

# Designing Education for Professional Expertise Development

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## Designing Education for Professional Expertise Development

Quincy Elvira<sup>a</sup>, Jeroen Imants<sup>a</sup>, Ben Dankbaar<sup>b</sup> and Mien Segers<sup>c</sup>

<sup>a</sup>Radboud Graduate School of Education, Radboud University, Nijmegen, The Netherlands; <sup>b</sup>Institute for Management Research, Radboud University, Nijmegen, The Netherlands; <sup>c</sup>Educational Research and Development, School of Business and Economics, Maastricht University, Maastricht, The Netherlands

### ABSTRACT

How to facilitate learning by novices (students) on their road to expertise has attracted the attention of a vast number of researchers in cognitive and educational psychology as well in the field of learning and instruction. Although many studies have investigated the phenomenon of expertise development, the implications of the findings for instruction are scattered throughout the literature. This article reports the results of a systematic literature review of 37 studies on expertise development. Using Tynjälä's Integrative Pedagogy Model as an organising framework, the implications for educational practice described in these studies are presented as 10 instructional principles. This study takes a step towards translating expertise development research into guidelines for instruction. Implications for future research are discussed.

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Experts have an important role in society as they are called in for advice on their respective subject. Experts' extensive knowledge base is widely recognised as a reliable source for problem solving, judging, or deciding rightly, justly, or wisely in a particular domain (e.g., Arts, Boshuizen, & Gijsselaers, 2006; Cannon-Bowers & Bell, 1997). However, an expert is not born overnight. The development towards expertise is a long and gradual process. Largely speaking, the road towards expertise distinguishes three levels: novice, competent, and expert (Alexander, 2003; Dreyfus & Dreyfus, 1986). Each of these levels is characterised by qualitative differences in knowledge, skills, attitudes, and performance.

As a critical purpose of formal education is to prepare students for their future professional lives (Kinchin, Cabot, & Hay, 2008), it plays a crucial role in the expertise development process. If formal education aims to educate professionals, "it makes sense to start with an understanding of the nature of professional expertise" (Fenton-O'Creevy & Hutchinson, 2010, p. 70). That does not mean that formal education produces experts. The goal of formal education is to help students develop the types of knowledge representations, ways of thinking, and social practices that define successful learning in specific domains (Goldman & Petrosino, 1999; Hatano & Oura, 2003) and thus lay the foundations for the development of expertise. Or, as Tynjälä, Nuutinen, Eteläpelt, Kirjonen, and Remes (1997) argue, "Education as an institution and educational practices have an important role in creating (or inhibiting) the preconditions for expertise" (p. 479). Indeed, former research (e.g., Gijsselaers, Arts, Boshuizen, & Segers, 2006) shows that graduates can reach the level of competence. Becoming an expert, reflected in a qualitative surplus of knowledge, skills, and attitudes and

**CONTACT** Quincy Elvira  [q.elvira@docentenacademie.ru.nl](mailto:q.elvira@docentenacademie.ru.nl)

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outstanding performance relative to the other levels, additionally requires extensive experience and continuous guided learning at the workplace.

Recognising the importance of education in the development of expertise (e.g., Alexander, 2005; Boshuizen, Bromme, & Gruber, 2004; Goldman & Petrosino, 1999), Tynjälä (2008) developed a pedagogical model of expertise development. This “Integrative Pedagogy Model” specifies an ideal learning environment in which all the elements needed to develop expertise—theoretical knowledge, practical skills, and self-regulation (reflective and metacognitive skills)—are present and integrated. Tynjälä gives a clear account of the knowledge components and learning processes that together constitute a suitable learning environment for the development of expertise, but little is said about the instructional principles that would enable researchers and educators to design and implement learning environments from this pedagogical perspective.

In defining these instructional principles, the vast number of studies that investigate the features of professional expertise development in a variety of professions (e.g., accounting, medicine, and biology) are informative. More concretely, the educational and/or instructional implications formulated on the basis of their results offer valuable insights for the development of valid instructional principles. However, to date, no comprehensive overview of instructional principles to support expertise development is available. In 2005, Alexander elaborated instructional principles for teaching towards expertise. With this paper, we aim to go one step further by synthesising the fragmented educational implications formulated in expertise development research studies into 10 instructional principles for education. By adopting a systematic approach, and using Tynjälä’s model as an organising framework, this set of instructional principles offers teachers and instructional designers a comprehensive perspective for the design of learning environments aiming at creating the preconditions for expertise. In addition, it guides researchers in the domain of Learning and Instruction, addressing the contribution of learning environment characteristics for students’ development towards expertise.

## Expertise Development Research

While top performance in any field, ranging from chess to composing, represented the main interest in expertise research during the 1970s and 1980s, *expertise in professions* has emerged as one of the most important areas of the 1990s (Tynjälä, Nuutinen, Eteläpelto, Kirjonen, & Pirkko, 1997). Most studies focused on the development of professional expertise in terms of knowledge structures and the cognitive strategies used in domain-specific problem solving.

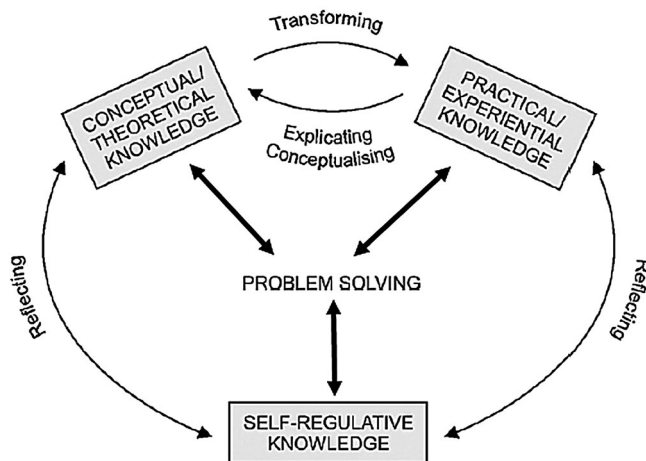
Development of professional expertise is described as a long and ongoing process, beginning with formal education and continuing throughout professional life, during which the different elements of knowledge, skills, and attitudes are continually transformed qualitatively and quantitatively (Boshuizen et al., 2004) to support better domain-specific problem solving. In this respect, expertise development research approaches expertise from a relative perspective, indicating that people have less or more expertise, instead of focusing on top performance (Chi, 2006). The literature on expertise development (e.g., Alexander, 2003; Boshuizen, Schmidt, Custers, & van de Wiel, 1995; Dreyfus & Dreyfus, 1986) provides us with different models that describe the path from novice to expert and identify characteristics and development activities at each stage (Grenier & Kehrhahn, 2008). For example, the model of Boshuizen et al. (1995) has shown that in the course of the development of expertise, the detailed theoretical concepts acquired by students will be replaced by concepts of a more general type that more or less summarise the detailed ones. This process of knowledge encapsulation is a result of repeated knowledge application in the context of practical experience (Tynjälä, 1999). Dreyfus and Dreyfus (1986) implied that by passing through stages of qualitatively different perceptions of a task or problem, points of development towards expertise are achieved.

Various authors (Chi, Glaser, & Farr, 1988; Feltovich, Prietula, & Ericsson, 2006; Tynjälä et al., 1997) have outlined the following important characteristics of expertise: experts perceive large,

meaningful patterns in their own domain; experts focus on relevant cues of the task; experts represent problems on a deeper level than novices; experts have better self-monitoring skills than novices; experts' knowledge structures are hierarchically organised and have more depth in their conceptual levels than those of novices; experts categorise problems in their domain according to abstract, high-level principles; and experts' knowledge structures are more coherent than those of novices. While the findings of expertise development research have been contributing to our insights in the gradual change in characteristics when a person passes through various stages towards expertise, little is known about the learning processes that lead to this change (Grenier & Kehrhahn, 2008). Identifying these learning processes is necessary "to understand how experts became that way so that others can learn to become more skilled and knowledgeable" (Chi, 2006, p. 23).

In recent decades, a large variety of instructional principles have been developed, implemented, and evaluated. These principles are partly derived from learning theories. An example of such is cooperative learning based on social-constructivist learning theories (Loyens & Rikers, 2011). Instructional methods have also been developed in support of particular skills or competencies, such as project-based learning, case-based learning, and enquiry-based learning, in support of the development of problem-solving skills (Loyens & Rikers, 2011; Pedaste et al., 2015). Problem-based learning is an example of an instructional approach informed by expertise and expertise development research (Boshuizen, 2009; Norman & Schmidt, 1992). However, Boshuizen (2009) and Norman and Schmidt (1992) have not explicitly drawn the connection between expertise and expertise development research and the Learning and Instruction domain.

Tynjälä (2008), on the other hand, makes explicit use of the insights offered by expertise development research, bridging expertise development research with the field of Learning and Instruction. From the viewpoint of pedagogy, Tynjälä developed a model that incorporates three core learning processes to promote desired learning in terms of developing expertise. Problem solving plays a central role in Tynjälä's "Integrative Pedagogy Model" of expertise development. The author does not distinguish specific stages, but argues that the various elements of expert knowledge and the learning processes underlying expertise development develop and unfold around problem solving (see Figure 1). Various other authors (e.g., Arts et al., 2006; Bereiter & Scardamalia, 1993) have also claimed that the key to expertise lies in an individual's capability to solve problems. Expert professionals are constantly solving problems and the ability to solve problems manifests the degree of expertise. The domain specificity of expertise is reflected in the type of problems being solved, such as diagnosing X-rays in radiology (Gunderman, Williamson, Fraley, & Steele, 2001), analysing



**Figure 1.** Integrative pedagogy model (adapted from Tynjälä, 2008).

legal cases (Nivelstein, van Gog, Boshuizen, & Prins, 2010), and approving financial statements (Bouwman, 1984).

Expert knowledge is another key feature of professional expertise. Expert knowledge consists of three kinds of knowledge that are closely related to each other (Tynjälä, 2008). *Conceptual/theoretical knowledge* is universal, formal, and explicit in nature and depends on conscious, conceptual thought processes supported by texts, figures, discussions, or lectures (Heikkinen, Jokinen, & Tynjälä, 2012). *Practical knowledge* (often referred to as procedural knowledge) is manifested as skills or “knowing how”; this type of unarticulated knowledge is seldom taught in educational settings, but is usually gained through practical experience (Heiberg Engel, 2008). Knowledge based on practical experience is personal and often tacit, which makes it difficult to express explicitly (Tynjälä, 1999). This is not to say that people cannot acquire procedural knowledge in textual mode through handbooks or manuals or instructions for use. *Self-regulative knowledge*, including metacognitive and reflective skills, is knowledge about learning strategies, and how to plan, monitor, and evaluate one’s own learning and work.

The Integrative Pedagogy Model offers an account of how these three knowledge components are both products of expertise and contributors to its development. Tynjälä (2008) argued that integration of the three types of knowledge occurs during problem solving by means of three learning processes: *transforming* conceptual/theoretical knowledge into practical/experiential knowledge; *explicating* practical knowledge; and *reflecting* on both practical and conceptual knowledge by applying and developing self-regulative knowledge (see Figure 1).

Transforming theoretical knowledge into practical knowledge requires that theories are considered in the light of practical experience, that is, theoretical knowledge is applied in a practical context. Explicating practical knowledge into conceptual knowledge is the process of making practical knowledge accessible and explicit (in the form of texts, figures, discussions, or lectures). The third learning process entails reflecting on conceptual and practical/experiential knowledge using self-regulative knowledge; self-regulative knowledge is developed further in the process. The latter process is a means for increasing awareness of effective learning strategies and developing an understanding of how these strategies may be used in other learning situations (Ertmer & Newby, 1996).

The model’s premise is that “the processes that lead to expertise are intriguingly domain general in their view of developmental origins” (Wellman, 2003, p. 247). However, expertise is definitely not domain general in terms of developmental outcomes and problem solving. Tynjälä’s (2008) Integrative Pedagogy Model reflects the essential role that integration of the three elements of expert knowledge plays in the development of expertise. The arrows in the model shown in Figure 1 represent the continuous, holistic character of expertise development.

Although Tynjälä outlined the learning processes that should be fostered in a learning environment, there has been little work from an integrative pedagogical perspective on instructional principles for such a learning environment. Employing Tynjälä’s framework as an organising device, we have reviewed the literature to identify instructional principles to facilitate and support the learning processes underlying professional expertise development. Following McKenney, Nieveen, and van den Akker (2006), we define instructional principles as theoretically and empirically grounded constructs (substantive knowledge) linking strategy components (prescribing what to do, when, and how) with intended pedagogic effects.

## Review Methods

This method builds on the updated integrative review method described by Whittemore and Knafl (2005). This revised method is a rigorous and widely used approach for summarising and analysing literature from diverse methodologies, thus providing a more comprehensive understanding of a phenomenon. This method incorporates the following five phases: the formulation of inclusion and exclusion criteria (Slavin, 1986); problem identification; literature search; data evaluation; and data analysis and presentation of the instructional principles (Fink, 2010). In this Methods section,

the focus will be on the formulation of inclusion and exclusion criteria, the literature search, data evaluation, and data analysis. The problem of identification is described in this paper's introduction. The instructional principles will be presented in the Results section.

### ***Formulation of Criteria for Inclusion and Exclusion***

Three inclusion criteria were formulated. Firstly, the reported studies explicitly took a relative perspective on expertise development. Secondly, the reported studies explicitly describe one or more characteristics of the learning environment and link these with students' learning towards expertise. Thirdly, specific studies carried out from a formal learning situation perspective pertained to this review, since this educational context was the focus of the study. Publications were removed from the selection that did not focus on developing expertise from a relative perspective. The reason is that the focus of this paper is on student acquisition of relative expertise in solving problems. Additionally, publications were excluded that solely addressed the description of one or more teaching strategies without examining the effect or influence on learning in terms of developing expertise.

### ***Literature Search Strategy and Data Evaluation***

An electronic database search was conducted using Educational Resources Information Centre (ERIC), PsychINFO and MEDLINE. The following terms were used in multiple combinations: "expertise," "expertise development," "instructional implications," "educational implications," "instructional principles," "formal education," "implications and education," "implications and instruction." Following Whittemore and Knafl (2005), relevant empirical as well as theoretical papers are included in the review.

The search resulted in a kick-off database of 1,435 references (663, ERIC; 506, PsychINFO; 266, MEDLINE). These references were loaded in EndNoteX4; 1,061 unique sources remained. The abstracts of these articles were reviewed for relevance and on the basis of the inclusion and exclusion criteria. After screening the abstracts, and where necessary screening the full text of the articles, this method resulted in a sample of 37 articles.

### ***Data Analysis***

The Appendix displays the references' publication type, methodological data, and country of study. Of the 37 selected publications, 19 reported empirical studies, while 18 articles were conceptual contributions. The articles were published in: multidisciplinary domains (8), the domains of Medicine (7), Physics (2), Law (2), Geography (2), Radiology (2), Nursing (2), Geography (2), and Therapy (2). Other domains (e.g., Biology, Counselling, Statistics Mathematics, Business, Special Education, Computer-Aided Design) were mentioned once. Seven of the reviewed publications were experimental or quasi-experimental studies, whereas six publications adopted a case study design, two publications a cross-sectional and a mixed method design, and one publication a correlational and ethnographical design. The majority of the empirical studies (10) used quantitative methods to analyse the effects of one or more characteristics of the learning environment on students' performance in terms of expertise development. Seven publications used qualitative analyses and two publications combined a qualitative and quantitative method. With regard to the country of study, the majority of the studies was conducted in the USA (21) and Canada (4). The European countries of study include: the Netherlands (4), the UK (3), Spain (1), and Sweden (1). Three publications were selected from Australia (2) and New Zealand (1).

The meaningful units of analysis are statements with regard to instructional strategies and their impact on student learning in terms of acquiring greater relative expertise. During the first step in the analysis, two researchers independently identified and collected meaningful units of analysis from three articles. These meaningful units of analysis were assigned to the relevant learning process of



Tynjälä's model. Where there were disagreements between the first and second author, they were resolved by reviewing the meaningful units of analysis and discussing these.

In the second stage, the first author classified each meaningful unit of analysis to the relevant learning process of Tynjälä's model for the remaining 34 publications. The Appendix displays the total number of meaningful units of analysis per article assigned to the relevant learning process. A total of 153 statements, divided into 79 related to learning and 74 to teaching, were assigned to the learning process transforming conceptual/theoretical knowledge into practical/experiential knowledge; 34 statements, divided into 16 related to learning and 18 to teaching, were assigned to the learning process explicating practical knowledge into conceptual knowledge; and, finally, 100 statements, divided into 51 related to teaching and 49 related to learning, were assigned to the learning process reflecting on both practical and conceptual knowledge by applying and developing self-regulative knowledge.

In the third stage, these statements were synthesised into an elementary form of an instructional principle, following the ideas of McKenney et al. (2006): *If you want to design intervention X (for the purpose/function Y in context Z), then you are best advised to give that intervention the characteristics A, B, and C (substantive emphasis), and to do that via procedures K, L, and M (procedural emphasis), because of (theoretical/empirical) arguments P, Q, and R.* For example: If you want to design intervention X (for the purpose of developing students towards a starting level of professional expertise), then help students in their epistemological understanding (substantive emphasis) by confronting students with the uncertainty and complexity of knowledge (procedural emphasis), as a consequence of which students do not think of the academic content in simple black or white, right or wrong terms (arguments).

The preliminary set of instructional principles was discussed by the first and second author. Following Van Ginkel, Gulikers, Biemans, and Mulder (2015), these discussions focused on the following aspects for each principle of the set: (1) the extent to which the underlying theoretical and empirical argumentations were convincing; (2) the extent to which the principle was distinctive; (3) the extent to which a principle could be applied in practice in higher education; and (4) the extent to which a principle met the qualification of readability. The principles on which no consensus was reached were presented to the fourth author. By use of these moderating meetings we arrived at a consensus. Following the agreement of all members of the research team, the last stage was launched. This final phase focused on the classification of the principles based on the learning processes of Tynjälä's model. This resulted in the final set of instructional principles for fostering expertise development in higher education.

## Results: 10 Instructional Principles

Our analysis of the literature uncovered 10 instructional principles. We have organised these 10 principles and accompanying procedures (*in italics*) according to the three learning processes presented in Figure 1.

### **Learning Process: Transforming Theoretical/Conceptual Knowledge into Experiential/Practical Knowledge**

#### **Principle 1: Support students in their epistemological understanding.**

Hallam (2010) argues that *concepts should be introduced early* in formal education so that naïve conceptions and oversimplifications have little opportunity to develop and, with that, misunderstandings are prevented. Furthermore, educators should *help students see the uncertainty and complexity of knowledge*. As a consequence, students will not think of the academic content in simple black or white, right or wrong terms, but probe the depths of ideas to reveal the "greys" of concepts (Alexander, 2005). Moreover, teachers should *forcefully pursue students' understanding and uncertainties* by questioning their ideas and practices in the classroom rather than forcing them to simply



memorise facts and procedures (Alexander, 2005; Botti & Reeve, 2003). Aforementioned activities and strategies should lead to students perceiving knowledge as complex and uncertain, as a result of which they are likely to process information on a deeper level (Schraw, 2006), reason more effectively (Hallam, 2010), and develop better problem solving and critical thinking (Alexander, 2005).

### ***Principle 2: Provide students with opportunities to differentiate between and among concepts.***

Nievelstein et al. (2010) find that novices may learn very little from solving cases with the aid of external sources, in this case a civil code; their performance does not seem to improve as a result of being allowed to use the civil code compared to not having an information source available at all. A reason why students may have problems is that the meaning of legal concepts varies according to the context (Nievelstein et al., 2010), which makes it difficult to build a well-organised conceptual knowledge structure. Students' lack of conceptual knowledge influences not only their interpretation of the case, but also their ability to use the civil code effectively. This is not only the case for law. For example, Postigo and Pozo (2004) find that novices have serious difficulties in processing information represented implicitly by means of the rules and codes characterising geographical maps as cultural systems of representation. Moreover, novices find it difficult to extract the conceptual knowledge that can be derived from the map as a geographical representation. Consequently, various authors (e.g., Anderson & Leinhardt, 2002; Brookes, Ross, & Mestre, 2011) suggest *providing repeated encounters with the concept/principle in several different contexts*, and, as Nievelstein et al. (2010) add, *annotating concept definitions in different cases and requiring students to make comparisons between the meaning of the concepts in cases* (see also Alacaci, 2004). These strategies should help students to see contrasts in the application of concepts in different contexts.

Successful enculturation into the community of a domain/profession leads participants to relinquish everyday versions of speech activities that have to do with external sources (e.g., law books, geographical maps, or profit and loss accounts) and to replace them with discipline-embedded special versions of the same activities (Lebeau, 1998). Therefore, Anderson and Leinhardt (2002) and Lebeau (1998) similarly argue that situations need to be created for students to *expose the knowledge and reasoning embodied in the tools of their profession (e.g. civil code, maps and profit and loss accounts)* as students engage in, or reflect upon, the tools. These experiences should expose the tools' implicit and explicit (Anderson & Leinhardt, 2002; Lebeau, 1998), and conceptual meanings (Postigo & Pozo, 2004), helping students unpack the language common to the tools and making it more likely that they will be able to successfully engage in problem solving.

### ***Principle 3: Practice with a variety of problems to enable students to experience complexity and ambiguity.***

When students are confronted with a broad, appropriate set of problems and challenged as to how these problems might be differentiated, it is likely that schemata will be formed (e.g., Coderre, Mandin, Harasym, & Fick, 2003; Gobet, 2005; Schmidt, Norman, & Boshuizen, 1990; Taylor, 2007). Schemata (experience-based knowledge structures) explain how humans understand real-world events and why this understanding in most cases occurs almost effortlessly (Schraw, 2006). As schemata arise from repeated experiences, it is not surprising that novices do not have rich schemata. This difference is potentially important for improving instruction. Working with a variety of problems will help students to recognise new problems as similar or identical to old ones already solved. This so-called pattern recognition enables individuals to perform tasks efficiently.

Others scholars focus more on the problem characteristics, resulting in *providing students with both typical and atypical problems* (e.g., Cannon-Bowers & Bell, 1997; Kulatunga-Moruzi, Brooks, & Norman, 2011). Arts et al. (2006) add that the accuracy of problem diagnoses and problem solutions (quality in expertise development) accelerates as a result of solving atypical, non-routine problems in different contexts.

Blasi (1995) and Cannon-Bowers and Bell (1997) argue that the *problems should resemble as closely as possible the complexities, nuances, and ambiguities* of situations that arise in practice, including the ever-present background noise of only potentially relevant detail. This strategy has been proven to produce successful outcomes of enhanced decision making among students (Patel, Gutnik, Karlin, & Pusc, 2008).

Yet, caution is of the essence when confronting students with complexity, which is precisely why several authors (e.g., Alacaci, 2004; Alexander & Jetton, 2000; Botti & Reeve, 2003; Brookes et al., 2011; Gick, 1986) propose to gradually increase the complexity when using problems/cases/representations. Starting any sequence of problems, cases, or representations with the most regular, simple forms available and minimising contextual features that could potentially confuse or distract the students, will enable students to “get their eye in” (Gilbert, as cited by Halverson, Pires, & Abell, 2011, p. 816).

**Principle 4: Enable students to understand how particular concepts are connected.**

Expert knowledge is not an accumulation of basic facts, it is organised around “big ideas” (e.g., principles and laws). Building a coherent knowledge structure takes time and during the early phases of professional expertise development, the instructor’s role should not be underestimated. Both Alexander and Jetton (2000) and Smith (2008) stress that guidance (e.g., guided reading; scaffolding) is important and that educators should make sure that the problem of limited knowledge is due to inaccessible knowledge or absence of knowledge and not an issue of preconceptions and prejudice.

To develop coherent and principled knowledge, Alacaci (2004), Alexander (2005), Gunderman et al. (2001), and Smith (2008) suggest *making the connections explicit between concepts* and providing a framework for novices *by focusing on higher-order concepts/big ideas*, so that it facilitates retention and retrieval of learned content (Alexander & Jetton, 2000; Heller, Reif, & Hungate, 1983). Additionally, Wilkerson-Jerde and Wilensky (2011) propose to *provide students with experiences and opportunities to identify or isolate specific subcomponents of a concept* (deconstruction). Those deconstructions, along with examples and definitions and even everyday understandings, can be brought together to not only underpin, but serve a generative role in, the testing and generalisation of conceptual relationships (coordination). Such procedures might lead novices to organise information into meaningful patterns, which tend to highlight features and suggest diagnoses that they normally fail to perceive (Gunderman et al., 2001; Heller et al., 1983).

**Principle 5: Target for relevance.**

Alexander (2005) argues that for newcomers in a domain, the academic content may have no link to their background knowledge, goals, or interests. This may lead to knowledge that has been memorised, but that cannot be used constructively when it comes to solving problems (Gunderman et al., 2001). Various authors, each in their own specific way, suggest linking learner and domain through curricular experience in order to foster a sense of relevance or applicability (e.g., Alexander, 2003; Arts et al., 2006; Gunderman et al., 2001). Additionally, this rooted relevance, in which learner and domain are linked through curricular experiences, captures and maintains students’ interest without distorting or trivialising the domain (Alexander, Sperl, Buehl, Fives, & Chiu, 2004). Motivational factors such as interest are crucially important in the development of expertise because of the considerable investment of time and effort that is required (Hallam, 2010).

Schmidt and Boshuizen (1993) argue that *repeatedly applying knowledge to real cases* is a necessary condition for organising concepts and their interrelations in the structure of higher order concepts resembling an expert-like knowledge structure. Scholars stress the importance of authenticity in this respect. Various authors (Alexander et al., 2004; Schmidt & Boshuizen, 1993) suggest *providing learners with opportunities for explicit exploration and participation in more professional activities*, as it may help to direct and influence their professional interest in the field. In a similar vein, Arts et al. (2006) and O’Byrne, Clark, and Malakuti (1997) suggest *focusing on enhancing the quality of experience* by sending more students to practise in a professional environment, or by bringing more

“practice” into education by enhancing the authenticity of assignments and the learning environment. Furthermore, they claim that education needs to implement strategies by which students *engage in similar cognitive activities* (e.g., selection of relevant cues and evaluation of contextual information) *as required in the workplace*. These latter two strategies will foster the development of what they call “dynamical” knowledge (applicability of theoretical knowledge into the professional context), which is crucial for accurate problem solving.

According to this principle, therefore, education needs to be rooted in practice in such a way that students are *challenged to embed new knowledge in everyday practice*, supported by people who understand the domain, the relevance of scientific knowledge for the domain, and who value the importance of learning as a continual process (Alexander, 2005; Jensen, Gwyer, Shepard, & Hack, 2000).

### **Learning Process: Explicating Procedural/Experiential Knowledge into Conceptual/Theoretical Knowledge**

#### **Principle 6: Share inexpressible knowledge.**

Converting procedural knowledge into conceptual knowledge means finding a way to express the inexpressible. Opportunities to ensure dialogue with peers about practice (King, 2009), modeling, and coaching (Cannon-Bowers & Bell, 1997; Heller et al., 1983) are likely to be straightforward strategies to share and express this inexpressible knowledge. Various authors (Alexander, 2005; Ertmer & Stepich, 1999; King, 2009; Lebeau, 1998) propose to *initiate small group discussions*, which help widen students’ perspectives on cases/problems and facilitate a higher level of performance than one might accomplish alone. Alacaci (2004) suggests that instructors “*think aloud*” to make the decision-making process of instructors visible (and audible). Moreover, it helps students to see that coming up with a solution is not magic, but builds on an existing knowledge grid that they can learn to mimic as they make their own decisions in similar situations.

Nilsson and Pilhammar (2009) stress the importance of the voices of both expert and novice. They encouraged the persons they interviewed (experts and novices) to use their own words and concepts when describing self-chosen incidents. This way of “thinking aloud” creates an understanding of how seniors and juniors differ in their use of knowledge in professional situations. This is crucial to understanding how professional experience is constituted and gives the senior insights into the struggles of early learners. Additionally, elucidating the knowledge used in professional situations by both juniors and seniors could be helpful in ensuring that the knowledge conveyed in theoretical classes corresponds to the knowledge required in professional situations.

#### **Principle 7: Pay explicit attention to prior knowledge.**

If the quality of students’ prior knowledge is insufficient or inaccurate, students will try to make sense of cases in ways that do not align with scientific (expert-like) explanations (Halverson et al., 2011; Sherin, 2001). Furthermore, an individual may have a wide range of strategies for developing understanding and supporting learning, for instance, rehearsal, summarising, elaboration, organisation, repetition. However, these will be of limited use unless the individual has sufficient and accurate prior knowledge in the domain to apply them (Hallam, 2010). Therefore, educators should *pay explicit attention to all prior knowledge of students* in such a way that instruction targets both students’ expected and unexpected alternative ideas (misconceptions). Depending on the domain, instructors should not only limit themselves to students’ prior knowledge in their own domain, but also take into account the prior knowledge students bring in from adjacent domains (e.g., mathematics in the case of physics).

Once it is clear that there are misconceptions inhibiting students’ understanding, educators must be able to recognise and understand the problems to be addressed. “Just telling them” is not the way to repair misconceptions. To overcome misconceptions, Halverson et al. (2011) suggest presenting new concepts or theories in such a way that students see them as plausible, intelligible, and simple.

Sherin (2001) suggests using analogies, by presenting a series of intermediate similar or analogous examples and linking these to the new, to be learned concept.

### **Learning Process: Reflecting on Both Practical and Conceptual Knowledge by Using Self-Regulative Knowledge**

#### **Principle 8: Supporting students in strengthening their problem-solving strategies.**

Instructors should *communicate the great value of qualitative processes during problem solving*. Consequently, the knowledge about when to perform procedures is important and must be made explicit along with knowledge of how to perform them (Heller et al., 1983). Various authors (e.g., Cannon-Bowers & Bell, 1997; Heller et al., 1983; Nilsson & Pilhammar, 2009; Smith, 2008) indicate that *modelling* is an important strategy to strengthen students' problem-solving abilities. Modelling makes the expertise trajectory clear by showing what the end goal of "expertise" looks like (King, 2009), and presents a desired behaviour or process of how to get there which can be imitated by the student (Alacaci, 2004; Jensen et al., 2000). Patel et al. (2008) found that if inexperienced nurses and nursing school students are required to spend considerable amounts of time shadowing experienced nurses, they will reiterate skills they have acquired and learn new ones through modelling. Yet, modelling does not necessarily have to be in person. "Worked examples" are problems with their solutions already worked out by experts. By comparing "worked examples," students acquire insights into the abstraction of a problem schema (i.e., generalisation) (Gick, 1986).

The second strategy for strengthening problem-solving strategies, *guided practice or coaching*, aims to oversee the students' performance and intervene when the individual is performing less than optimally. Depending on the students' success or failure, they can be encouraged to personalise or modify their strategies and to transfer them to other problems and contexts (e.g., Alexander, 2005; Arts et al., 2006; Cannon-Bowers & Bell, 1997; King, 2009; Heller et al., 1983; O'Byrne et al., 1997; Taylor, 2007). Ertmer and Stepich (1999) found that students, on an irregular basis, show expert characteristics when solving problems. This "coached expertise," as they called it, had a strong relationship with the intensity and type of instructors' coaching.

#### **Principle 9: Evoke reflection.**

Through reflection, tacit knowledge can become explicit. In order to evoke reflection, both Heller et al. (1983) and Nilsson and Pilhammar (2009) argue that students should be encouraged to generate solution processes themselves and think about differences between experts' and their own thought processes. This means that students should solve a problem aloud, then examine or observe a model solution of the same problem. Finally, students should discuss the differences between their own and the model's procedures, which will help them to reflect and to explicate what they know or do and do not know or not do. Repeated activities of this type should help to develop students' explicit awareness of the processes involved in describing and solving problems (Heller et al., 1983; Nilsson & Pilhammar, 2009).

Various authors (e.g., Arts et al., 2006; Gobet, 2005; Taylor, 2007; Yelder, 2004) state that clear feedback on performance stimulates reflection. In turn, reflection can lead to performance improvement (e.g., problem solving). Without reflecting on performance, one cannot easily refine, improve, or accelerate expertise; lack of critical enquiry leads to "false expertise" (Kirsner, as cited in Yelder, 2004, p. 65). Importantly, to be effective, feedback has to be immediate (King, 2009) and formative (Hallam, 2010), that is, learners are given feedback about the quality of their work and what they can do to make it better; are given advice about how to go about making improvements, and are fully involved in deciding what needs to be done next and who can give them help if they need it. Another essential aspect of the experience required to develop expertise is to not only to reflect on feedback about performance, but also to reflect on the self and interactions with others (King, 2009). King argues that reflection can be facilitated by models and by self-feedback strategies such as guided

self-reflection, journal writing, and other informal techniques in which thoughts, goals and intentions are put into writing.

***Principle 10: Facilitating the development of metacognitive knowledge (learning strategies) and skills (self-monitoring, planning, and evaluation).***

Alexander et al. (2004) and Arts et al. (2006) underline that those who guide others on the journey toward expertise need to give explicit attention to the development of strategies relevant to learning. Alexander (2003, 2005) and Gick (1986) suggest that students *explicitly need to be taught to be strategic* in a domain. This teaching should focus on three types of metacognitive knowledge: (1) declarative (what a strategy is); (2) procedural (how it generally works); and (3) conditional (under what situations it would be useful) (Alexander, 2005). Chester (2007) adds that prior experience and instruction, with its emphasis on the acquisition of procedural knowledge through the application of a behaviourist, didactic approach to teaching, had an obstructive effect on the process of learning strategies. Results show an improvement in the use of strategic knowledge when changing the manner of initial instruction away from the behaviourist, didactic methods towards a cognitive apprenticeship model that incorporates modelling of problem solving heuristics, collaborative problem solving, and sketching. Students also need to develop metacognitive regulation, consisting of three skills: self-monitoring, planning, and evaluating. Students should *witness the inherent value of self-monitoring*, that is, instructors should show the benefits of devoting time upfront to analysing the problem and planning a solution strategy (Alexander, 2005). Furthermore, instructors should *“think aloud,”* explicating their tacit processes (e.g., during decision making), so that students can hear effective ways of using metacognitive knowledge and skills, giving students ideas how to plan, monitor, and evaluate their learning (Alacaci, 2004; Patel et al., 2008). In addition, novices must have *possibilities to plan, monitor, and evaluate their own work*, using tools/instruments such as visual prompts (tangible reminders) and checklists (Alexander, 2005). Finally, as there is evidence that self-regulatory skills acquired in one domain to some extent transfer to other domains, students’ metacognition can be fostered *by highlighting similarities across domains and in this way encouraging students to use metacognitive skills across the curriculum* (Schraw, 2006).

## **Conclusion and Discussion**

To meet the goal of programmes in higher education, that is, developing students towards a starting level of professional expertise, instruction should be designed in a manner consistent with the findings on expertise research (Niemi, 1997). Our synthesis of the literature revealed 10 principles supporting the process of learning from a professional expertise development perspective, which we have organised by means of the Integrative Pedagogy Model. We present these principles as an answer to the calls by various authors to come up with design instructions for teaching towards expertise (e.g., Hatano & Oura, 2003; Kinchin et al., 2008; Penttinen, Skaniakos, & Lairio, 2013). The principles provide a framework beneath which teachers from different backgrounds and disciplines can work together to plan, develop, and provide coherent learning experiences for students.

Earlier contributions to the literature on professional expertise were mainly concerned with defining (levels of) expertise (e.g., Kinchin et al., 2008) and when they dwelt on instructional principles, the identified implications for education were not presented in a comprehensive way building on a pedagogical model (e.g., Alexander, 2005). Using Tynjälä’s model, we are able to argue that the 10 principles uncovered represent a consistent, coherent, and encompassing approach to teaching towards expertise.

We have identified 10 distinct, yet related, instructional principles to support expertise development during the course of formal education. The 10 principles refer to the three core learning processes for expertise development, as described by Tynjälä (2008) (see Table 1). With respect to the first learning process, transforming theoretical/conceptual knowledge into experiential/practical knowledge, the five instructional principles all refer to the importance of giving students access to a variety of experiences combined with instructional strategies to make explicit what is learned



**Table 1.** Instructional Principles and Learning Processes Fostering Professional Expertise Development.

Instructional principles	Learning processes
Support students in their epistemological understanding	Transforming theoretical/conceptual knowledge into experiential/practical knowledge
Provide students with opportunities to differentiate between and among concepts	
Practice with a variety of problems to enable students to experience complexity and ambiguity	
Enable students to understand how particular concepts are connected	
Target for relevance	
Share inexpressible knowledge	Explicating procedural/experiential knowledge into conceptual/theoretical knowledge
Pay explicit attention to prior knowledge	
Supporting students in strengthening their problem-solving strategies	Reflecting on both practical and conceptual knowledge by using self-regulative knowledge
Evoked reflection	
Facilitating the development of metacognitive knowledge (learning strategies) and skills (self-monitoring, planning and evaluation)	

from these experiences. The two instructional principles related to the second learning process, explicating procedural/experiential knowledge into conceptual/theoretical knowledge, have in common the focus on the explicit elicitation of knowledge through dialogue, discussion, and so on. Finally, the instructional principles supporting the learning process of reflection on both practical and conceptual knowledge address the effectiveness of strategies such as modelling and coaching if students develop and use appropriate learning strategies as well as the metacognitive skills of self-monitoring, planning, and evaluation. With respect to the latter cluster of principles that refer to the third core learning process, reflection as a mode of self-evaluation is explicitly discerned as a valid instructional principle.

These instructional principles may guide, but do not guarantee, better learning. The true test of the instructional principles is to validate them using intervention studies, giving insights into the usefulness (to what extent the principles give meaning to instructors' own practice), effectiveness (ability of the instructional principles to achieve their proposed goals), and efficiency (achieving its proposed goal with the least resources possible). Additionally, more research is needed on the question of whether there is a ranking in importance of the principles, possibly also in relation to different phases of learning. The question remains if the usefulness and effectiveness of the principles differ depending on the phase of expertise development of the student and, partly related, the stage of higher education. Moreover, the principles can be used as a framework for the development of classroom learning environments aiming to foster expertise development. In addition, they can be used as guidelines for the evaluation of the effects of learning environments implementing instructional approaches that are argued to be supportive of expertise development (for example, problem-based learning, project-based learning, or case-based learning) (e.g., Boshuizen, 2009; Tynjälä, 2008).

Conducting triangulation of methods, by using in-depth interviews, focus-group discussion sessions, and large-scale surveys, will facilitate elaboration on the following questions: To what extent do the instructional principles line up with teachers' experience? To what extent are the principles followed in educational practice? How to develop and validate an instrument that assesses the degree to which the learning environment in a particular classroom is consistent with known principles for promoting the development of professional expertise? What are the perceived relationships between the instructional principles and learning outcomes? These questions are important as the next focus of follow-up research to this study.

The aim of this research was to derive instructional principles to promote learning environments that direct learning toward expertise. Alongside the importance of these instructional principles, the literature conveys the need to take other aspects of the learning environment into account, aspects that are more difficult to capture in such principles. First, the quality of the guide (e.g., instructor, teacher, coach, senior employee) is of great importance on the journey to expertise (e.g., Alexander, 2005; Arts et al., 2006). Research by Anderson and Leinhardt (2002) was illustrative: "the requests for

better classroom instruction have largely failed, as many teachers lack a formal background in geography and training to teach geography” (p. 316). In addition, Alexander (2005) stated: “Teachers’ subject matter knowledge must extend beyond general pedagogical techniques into the knowledge and strategies that reflect an understanding of the target domain” (p. 36).

Second, various authors (e.g., Gobet, 2005; Gunderman et al., 2001; Heiberg Engel, 2008; King, 2009) indicate that time may play a pivotal role in fostering the advancement toward expertise. For instance, Alexander (2005) and Gunderman et al. (2001) criticised the “one inch deep, one mile wide” curricula, representing the tendency to touch briefly on concepts or processes rather than devote any substantial classroom time to the explication and practice of that content. Other authors stressed the role of time during the professional phase, which should result in better and wiser professionals (Jensen et al., 2000); or, as Heiberg Engel (2008) suggested, time is needed to fully attain the requisite competencies of an expert. Future research should take into account aspects such as time, school curriculum overload, and students’ perceived workload in relation to promoting expertise.

Third, various authors (e.g., Alexander et al., 2004; Ericsson, 1996; Hallam, 2010) emphasise that expertise cannot be fully understood if disconnected from factors such as personal interest. Ericsson (1996) claims that individuals who exhibit the highest levels of expertise show an almost obsessive interest in the domain from a very early age. Although we recognise the importance of interest for the development towards expertise, no instruction principle has explicitly been formulated for interest in this paper. A reason is that while statements in the articles were focused on why interest is important for learning, explicit instruction strategies were barely mentioned. For future research, this suggests the importance of cross-fertilisation between interest research and expertise development research, aiming to understand the role of various motivational variables in the development of expertise during education and especially its implications for instruction.

Lastly, the fact that only 37 articles out of a body of 1,061 articles related to expertise development were eligible for the present review underlines that expertise development research so far has resulted in few instructional implications, as also observed by Chi (2011) and Patel, Arocha, and Kaufman (1999). Chi (2011) states that we still lack sufficient insight into how relative expertise can be taught, or how we can accelerate the acquisition of relative expertise. This paper fills this gap of how relative expertise can be taught by synthesising data from previous studies with the aim of formulating a comprehensive set of instructional principles, consisting of the instructional principles’ characteristics, its effects on students’ learning in terms of fostering expertise, and the authors’ arguments used. As mentioned above, future research should focus on the question of whether these instructional principles accelerate the acquisition of relative expertise.

This integrative review has some limitations. Firstly, concerning the representativeness of the studies: the reviewed studies revealed a profile consisting of more quantitative than qualitative studies; studies were more frequently conducted in Western than in non-Western countries; and with a bias towards medicine-like domains. Secondly, not all constructed instructional principles are equally based on arguments supported by empirical data: 7 out of the 19 studies used to construct Principle 3 were empirical; in relation to the development of Principle 1, only one empirical study was used. Besides these described limitations related to the reviewed publications, one primary limitation concerning this review study is the complexity of combining diverse methodological approaches (quantitative and qualitative). This might contribute to lack of rigour and inaccuracies in the results.

## Disclosure Statement

No potential conflict of interest was reported by the authors.

## References

- Alacaci, C. (2004). Understanding experts’ knowledge in inferential statistics and its implications for statistics education. *Journal of Statistics Education*, 12(2), 1–46. Retrieved from <http://www.amstat.org/publications/jse/v12n2/alacaci.html>



- Alexander, P. A. (2003). The development of expertise: The journey from acclimation to proficiency. *Educational Researcher*, 32(8), 10–14.
- Alexander, P. A. (2005). Teaching towards expertise. [Special Monograph on Pedagogy—Learning for teaching] *British Journal of Educational Psychology*, Monograph Series II, 3, 29–45.
- Alexander, P. A., & Jetton, T. L. (2000). Learning from text: A multidimensional and developmental perspective. In M. L. Kamil, P. B. Mosenthal, P. D. Pearson, & R. Barr (Eds.), *Handbook of reading research: Vol. III* (pp. 285–310). Mahwah, NJ: Lawrence Erlbaum Associates.
- Alexander, P. A., Sperl, C. T., Buehl, M. M., Fives, H., & Chiu, S. (2004). Modeling domain learning: Profiles from the field of special education. *Journal of Educational Psychology*, 96(3), 545–557.
- Anderson, K. C., & Leinhardt, G. (2002). Maps as representations: Expert novice comparison of projection understanding. *Cognition and Instruction*, 20(3), 283–321.
- Arts, J. A. R., Boshuizen, H. P. A., & Gijsselaers, W. H. (2006). Understanding managerial problem-solving, knowledge use and information processing: Investigating stages from school to the workplace. *Contemporary Educational Psychology*, 31(4), 387–410.
- Bereiter, C., & Scardamalia, M. (1993). *Surpassing ourselves: An inquiry into the nature and implications of expertise*. Chicago, IL: Open Court.
- Blasi, G. L. (1995). What lawyers know: Lawyering expertise, cognitive science, and the functions of theory. *Journal of Legal Education*, 45(3), 313–397.
- Boshuizen, H. P. A. (2009). Teaching for expertise: Problem-based methods in medicine and other professional domains. In K. A. Ericsson (Ed.), *Development of expertise: Toward measurement of expert performance and design of optimal learning environments* (pp. 379–404). New York, NY: Cambridge University Press.
- Boshuizen, H. P. A., Bromme, R., & Gruber, H. (Eds.) (2004). *Professional learning: Gaps and transitions on the way from novice to expert*. Dordrecht, the Netherlands: Kluwer Academic.
- Boshuizen, H. P. A., Schmidt, H. G., Custers, E. J. F. M., & van de Wiel, M. W. (1995). Knowledge development and restructuring in the domain of medicine: The role of theory and practice. *Learning and Instruction*, 5, 269–289.
- Botti, M., & Reeve, R. (2003). Role of knowledge and ability in student nurse' clinical decision-making. *Nursing and Health Sciences*, 5(1), 39–49.
- Bouwman, M. (1984). Expert vs. novice decision making in accounting: A summary. *Accounting, Organizations and Society*, 9(3–4), 325–327.
- Brookes, D. T., Ross, B. H., & Mestre, J. P. (2011). Specificity, transfer, and the development of expertise. *Physical Review Special Topics: Physics Education Research*, 7, 8.
- Cannon-Bowers, J. A., & Bell, H. H. (1997). Training decision makers for complex environments: Implications of the naturalistic decision making perspective. In C. E. Zsombok & G. Klein (Eds.), *Naturalistic decision making* (pp. 99–110). Mahwah, NJ: Erlbaum.
- Chester, I. (2007). Teaching for CAD Expertise. *International Journal of Technology and Design Education*, 17(1), 23–35.
- Chi, M. T. H. (2006). Two approaches to the study of experts' characteristics. In K. A. Ericsson, N. Charness, P. J. Feltovich, & R. R. Hoffman (Eds.), *The Cambridge handbook of expertise and expert performance* (pp. 21–30). Cambridge: Cambridge University Press.
- Chi, M. T. H. (2011). Theoretical perspectives, methodological approaches, and trends in the study of expertise. In Y. Li (Ed.), *Expertise in Mathematics Instruction: An international perspective* (pp. 17–39). New York, NY: Springer.
- Chi, M. T. H., Glaser, R. & Farr, M. J. (Eds.) (1988). *The nature of expertise*. Hillsdale, NJ: Erlbaum.
- Coderre, S., Mandin, H., Harasym, P. H., & Fick, G. H. (2003). Diagnostic reasoning strategies and diagnostic success. *Medical Education*, 37(8), 695–703.
- Dreyfus, H. L., & Dreyfus, S. E. (1986). *Mind over machine: The power of human intuition and expertise in the era of the computer*. New York: Free Press.
- Ericsson, K. A. (1996). *The road to excellence*. Mahwah, NJ: Lawrence Erlbaum Associates.
- Ertmer, P. A., & Newby, T. J. (1996). The expert learner: Strategic, self-regulated, and reflective. *Instructional Science*, 24(1), 1–24.
- Ertmer, P. A., & Stepich, D. A. (1999). Case-based instruction in post-secondary education: Developing students' problem-solving expertise. (ERIC Document Reproduction Service No. ED 435375).
- Feltovich, P. J., Prietula, M. J., & Ericsson, K. A. (2006). Studies of expertise from psychological perspectives. In K. A. Ericsson, N. Charness, P. J. Feltovich, & R. R. Hoffman (Eds.), *The Cambridge handbook of expertise and expertise development* (pp. 41–67). Cambridge: Cambridge University Press.
- Fenton-O'Creevy, M., & Hutchinson, S. (2010). Building the foundations of professional expertise: Creating a dialectic between work and formal learning. *Learning and Teaching in Higher Education*, 4(1), 69–92.
- Fink, A. (2010). *Conducting research literature reviews: From the Internet to paper* (3rd ed.). Los Angeles, CA: Sage.
- Gick, M. L. (1986). Problem-solving strategies. *Educational Psychologist*, 21(1–2), 99–120.
- Gijsselaers, W. H., Arts, J. A., Boshuizen, H. P. A., & Segers, M. S. R. (2006). A trade-off between formal and dynamic knowledge occurs as graduates enter the workplace. In R. De Filippi & C. Wankel (Eds.), *New visions of graduate management education, volume 5* (pp. 65–86). Greenwich, CT: Information Age.

- Gobet, F. (2005). Chunking models of expertise: Implications for education. *Applied Cognitive Psychology*, 19(2), 183–204.
- Goldman, S. R., Petrosino, A. J., & CTGV. (1999). Design principles for instruction in content domains: Lessons from research on expertise and learning. In F. T. Durso, (Ed.), *Handbook of applied cognition* (pp. 595–628). Chichester, UK: Wiley.
- Grenier, R., & Kehrnhahn, M. (2008). Toward an integrated model of expertise and its implications for HRD. *Human Resource Development Review*, 7(2), 198–217.
- Gunderman, R., Williamson, K., Fraley, R., & Steele, J. (2001). Expertise: Implications for radiological education. *Academic Radiology*, 8(12), 1252–1256.
- Hallam, S. (2010). Transitions and the development of expertise. *Psychology Teaching Review*, 16(2), 3–32.
- Halverson, K. L., Pires, J. C., & Abell, S. K. (2011). Exploring the complexity of tree thinking expertise in an undergraduate plant systematics course. *Science Education*, 95(5), 794–823.
- Hatano, G., & Oura, Y. (2003). Commentary: Reconceptualising school learning using insight from expertise research. *Educational Researcher*, 32(8), 26–29.
- Heiberg Engel, P. J. H. (2008). Tacit knowledge and visual expertise in medical diagnostic reasoning: Implications for medical education. *Medical Teacher*, 30, e184–e188.
- Heikkinen, H., Jokinen, H., & Tynjälä, P. (2012). Teacher education and development as lifelong and lifewide learning. In H. Heikkinen, H. Jokinen, & P. Tynjälä (Eds.), *Peer-group mentoring for teacher development* (pp. 3–30). Milton Park, UK: Routledge.
- Heller, J. I., Reif, F., & Hungate, H. N. (1983, April). *Toward theory-based instruction in scientific problem solving*. Paper presented at AERA meeting, Montreal. (ED233886).
- Jensen, G. M., Gwyer, J., Shepard, K. F., & Hack, L. M. (2000). Expert practice in physical therapy. *Physical Therapy*, 80(1), 28–43.
- Kinchin, I. M., Cabot, L. B., & Hay, D. B. (2008). Visualising expertise: Towards an authentic pedagogy for higher education. *Teaching in Higher Education*, 13(3), 315–326.
- King, G. (2009). A framework of personal and environmental learning-based strategies to foster therapist expertise. *Learning in Health and Social Care*, 8(3), 185–199.
- Kulatunga-Moruzi, C., Brooks, L. R., & Norman, G. R. (2011). Teaching posttraining: Influencing diagnostic strategy with instructions at test. *Journal of Experimental Psychology: Applied*, 17(3), 195–209.
- Lebeau, R. B. (1998). Cognitive tools in a clinical encounter in medicine: Supporting empathy and expertise in distributed systems. *Educational Psychology Review*, 10(1), 3–24.
- Loyens, S. M. M. & Rikers, R. M. J. P. (2011). Instruction based on inquiry. In R. E. Mayer & P. A. Alexander (Eds.), *Handbook of research on learning and instruction* (pp. 361–381). New York, NY: Routledge.
- McKenney, S., Nieveen, N., & van den Akker, J. (2006). Design research from the curriculum perspective. In J. van den Akker, K. Gravemeijer, S. McKenney, & N. Nieveen (Eds.), *Educational design research* (pp. 67–90). London: Routledge.
- Niemi, D. (1997). Cognitive science, expert-novice research, and performance assessment. *Theory into Practice*, 36(4), 239–246.
- Nivelstein, F., van Gog, T., Boshuizen, H. P. A., & Prins, F. J. (2010). Effects of conceptual knowledge and availability of information sources on law students' legal reasoning. *Instructional Science*, 38(1), 23–35.
- Nilsson, M. S., & Pilhammar, E. (2009). Professional approaches in clinical judgements among senior and junior doctors: Implications for medical research. *BMC Medical Education*, 9(25), doi:10.1186/1472-6920-9-25
- Norman, G. R., & Schmidt, H. G. (1992). The psychological basis of problem-based learning: A review of the evidence. *Academic Medicine*, 67, 557–565.
- O'Byrne, K., Clark, R. E., & Malakuti, R. (1997). Expert and novice performance: Implications for clinical training. *Educational Psychology Review*, 9(4), 321–332.
- Patel, V. L., Arocha, J. F., & Kaufman, D. R. (1999). Expertise and tacit knowledge in medicine. In R. Sternberg & J. Horvath (Eds.), *Tacit knowledge in professional practice: Researcher and practitioner perspectives* (pp. 75–99). Mahwah, NJ: Lawrence Erlbaum.
- Patel, V. L., Gutnik, L. A., Karlin, D. R., & Pucsi, M. (2008). Calibrating urgency: Triage decision-making in a pediatric emergency department. *Advances in Health Sciences Education*, 13, 503–520.
- Pedaste, M., Mäeots, M., Siiman, L. A., de Jong, T., van Riesen, S. A. N., van Kamp, E. T., ... Tsourlidaki, E. (2015). Phases of inquiry-based learning: Definitions and the inquiry cycle. *Educational Research Review*, 14, 47–61.
- Penttinen, L., Skaniakos, T., & Lairio, M. (2013). Supporting student's pedagogical; working life horizon in higher education. *Teaching in Higher Education*, 18(8), 883–894.
- Postigo, Y., & Pozo, J. I. (2004). On the road to graphicacy: The learning of graphical representation systems. *Educational Psychology*, 24(5), 623–644.
- Schmidt, H. G., & Boshuizen, H. P. A. (1993). Kennisencapsulatie [Knowledge encapsulation]. *Tijdschrift voor Onderwijsresearch*, 18, 135–148.
- Schmidt, H. G., Norman, G. R., & Boshuizen, H. P. A. (1990). A cognitive perspective on medical expertise: Theory and implications. *Academic Medicine*, 65(10), 611–621.

- Schraw, G. (2006). Knowledge: Structures and processes. In P. A. Alexander & P. H. Winne (Eds.), *Handbook of educational psychology* (2nd ed., pp. 245–263). Mahwah, NJ: Erlbaum.
- Sherin, B. (2001). How students understand physics equations. *Cognition and Instruction*, 19(4), 479–541.
- Slavin, R. E. (1986). Best-evidence synthesis: An alternative to meta-analysis and traditional reviews. *Educational Researcher*, 15(9), 5–11.
- Smith, C. S. (2008). A developmental approach to evaluating competence in clinical reasoning. *Journal of Veterinary Medical Education*, 35(3), 375–381.
- Taylor, P. M. (2007). A review of research into the development of radiologic expertise: Implications for computer-based training. *Academic Radiology*, 14(10), 1252–1263.
- Tynjälä, P. (1999). Towards expert knowledge? A comparison between a constructivist and a traditional learning environment in the university. *International Journal of Educational Research*, 31(5), 357–442.
- Tynjälä, P. (2008). Perspectives into learning at the workplace. *Educational Research Review*, 3(2), 130–154.
- Tynjälä, P., Nuutinen, A., Eteläpelto, A., Kirjonen, J., & Pirkko, R. (1997). The acquisition of professional expertise—a challenge for educational research. *Scandinavian Journal of Educational Research*, 41(34), 475–494.
- Van Ginkel, S., Gulikers, J., Biemans, H., & Mulder, M. (2015). Towards a set of design principles for developing oral presentation competence: A synthesis of research in higher education. *Educational Research Review*, 14, 62–80.
- Wellman, H. M. (2003). Enablement and constraint. In U. Staudinger & U. Lindenberger (Eds.), *Understanding human development* (pp. 245–263). Dordrecht, the Netherlands: Kluwer.
- Whittemore, R., & Knafl, K. (2005). The integrative review: Updated methodology. *Journal of Advanced Nursing*, 52, 546–553.
- Wilkerson-Jerde, M., & Wilensky, U. (2011). How do mathematicians learn math? Resources and acts for constructing and understanding mathematics. *Educational Studies in Mathematics*, 78, 21–43.
- Yelder, J. (2004). An integrated model of professional expertise and its implications for higher education. *International Journal of Lifelong Education*, 23(1), 60–80.

## Appendix

**Table A1.** Articles Used in the Analysis and Overview of Meaningful Units of Analysis Organised Per Learning Process and Instructional Principle.

Type of publication	Type of analysis	Design	Country	Field	Authors	Learning processes (T=teaching; L=learning) P= Instructional principles																	
						Transforming theoretical/ conceptual knowledge into experiential/practical knowledge					Explicating procedural/ experiential knowledge into conceptual/theoretical knowledge			Reflecting on both practical and conceptual knowledge by using self-regulative knowledge									
						P1		P2		P3	P4		P5		P6		P7	P8		P9	P10		
						T	L	T	L	T	L	T	L	T	L	T	L	T	L	T	L		
Empirical	Qualitative	Case study	USA	Statistics	Alacaci (2004)		1	1	2	1	2	2		1		1		1	1				
Conceptual			USA	Multidisciplinary domains	Alexander (2003)					1	2	1	1						1	2			
Conceptual	–		USA	Multidisciplinary domains	Alexander (2005)	2	1				1	1	1	1		2		2	1	4	2		
Conceptual	–		USA	Reading	Alexander and Jetton (2000)				1	1	1	1								2	2		
Empirical	Quantitative	Cross-sectional	USA	Special Education	Alexander et al. (2004)								1	1						1	1		
Empirical	Quantitative/ qualitative	Mixed	USA	Geography	Anderson and Leinhardt (2002)		4	3															
Empirical	Quantitative	Cross sectional	The Netherlands	Business	Arts et al. (2006)				1	1			7	4				2	1	1	2		
Conceptual	–		USA	Law	Blasi (1995)						1	1											
Empirical	Quantitative	Quasi-experimental	Australia	Nursing	Botti and Reeve (2003)	2	1				1	1											
Empirical	Quantitative	Experimental	USA	Physics	Brookes et al. (2011)		3	2															
Conceptual	–	–	USA	Multidisciplinary domains	Cannon-Bowers and Bell (1997)								3	2				3	3				
Empirical	Quantitative	Experimental	Australia	Computer Aided Design	Chester (2007)																1	1	
Empirical	Quantitative	Correlational	Canada	Medicine	Coderre et al. (2003)						1	1											
Empirical	Quantitative/ qualitative	Mixed	USA	Instructional Design	Ertmer and Stepich (1999)																		
Conceptual			Canada	Multidisciplinary domains	Gick (1986)						1	3						1	1			1	1
Conceptual			United Kingdom	Multidisciplinary domains	Gobet (2005)						5	5								1	1		
Conceptual			USA	Radiology	Gunderman et al. (2001)						1	2	2	1	1								

(Continued)

