couple of months (Bahrick, Bahrick, & Wittlinger, 1975; Squire, 1989; Stolpe & Björklund, 2012b) adding to the shortcomings of this system. One advantage of the explicit memory system is that knowledge processed in this system is possible for humans to verbalise and communicate. Therefore, it is possible to teach and to formulate explicit rules which are applicable for a novice (Dreyfus & Dreyfus, 1986). It can also be used to reflect on past experiences and to plan for the future.

The Implicit Memory System

In addition to the explicit memory system, humans also have a non-conscious and non-declarative system known as the implicit memory system (Berry & Dienes, 1993). The implicit memory system deals with non-conscious knowledge. Implicit memories are stored as multimodal sensory patterns of phenomena that we perceived, even non-consciously, in a specific situation – what we heard, felt, saw, and smelled. Logan (1988) suggested that:

> Subjects store and retrieve representations of each individual encounter with a stimulus. According to the instance theory, automatization reflects a shift from reliance on a general algorithm to reliance on memory for past solutions. Thus, automatization reflects the development of a domain-specific knowledge base. (p. 501)

It is therefore feasible to suggest that each representation of a situation is stored in the implicit memory system as a unique holistic pattern. The implicit memory system will constantly perform pattern-matching processes between stored patterns and observations of the surrounding world. When we re-experience a situation, the match will help us feel and act in the same way as we did the last time (Lieberman, 2000). Hence, we will experience a feeling of familiarity with the situation. Pattern matching is an automatic and rapid process which can impact behaviour directly without being constrained by the processing limitations of working memory. Since the use of implicit memories should be considered as knowledge that is "hidden" from the practitioner, it could be characterised as *tacit knowledge* (Björklund, 2008a; Polanyi, 1966). Even though the process of pattern matching is non-conscious, the implicit memory system may trigger a corresponding declarable label in the explicit memory system (Stolpe & Björklund, 2012a) and make us be aware and recognise an object (see Figure 2). Using holistic pattern recognition as a way to solve problems or identify phenomena has been described in other writings as non-analytic reasoning (Norman et al., 2007). It follows that automatic action initiated by pattern matching makes the implicit memory system rapid (Lieberman et al., 2002). Hence, it should be noted that pattern-matching functions do not employ working memory, which implies that the implicit memory system does not suffer from constraints such as cognitive overload. Björklund (2008a) made it probable to infer that expertise was possible in response to a large amount of implicit knowledge explaining several of the phenomena linked to experts. Among those qualities that characterise experts, several could be linked to a well-developed implicit memory system. An expert uses forward reasoning when solving problems in his or her area of expertise (Middleton, 2002; Newell & Simon, 1972). Following an extended phase of exploring the problem zone, the expert will recognise earlier implicit memories and generate solutions that very often will lead towards the goal zone. Since experiences of earlier encounters with a similar problem or situation are stored in implicit memory, a matching may occur, but only if the two instances share structural similarities. Stress and anxiety about possible failure will transfer cognitive control to the explicit system and hence stop the use of implicit memory in problem solving. Another typical trait of an expert is speed and automation. Tasks will be performed quickly and sometimes without later recollection. This makes it difficult to obtain information from experts about their use of knowledge, which is the "data acquisition problem." Using the "think aloud method" will often disturb the implicit processing.

Observational Skills Build on Implicit Memories

One of the most important skills of experts is their extraordinary ability to observe and discern. Humans' vision field is normally very narrow. We are able to focus on only a small area, just one detail at a time (Bullier, 2001; Milner & Goodale, 2008). To detect several objects in a large visual scene, we need to make a conscious effort to change our focus. However, it is not clear *how* humans locate and select which objects to attend to. By studying human behaviour, Milner and Goodale (2008) identified two anatomically separated vision systems. The first system is named "vision for perception" and is active when people consciously look at an object trying to identify it. However, when people act, for example, when they are moving their hand to manipulate an object, this system is *not* used to control the actions; rather, people use an anatomically separated cortical system that provides "vision for action." When vision for perception is used, it is possible to perceive only those details that are in focus. In vision for action, the periphery is relatively well represented, which gives an opportunity to detect objects in a large visual scene (Milner & Goodale, 2008). Furthermore, when a situation that has been encountered before and stored in the implicit memory system is re-lived, pattern-matching functions direct our conscious vision to details that are of importance in a specific situation (Chun & Jiang, 1999; Maljkovic & Nakayama, 2000). Stolpe and Björklund (2012a) proposed that these two systems are linked to the explicit and the implicit memory systems, respectively, and from empirical data documented how an expert teacher used his implicit pattern recognition system to detect and recognize birds and other natural objects. This phenomenon is known by ornithologists as using the "jizz" of the bird or identifying the bird on "habitus" (Ellis, 2011; Macdonald, 2002). This skill is present only in the specific area of expertise and is not a general quality of the experts' sensory organs. A chess master will recognize dangerous patterns on a chess board; a billiard player will remember balls on the billiard table if they belong to a set of balls in a realistic situation. Since it is implicit knowledge it will not transfer to new situations.

However, a biology teacher wants to teach their students how to identify different species and objects in the forest. His own skill is tacit and therefore he uses a more analytical procedure when he is teaching his students.

Operation of the Two Systems

The following two graphical examples of analysis show the interaction between the implicit and the explicit memory systems according to the model proposed by Stolpe and Björklund (2012a). Figure 1 is a model of automatic response. Eric's behaviour on the peat bog is an illustrative example. Since the implicit memories may have a somatic marker, the pattern matching may warn him of dangerous passages but otherwise just keep him walking along. The positive memories are linked to the basal ganglia, a control centre for all muscular activities and, hence, Eric does not have to make any conscious decisions; he just walks across the bog. Stolpe and Björklund claimed that when Eric walked on the peat bog knowing exactly where to put his feet without getting wet, he acted in accordance with previous "sinking" experiences that had been stored in his implicit memory system. On a non-conscious level, he recognised the dangerous as well as the safe paths and acted automatically (Figure 2). He recognised the specific situation and acted intuitively in accordance with the sensory experiences that included the wide-angle view of his implicit memory system. During the interview, it became clear that this was a skill that he could not explain nor describe; "it is trial and error." He knew that he used some knowledge of which he was not aware; in Polanyi's (1966) words: "You know more than you can tell" (p. 4). Such knowledge is tacit and stored in the implicit memory system.

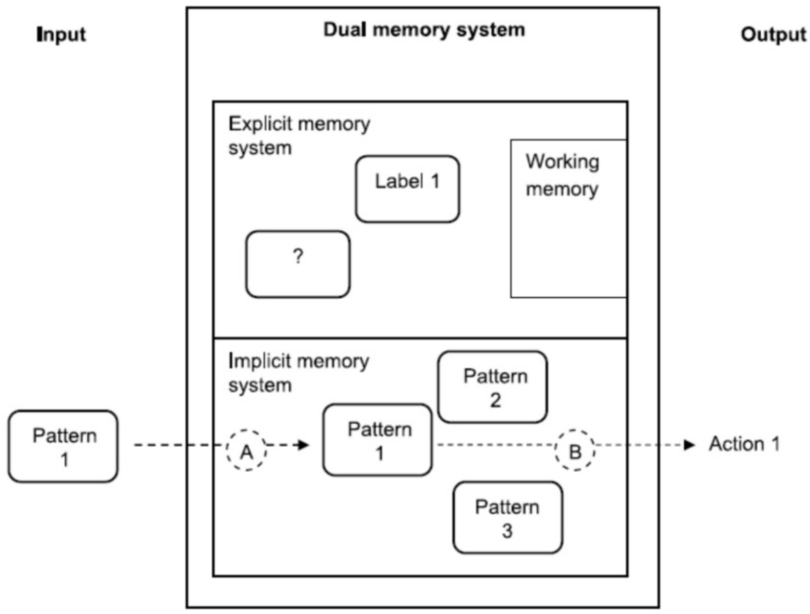

Figure 1. Behaviour as an automatic response

In the pattern-recognition process (A) shown in Figure 1 above, an external stimulus is matched against one of the patterns of earlier encountered situations stored in the implicit memory system. This process activates (B) a specific action that for the individual through experience has proven to be useful in the specific situation. Since the process never activates working memory, the action will remain non-conscious.

In another episode, Carl, the other teacher, talked to a small group of students about how to identify a grass species: "Look where the blade leaves the straw. There are tiny hair tufts. Do you see it? It is very easy to recognise. And then it's pretty large and has broad leaves. This is Calamagrostis arundinacea." Carl said that he himself did not use the hair tuft for identification. He merely identified the grass by familiarity, on which the environment also had a great impact. The plant and the name of the species just "pops up." He emphasised that it is hard to verbalise this knowledge and that it is based on experience. The authors' conclusion was that Carl employed non-analytic pattern recognition, which used implicit memories of encountered exemplars of this particular grass. Such a process is non-verbalisable and an example of tacit knowledge. However, when such pattern matching occurs, an explicit memory of the name and details of that species will be triggered – a declarative knowledge – which, in turn, is possible to verbalise. Since the explicit memory does not have the same retention as the implicit part we will sometimes just recognise something, but not be able to recall its name. This was documented in a follow-up study of a group of students attending this excursion. Six months later, declarative knowledge of names and episode were forgotten (Stolpe & Björklund, 2012b).

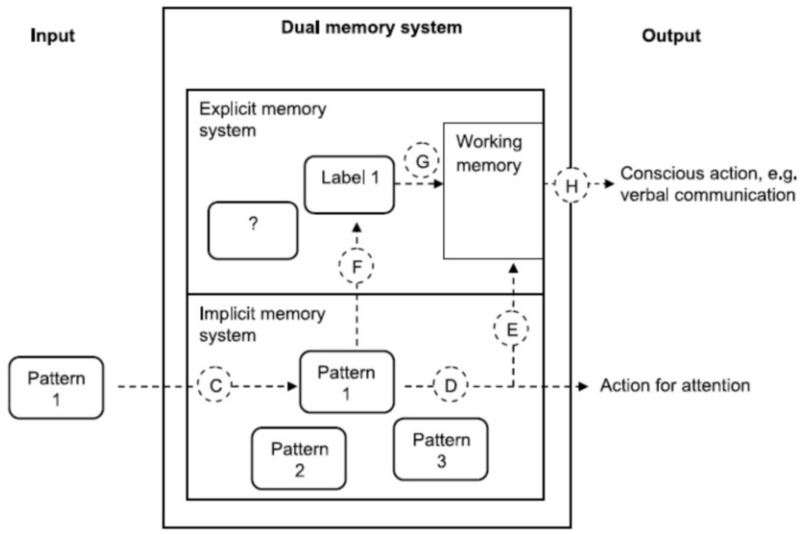

Figure 2. Non-analytic identification

In the pattern-recognition process (C) in Figure 2 above, an external stimulus is matched against one of the patterns of earlier encountered situations stored in the implicit memory system. This process may lead to an action that directs attention (D), such as turning the head and changing the visual focus. With attention, working memory becomes receptive (E) for labels. These labels are activated by the pattern-matching process (F). Both attention and the activation of the corresponding label are necessary for us to be conscious about what we attend to. When the label becomes available in working memory (G), it is available for verbal communication (H). However, there are situations when we have forgotten (or never had) the label. We will then be aware only of a feeling of familiarity

RESEARCH ON TRANSFER: A REVIEW

In all kinds of education, transfer is seen as important; teachers want their students to be able to use their learned knowledge. Hence educational researchers have been studying transfer of training and learning for more than a century, and the literature is ripe with empirical data, conclusions, and different theoretical models. Two major strands have developed, one built upon behaviourist theories, studying how similar two different stimuli must be to trigger the same response. The second parallel strand promotes more general skills and relies on cognitive theories.

Identical Elements in Transfer

In the beginning of the 20th century, several psychologists challenged the idea that there were such things as "general skills of learning and attention." Thorndike and Woodworth (1901) wrote:

> The mind is … a machine for making particular reactions to particular situations. It works in great detail, adapting itself to the special data of which it has had experience … Improvement in any single mental function rarely brings about equal improvement in any other function, no matter how similar, for the working of every mental function group is conditioned by the nature of the data of each particular case. (pp. 249-250)

In one of their experiments, students were trained to estimate the area of some rectangles, and later their skills of estimation were tested on rectangles with larger areas but also on triangles and objects with other shapes (Thorndike & Woodworth, 1901). Estimations of weight and length of different objects were also trained and tested in a similar way. If the property of the tested object was within the same interval as that of training, effects of learning could be found. When the shape of the object was different or the properties were outside the interval of training there was very little transfer. Thorndike hence proposed the theory of identical elements: "By identical elements are meant mental processes which have the same cell action in the brain as their physical correlate" (Thorndike, 1913, p. 359)

Training would transfer when previously learned elements appeared in later situations. This is the reflex arc or stimulus-response bond concept as in a typical behaviourist paradigm (Bayles, 1936). Today we recognise these results as a typical example of implicit memory system activity. Identical or very similar patterns in the stimuli will activate implicit memory patterns, leading to awareness, a feeling of familiarity, and automatic action. Eric's locomotion on the peat bog is a typical example. The students, lacking these implicit memory patterns, will have to resort to explicit, in this case, incomplete, and often useless knowledge.

A school subject that caught the attention of researchers in transfer was mathematics, a subject where teachers try to teach general problem-solving skills. Lehman (1933) designed a test of transfer in algebra, and showed that although students were proficient in the use of algebraic procedures and methods when the problems were similar in surface structure to the ones trained, almost no-one used the same procedures when the problems were presented in another structural form.

$$\frac{22x + 5x - 20x}{7x} = ?$$

Figure 3a.

$$\frac{22 \times 12 + 5 \times 12 - 20 \times 12}{7 \times 12} = ?$$

Figure 3b.

When given the problem in Figure 3a, all of the students used algebraic procedures to make the equation simpler, dividing with x to reduce the equation. In the problem in Figure 3b, only 6% of the students used this technique. Lehman concluded that almost no transfer of algebraic skill was to be found.

In the 1950s and 1960s several studies were conducted using Thorndike's (1913) paradigm. Industrial processes were developing at a fast pace and vocational training for transfer was considered necessary. Skills of different kinds were trained and tested using small differential changes in the stimulus of training versus testing. Speed, force feedback, display size, scaling, and many other parameters (Holland & Henson, 1956; Lincoln & Smith, 1951; Moss, 1964; Poulton, 1969; Ritchie & Michael, 1955) were changed and tested for transfer. Most of the results confirmed Thorndike's theory. To promote transfer, identical or almost identical stimuli were required. Some surprising results had been reported much earlier by Hulin and Katz (1934), who found transfer of Braille reading skills between the trained right index finger and the left non-trained index finger and, to a lesser extent, between visual and tactical training:

> There is a ready transfer from one hand to the other in tactually reading the Braille alphabet. The transfer of the tactual reading ability is greater from a tactual training than from a visual training, which indicates that the transfer is not carried wholly in terms of visual imagery. (p. 631)

This seems to contradict the identical element theory, but a possible explanation would be that the performers were allowed up to 30 seconds to identify a Braille letter. This indicates that training was not extensive enough to produce implicit memories (priming) but instead explicit memories were formed and were used to analyse and recall the letters. Comparable studies on people in crafts and other manual practice where fast automatic action had developed did not show this kind of transfer.

Orata (1928, in Cutujian, 1942) was one of the first authors to challenge Thorndike and the identical elements theory. He used gestalt psychology (Humphrey, 1924) to argue for two different aspects of similarity – the surface identity and the meaning:

> Of course it is possible for any two situations to arouse both a sense of identity and a sense of similarity. It is, however, the "sense of similarity" and not the "sense of identity" that is important in generalized transfer. (Cited by Cutujian, 1942, p. 31)

Cutuijan elaborated further on this difference and concluded that sense of identity is dependent upon identical elements in the stimulus field. Similarity of meaning may be said to be independent of identical stimulus elements in that they are not essential to judgements of similarity of meaning, since the empirical result in the study showed that the similarity of sensory stimuli takes over if present. Cutuijan proposed some implications for transfer:

> We have indicated that considerable and general transfer depends on a sense of similarity which in turn results from the process of generalization. It is important therefore to provide situations that will permit generalization and the resulting sense of similarity favorable to transfer. Our experiment has shown that the best situations for a sense of similarity are those in which there are very few or no identical elements. (Cutujian, 1942 p. 32)

The Cognitive Strand of Transfer Research

The idea that transfer is possible if the student comprehends the principle or the rule governing a phenomenon had been proposed much earlier by Judd (1908). Between 1908 and 1920 there was an intense debate between Thorndike and Judd as to whether transfer was to be obtained through the agency of identical elements or of generalisations. Judd's dart-throwing experiment (Judd, 1908), where children learned about refractive laws governing rays of light in water, making them more skilled when the depth of water changed, seemed to show that identical elements in the environment was not good enough. It appeared to show the advantages of a "generalised" training; that is, an individual must have been shown, during his training, that situations seem to work according to a discoverable "rule," and that one must become able to apply the rule (or generalisation) before one can take advantage of environmental recurrences and use one's training profitably.

Some results in this paradigm showed transfer and some authors started to criticise education that trained automatic responses. Research during the 1960s and 1970s showed that experts did not maintain their skills in a new different situation. Their knowledge was confined to what was trained and practiced. Hesketh (1997) and Reeves and Weisberg (1994) proposed training where automatic expertise should be avoided by always demanding rational and reflective arguments. If the student did not apprehend automatic recognition but could be trained to apply general rules and principles, then transfer would be possible. Today we would say that the idea to shut off implicit learning is not feasible. The dual system model was unknown at the time and the usual model of automation always started with a conscious controlled action that over time transformed into a fluent automatic action.

From the 1960s interest focused not only on the stimuli and the object itself but also on the context. Lave (1988) challenged the view that people typically learn to master decontextualised tasks and that what they learn is transferred to other decontextualised tasks. Lave's alternative to the culture of transfer experiments was to focus attention on questions about how people establish relations of similarity between the problems they encounter in different environments.

Engeström, Engestrom and Karkkainen (1995), wrote about another contextual influence on transfer, the community of practice.

With so many results showing little transfer in education, researchers started to try to find explanations and new designs that could change the outcome of training. Influences of motivation, self-efficacy, anxiety, and goal setting were investigated (Machin & Fogarty, 1997). Marton (2006) wrote a seminal article where he emphasised that not only was the similarity between stimuli at training and test important to attend to, but so too were the differences. He suggested that his variation theory would help to understand transfer, especially to train people in discerning the differences between instances. Marton's work is interesting because the use of a variety of examples to teach a principle or a concept comes very close to the dual system model and the building of a library of implicit memories of instances (Logan, 2002) that could be evoked in a specific situation. The idea of attention to differences cannot be incorporated in the model of implicit pattern-recognition mechanisms, but rather seems to rely on a conscious, deliberate, and explicit process. The proposed use of intentional thinking and the use of rules, processes, and general concepts has been a core concept of the cognitive strand of transfer research since Judd. As Day and Goldstone (2011) observed:

> There are many reasons to predict that transfer would strongly rely on participants' explicit, verbalizable knowledge of the structural commonalities between the tasks. For example, it has repeatedly been found that providing participants with an explicit hint to think about a relevant previous situation when approaching a new task can greatly increase transfer … More generally, many have argued that explicit declarative memory is a necessary requirement for any flexible application of knowledge. (p. 553)

Hesketh (1997) analysed three dilemmas in training for transfer and concluded:

> When learning a new skill, information processing is effortful and knowledge is in a rule-based or declarative form. With practice, proceduralisation or skill compilation occurs, until the skills have been automated. It is the well-automated skilled expertise, often grounded in context-specific examples that contributes to one of the dilemmas in training for transfer. (p. 320)

These and other results from the cognitive strand of transfer research infer that training in use of the explicit memory system will render knowledge that could be transferred to new situations and to a new context. The training of the implicit system, being responsible for the identical element phenomena, will not have such an effect. This was a conclusion also made by Lee and Vakoch (1996).

Knowing That or Knowing How

In many areas of vocational education there is a large gap in the teaching of theoretical and practical knowledge. The student will meet evidence-based knowledge promoted in university courses and endorsed by teachers living in an academic world built upon scientific theories, models, and laws. They will, as all novices do, learn rules, methods, and *knowing that* (Dreyfus & Dreyfus, 1986). Later on, in their practical courses situated at the clinic, the factory, or the classroom, they will meet mentors and supervisors with a long time of experience and *knowing how*. These teachers will often have a moderate or low theoretical knowledge background. Very often there will be a clash between these two cultures of knowledge.

The knowledge of the supervisor is a result of many years of practice, a knowledge generated by trial and error or in a master-based learning. The knowledge is very often tacit. *The supervisor knows more than they can tell*, and even if they know, they have a hard time verbalising their knowledge. All this makes the transfer to the student complicated. Most supervisors are experts and have special skills in observing, assessing, and acting – skills that they take for granted. They cannot understand why their students are so "blind" and helpless. There is also a problem in the communication between theory teachers and supervisors, where the latter often have a feeling of subordinance, thinking that their knowledge is inferior to the theoretical knowledge taught in the classroom by the theory teacher. Science teachers often believe that scientific theories always drive technological developments: Technology is applied science. If theory always precludes practice, how will then a theory come to mind? Ryle (1949) separated knowing that from knowing how, but did not have an answer but made the following observation:

> The crucial objection to the intellectualist legend is this. The consideration of propositions is itself an operation the execution of which can be more or less intelligent, less or more stupid. But if, for any operation to be intelligently executed, a prior theoretical operation had first to be performed and performed intelligently, it would be a logical impossibility for anyone ever to break into the circle. (p. 30)

Stolpe and Björklund (2012a) suggested that:

> There is a constant interplay between the explicit and implicit memory systems. The pattern matching in the implicit memory system will trigger the label of the object in the explicit memory system and thereby make the name of the object conscious and possible to verbalize. The interplay between the two systems could then be seen as a tentative answer to Ryle's question of what starts our thinking process. (p. 123)

If this is true, then training of the implicit system is mandatory to help the student recognise some element in the new situation that could evoke conscious explicit knowledge about rules and principles.

PROBLEMS AND DILEMMAS ACCORDING TO THE MODEL

Experts sometimes show low transfer, implying that not too much implicit knowledge should be trained. The identified problems with expertise in a field show that specific knowledge of instances will obstruct transfer (Day & Goldstone, 2012). General knowledge, rules, principles, and a reflective stance, that is, the use of the explicit memory system and working memory, should be promoted. What are the drawbacks of such a proposal?

Retention

Many studies (Fleischman, Wilson, Gabrieli, Bienias, & Bennett, 2004; Stolpe & Björklund, 2012b; Tunney, 2003) have shown that explicit memories fade away and are forgotten in relatively short time. This would mean that rules, theories, algorithms, and names, which are important for explicit problem solving, will not be there when needed.

Observational Skill and Attention

When someone consciously observes and tries to assess a complicated situation, they are using their explicit cognitive system and their working memory. Hence they will be prone to cognitive overload. Furthermore, it seems to be impossible to look for two or more categories at the same time when we search for an object. The narrow field of view utilised by the explicit system will make it hard to find relevant clues in a complex and noisy context.

Assessment

Deliberate evaluation of a situation using a logical, analytical method will be slow and restricted by the limitations of working memory.

Speed

In every situation where speed is important the explicit system will tend to be slow.

Problem Solving

Decision making and problem solving are constrained because of the earlier dilemmas, but also out of cognitive overload. Military trainers have abandoned the analytical type of decision-making training and are focusing on the implicit memory system training intuitive thinking: recognition-primed decision making (Klein, 2004; Thunholm, 2003).

Anxiety and Stress

Several studies have shown that explicit knowledge and skills are very sensitive to stress and the load of multiple tasks. Masters (1992) and other researchers have even shown that declarative and explicit knowledge could be disadvantageous to actions usually controlled by the implicit system. Verbal overshadowing may also disturb our perception and assessment skills (Fallshore & Schooler, 1995; Melcher & Schooler, 1996).

Drawbacks of the Implicit System

Automaticity, a well-trained reaction to a stimulus in the implicit system, is very fast and usually very effective. If the triggering pattern looks the same but the appropriate reaction should be another, this will lead to erroneous actions. The monitoring explicit system is very often too slow to interact. Furthermore, the expert, full of implicit, tacit knowledge, is unaware of her own skills – everything just seems obvious. She cannot understand why *the students cannot see what she sees*, and for a teacher or supervisor this is precarious as she will not understand that her student does not assess a situation in a similar way. Rigidness and prejudice are other things that come with implicit knowledge. An expert observes, assesses, and acts in one integrated action and will hence have great difficulty in learning new tools and new way to handle old problems. Experts do not see problems; they recognise solutions!

A combination of implicit and explicit knowledge training seems to be a good way to design education for transfer, but there is a catch. Masters (1992) and many others showed that we are susceptible to stress if we have too much explicit knowledge on a task where implicit knowledge is needed. Masters trained golf players with and without verbal instructions and later, during the test, made them feel stressed. He claimed that those who did not have any declarative, explicit knowledge performed better under stress. Several studies were conducted to refute his results but all seem to come to the same conclusion: Verbal knowledge may be detrimental to performance. The reason is not fully understood, but Masters's original idea, that stress evoked conscious explicit control of a situation where implicit knowledge should have be used, seems plausible.

The research on transfer is in many ways parallel to studies on creativity and problem solving, and this chapter will end with a discussion on this topic, with some implication for education.

Implications for Creative Work and Problem Solving

Wallas (1949) identified four phases in the creative solving of a problem and proposed that, during these four stages, the thought process would move from conscious thought patterns to unconscious patterns, and then back again to conscious patterns. Low (2006) elaborated on these stages in his thesis:

> Preparation – This stage involves an intense effort to solve the problem: the gathering of all data possible, problem identification and problem definition, and if a solution is not found the problem is abandoned.
>
> Incubation – During this stage the problem solver's conscious thought processes are turned to matters other than the problem, while subconscious

thought processes work on the solving of the problem. When a solution is arrived at the mind delivers the proposed solution from the subconscious to the conscious.

Illumination – This is the “aha” or sudden insight into the possible cause of or solution to a problem on which the researcher may have been working. In this model the subconscious mind “delivers” the solution or idea to the conscious mind.

Verification – During this stage, the details of the solution found are checked against the reality and found to be either a valid solution to the problem or another way of not solving the task at hand.

Björklund (2009) proposed that in this four-stage model of creative thought, the stage of preparation activates patterns stored in implicit memories. Since these are memories of specific instances (Nosofsky & Zaki, 2002), a very close likeness must be at hand for recognition to happen. A huge library of experience patterns and elaborate exploration will facilitate the match (Reber, Ruch-Monachon, & Perrig, 2007). In the case of an impasse, this unconscious pattern-matching process may continue during the incubation stage, which has been demonstrated recently giving birth to “a theory of unconscious thought” (Cronin, 2004; Dijksterhuis, 2006). Since implicit memories may be shut down by the explicit system, it is import that the environment is friendly so that the individual does not feel anxious. He or she must be allowed to make mistakes and to take a risk when generating hypotheses or ideas for a solution. Otherwise, the explicit system takes charge (Markman, Maddox, & Worthy, 2006).

Lindström (2006) found four process criteria significant for the development of creativity, and, according to Björklund, Lindström’s model is supported by the dual system model in the following ways:

– Ability to use models: The student is building a library, partly explicit, partly implicit of solutions to specific problems, a base of patterns that later can be used in a pattern recognition process.
– Investigative work: This is the exploratory phase when the student is trying to find a perspective, a viewpoint from which implicit patterns may match the problem.
– Inventiveness: The importance of a friendly context has been noted already, making access to implicit memories feasible.
– Capacity for self-assessment, knowing one’s strengths/weaknesses: A process where patterns are assessed and given a somatic marker and stored in implicit memories. Every task that doesn’t give immediate feedback needs this step to be stored with a somatic marker. (Björklund, 2009, p. 71)

Since these “habits of mind” will develop and foster an implicit memory system regardless of the object of design, Lindström’s process criteria are not confined to the creative work of art but can be used to analyse and foster creativity and problem solving in other activities.

IMPLICATIONS AND CONCLUSIONS

If training has a goal of making the learner proficient in a real-world workplace, he or she must be able to cope with a complicated and noisy environment and to act quickly and with precision. Furthermore, if we want learners to be able to cope with stress, build a good sense of self-efficacy, and be intrinsically motivated, we do not have any alternative but to train them into expertise in the specific tasks and situations. In accordance with Marton's (2006) variation theory, we can make them recognise many different instances in various problem situations. This will give them a large library of implicit patterns and an ability to react in different situations. Björklund (2009) proposed that this is a key to the ill-understood concept of creativity. If the individual learner is going to be a supervisor or teacher, he or she has to be given complementary explicit knowledge and, most important of all, a metacognitive knowledge of his or her own tacit skills. Methods like the repertory grid technique could be used to elicit the tacit expert knowledge (Björklund, 2008b). Training of implicit knowledge is done in deliberate practice characterised by well-defined tasks, informative feedback, repetition, self-reflection, motivation, and endurance (Moulaert, Verwijnen, Rikers, & Scherpbier, 2004). Implicit memories consist of multimodal sensory experiences, hence training should be full of practical work and the learner should be exposed to many sensory-based stimuli, preferably in a realistic workplace setting.

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