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Framing the features of good quality knowledge for teachers and students

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Abstract

In this paper we have two concerns. First we consider the features used to describe good quality learning actions and knowledge representations. Our second concern is the need to develop students' knowledge of how to act, during teaching-learning transactions, in order to generate good quality knowledge representations. There is a convergence of views, at a broad level, about the character of good quality knowledge. Although there are frequent specifications of the features of good quality learning these discussions mostly do not build on one another so that a coherent representation of such learning is built up. There is therefore a need to consider further the characteristics of learning that are regarded as being of good quality. For this purpose we set out a framework based around six dimensions of good quality knowledge, namely, extent, well-foundedness, structure, complexity, generativity, and variety of representational format. In the final section of the chapter we advance arguments that point to the need to attend to the state of students' and teachers' knowledge about how to act, in strategic cognitive and metacognitive ways, in order to generate good quality knowledge representations.

Introduction

Macedon Primary School is committed to providing a comprehensive and progressive program leading children to become confident, independent, responsible self learners, equipped with skills and knowledge for the future. Academic achievement in Maths and English is high with quality learning programs provided in a range of curriculum areas.

This website statement for a small country school in Australia, where one of us began school, establishes commitments that are typical at all levels of education. When our students graduate from our early childhood centers, schools, universities, and training programs we want them to be competent and confident. Because students will face known problems of great complexity like climate change, and problems of similar complexity that have not yet emerged, we want their learning to be of good quality. Indeed one of our foundational beliefs in all levels of education is that good quality knowledge is necessary for the complex problem solving that will be required of students in their later lives. So what is good quality knowledge like and do the key players in the game of learning know how to play that game so that they develop such knowledge? These are the two issues that are the focus of this chapter.

We need to make three framing comments about our approach. First, within the fields of psychology concerned with learning and teaching, the broad range of discussions about good quality learning and good quality knowledge do not all have the same focus. Some focus on learning processes or learning actions during which a knowledge representation is constructed, and some focus more on the nature of the knowledge representation itself. We see both of these closely related issues as being

relevant, in the sense that learning processes, or learning actions, that are of good quality will result in good quality knowledge representations. Good quality learning actions and good quality knowledge representation have common features. So in this chapter we include the quality of both learning actions and the resulting knowledge representation when referring to the quality of learning. It is also relevant to note that when we refer to the quality of a knowledge representation we are in fact referring to the quality of an articulation of a knowledge representation in some type of performance. Second, we do not take a single theoretical perspective on knowledge representation, but note that it is a construct central to current thinking in a diverse range of fields, such as cognitive psychology (e.g., Hunt, 1989; Bower, 2008), computing science (e.g., Cheng & Hu, 2010; Larkin, Reif, Carbonell, & Gugliotta, 1988), and neuroscience (e.g., Gainotti, Ciaraffa, Silveri, & Marra, 2009; Wirth et al., 2007). Finally, in this chapter we do not consider the role of dispositional or motivational factors, though these are critical influences on learning and performance and are discussed in other chapters in this book. Mayer (1998) made this link clear when he argued that in any instance of problem solving we need to recognize three broad factors of influence: motivation, cognition, and metacognition. However, the focus of this chapter is on cognitive and metacognitive factors.

A knowledge representation is constructed by the learner and the constructive nature of knowledge formation is a central assumption of cognitive approaches to learning. As J. R. Anderson, Reder, and Simon (1998) argued:

> A consensus exists within cognitive psychology that people do not
> record experience passively but interpret new information with the help
> of prior knowledge and experience. The term "constructivism" is used
> in this sense in psychology, and we have been appropriately referred to
> as constructivists (in this sense) by mathematics educators. (p.232)

Knowledge representations are developed for every part of our lives – for the self, social relationships, cooking, hockey, motor mechanics, mathematics, biology, art, dance and so on. Most importantly for our current purposes, knowledge representations are developed about learning: about how to construct knowledge. If we see classroom learning as resulting in the development of domain knowledge (Alexander, 2005), then learning must be recognized as one of those domains. The significance of knowledge about learning is that it can influence the outcomes of knowledge construction in many other domains (e.g., see Hattie, 2009). Although this spreading influence is not unique to the domain of knowledge about learning, it is important that this domain be given appropriate recognition by teachers and learners, especially as it is a domain of knowledge that can be developed through explicit instruction.

When Fenstermacher and Richardson (2005) addressed the issue of quality in teaching they argued that it was useful to consider the nature of quality by working back from the specific features of examples generally recognised as indicating good quality teaching practice. We have taken such an approach here. In the first section of this chapter we review the work of different researchers who have identified features of good quality learning, and then propose a framework for further consideration of these features.

Stimulating good quality knowledge construction

A major motivation for much of the study of learning and teaching is the stimulation of good quality learning actions that will result in good quality knowledge representations. In educational psychology, a driving force over many decades has been to identify how teaching-learning interactions can result in students developing

better quality subject-matter understanding and problem-solving capabilities. The chapters in this book are also manifestations of this research effort.

In Chapter 1 of this book, high quality learning is described as "extensive, well integrated, deep, and supportive of transfer." These features have emerged in many different sources in recent times. Features of good quality knowledge were made explicit in research such as that of Gobbo and Chi (1986) that analysed differences in the knowledge representations of child novices and child experts. The knowledge of the child experts was more extensive. The research also provided examples of differences in the nature of the structuring and integration of the knowledge reported by the two different groups. The child experts' knowledge was rated as being better integrated.

The rationale for nominating transfer as an indicator of quality of the original learning is apparent in Bassock's (2003) definition of positive transfer: "When people encounter a novel problem, they might be reminded of a problem they solved previously, retrieve its solution, and use it, possibly with some adaptation, to solve the novel problem." (p. 343). In an earlier discussion, Bruner (1966) related such positive transfer to a quality of a knowledge representation that he termed *power*: A powerful form of representation, in Bruner's account, enabled a learner to generate solutions to a wider range of problems, and allowed "a learner to connect matters, that on the surface, seem quite separate" (p. 48).

Teachers hope that students will develop an understanding of a topic that will allow them to 'run with' that topic beyond the point reached during the lesson. Indeed most summative, high stakes assessment tasks include items that will provide evidence that such extended application of understanding has occurred, and high value is placed on such evidence. Two reasons for valuing such extension are suggested in Bassock's (2003) argument above: the transfer is initiated by the learners

themselves, and it shows that the learners can apply their new learning to problems that involve some adaptation of the original learning. Campione and Brown (1978) referred to such transfer in terms of the *flexible* use of knowledge. Later, the same authors noted such transfer of learning was evident in the "sustained complex thinking" they observed in groups of students who were effectively engaged with their communities of learners (Brown & Campione, 1996, p. 261). A similar description of high road, or mindful, transfer was given by Salomon and Perkins (1989). In each of these cases, the researchers were describing a characteristic of high quality learning that was supportive of more extensive application of knowledge to novel situations.

Deep learning

However, it is the term *deep* in the framing description of quality learning in Chapter 1 that has been most commonly used as a shorthand description of high quality learning actions and knowledge representation. The idea of deep processing gained popularity following the publication by Craik and Lockhart (1972) of the levels of processing framework for memory research, although there were related conceptions in a variety of literature before and around that time. The idea of layers of knowledge representation that involve depth is central to Freudian psychology and a similar conception was used by Barker (1951, p.6) in reference to "children's deep motivations." The terms "deep structure" and "surface structure" were used by Chomsky (1957) to refer to levels of linguistic representation, the latter being generated through a series of transformations of the former. In educational psychology, Frase (1969) considered ideas of "deeper knowledge", "deeper understanding" and "deeper analysis" in his studies of text recall. In their Annual Review paper Glaser and Resnick (1972, p. 217) discussed Frase's work on the "depth of inferential reasoning" and noted the positive impact on retention of such

deep analysis. So by 1972 some researchers were quite sympathetic to Craik and Lockhart's discussion of levels and depth of processing. One attraction of deep processing, as a description that indicated quality, was that it indicated that considerable cognitive work had been undertaken as the information initially presented to the learner was subjected to a series of transformations or abstractions.

The ideas of levels and depth of processing were quite quickly taken up by other researchers in analyses of the qualities of student learning actions, most notably by Marton (1975), Marton and Säljö (1976a; 1976b), Biggs (1979), and Entwistle and colleagues (1979, 2002). Deep learning has been maintained as a synonym for high quality learning and is widely used in discussions of learning in both research literature and in more practical discussions of teaching and learning. A sense of the latter use is given by Tagg (2003, p. 70) in a text on college teaching: "Deep learning is learning that takes root in our apparatus of understanding, in the embedded meanings that define us and that we use to define the world." It is also interesting to note that in contemporary discussions of machine learning, layers of representation are discussed in similar terms to those used by Craik and Lockhart, Marton and others: "deep learning", "deep architectures" and "deep belief networks" (e.g., Erhan, Courville, Bengio, & Vincent, 2010).

However, along with the widespread use of deep learning as a synonym for learning that results in a high quality knowledge representation, has come the challenge of how to further conceptualise such learning.

Craik and Lockhart's (1972) original description of levels of processing was quite simple: "trace persistence is a function of depth of analysis, with deeper levels of analysis associated with more elaborate, longer lasting and stronger traces" (p. 675). This idea has proved attractive to large numbers of researchers and students, despite being the subject of very powerful critiques, including some by its originators

(for reviews see Roediger & Gallo, 2002; Watkins, 2002). Even though the original proposals of specific levels of perceptual processing have been effectively criticized, the emphasis on active, constructive processing that influences retention has endured. Perhaps the most valuable insight by Craik and Lockhart was that the quality of processing the learner carried out during encoding (during the construction of the knowledge representation) made the major difference to the quality of subsequent knowledge use.

In educational psychology, Marton (1975) described differences in the quality of students' learning actions in terms of different levels of processing, using Craik and Lockhart's (1972) analysis, and noted that these differences in processing covaried with differences in performance. Subsequently Marton and Säljö (1976a, 1976b) labeled the different qualities of processing as surface-level and deep-level, linking surface level processing to reproductive and rote-learning and deep level processing to "comprehending what the author wants to say" (Marton & Säljö, 1976a, p. 8). In closely related research, Biggs (1984) and Entwistle, Hanley and Hounsell (1979) made distinctions between surface and deep *approaches* to learning. In Biggs' model, an approach to learning involved both motive and cognitive strategy components, with deep approaches being of higher quality than surface approaches (e.g., Biggs, 1987). A deep approach was indicated by motive features of intrinsic interest and commitment to work, and strategy features of relating ideas and understanding (Kember, Biggs & Leung, 2004). The differences in quality between the two approaches were indicated by the extent of presence of these different features.

Within memory research, interpretations of depth of processing have been matters of dispute (e.g., see Roediger & Gallo, 2002; Watkins, 2002). "Degree of stimulus elaboration" was included as a translation for depth in the original Craik and Lockhart (1972) paper, and Lockhart (2002) used a number of other interpretations of

depth, such as *distinctiveness*, *strength*, *transfer appropriate proc*essing and *robust encoding*. We will not go further into the details of these arguments in memory research here, but note that they point to a need to consider further the relationship between deep learning and learning quality. Indeed the limitations of representing the nature of high quality learning actions in a single term such as 'deep' is shown in the characterisation of deep approaches and deep strategy by Kember et al. (2004) as a multiple-feature construct. In the next section we consider features additional to depththat have been used to describe differences in the quality of learning actions and knowledge representations.

Features of good quality learning

Studies of expertise make claims about the nature of learning quality, based on the reasonable assumption that expertise is a reflection of good quality knowledge. For example, Alexander (2005) reviewed accounts of expertise that refer to features such as extensive knowledge, deep knowledge, strategic processing, inter-related complex knowledge, and dispositions of high interest and willingness to expend effort. Other characteristics of expertise identified by Glaser and Chi (1988) were faster processing, deeper problem representation, more thorough problem analysis and better monitoring of performance.

The Structure of Observed Learning Outcomes (SOLO) taxonomy developed by Biggs and Collis (1982) identified four features of quality in learning actions: (a) capacity, which is related to working memory and Bruner's (1966) economy of a knowledge representation; (b) relating operation, which referred to the way in which instructional cues and the student's response were interrelated; (c) consistency and closure in relating data and conclusions; and (d) structure. These features of quality of learning actions are seen to interact in the generation of the different levels of quality

of learning outcome that make up the SOLO Taxonomy. This taxonomy has proved to be of great value in making judgements about the quality of student performance for both research and practical school and university assessment (e.g., Hattie, Biggs & Purdie, 1996; Taylor, n.d.).

Another multi-feature perspective on the quality of a cognitive structure was proposed by White (1979) and White and Gunstone (1980). White's list of features of quality of memory structure were (a) extent, (b) precision, (c) internal consistency, (d) accord with reality, (e) variety of types of memory element, (f) variety of topics, (g) shape, (h) ratio of internal to external associations, and (i) availability. Since these early papers, White and Gunstone (1992) and others (e.g., Martin, Mintzes, & Clavijo, 2000; McKeown & Beck, 1990) have looked in detail at some of these features, examining differences in the quality of students' understanding of a variety of topics using techniques such as concept mapping. Those types of analyses, and the analyses of internal and external connectedness between nodes in the memory network discussed by Mayer and Greeno (1972), have also been used in investigations of the structural complexity of teacher knowledge by Chinnappan and Lawson (2005).

The two-dimensional revision of Bloom's early Taxonomy of Educational Objectives by L. W. Anderson and Krathwohl (2001) relates a qualitative ordering of processing events on one dimension (Remember, Understand, Apply, Analyse, Evaluate, and Create) to different types of knowledge representations on the other (Factual, Conceptual, Procedural, and Metacognitive). In the first of these dimensions there is a clear reliance on transfer as a basis for ordering the quality of performances, so that the more that students extend their understandings using their own resources, the more highly regarded is the performance. Other features included in the analyses by White (1979) and in the SOLO Taxonomy (Biggs and Collis, 1982) are not given explicit attention in the revised Bloom taxonomy.

However the focus on different representational formats in the second revised-Bloom dimension does relate to another of White's (1979) features of quality, namely, variety Variety in types of representational formats has been documented by Munby, Russell and Martin (2001), including, inter alia, situated knowledge (Wenger, 1998), knowing-in-action and personal practical knowledge (Schön, 1988), declarative and procedural knowledge (J. R. Anderson, 2010), semantic and episodic knowledge (Tulving, 1972; Tulving & Craik, 2000), conceptual and procedural knowledge (Hiebert, Gallimore, & Stigler, 2002) and metacognitive knowledge (Flavell, 1979; Hacker, Dunlosky, & Graesser, 1998). These classifications of types of knowledge are similar in kind to the variety of memory elements identified in White's (1979) account, but are not identified explicitly in discussions of deep approaches to learning.

Other features of knowledge quality have been identified by McKeown and Beck (1990), and by Hogan and colleagues (Hogan, 1999a, 1999b; Hogan & Fisherkeller, 2000; Hogan, Nastasi, & Pressley, 2000). McKeown and Beck (1990), in their investigation of the quality of students' knowledge of a topic in history, identified a mixture of quantitative and qualitative features, including measures of correctness of responses, quantity of major ideas, quantity of elaborative ideas, the nature of the relationships between ideas and the organization of ideas. Hogan and her colleagues rated the quality of high school students' mental models of matter using indicators that included coherence with prior beliefs, knowledge and values, generativity, degree of elaboration of a topic, specificity, of knowledge about a topic, adequacy of justification, adequacy of explanation, scope of knowledge, degree of synthesis, and logical coherence. Although the emphasis in Hogan's work on quality of explanation has not been discussed explicitly in other analyses, the list of indicators in her work are closely related to those identified by other researchers discussed above.

This review indicates that there has been a consistent need in research on learning for specification of the ways in which good quality and poor quality learning actions and knowledge representations differ. However, there are two limitations of these accounts. First, most do not make explicit connections to any of the other accounts. As a result, there is less explicit focus on the nature of quality of knowledge representations than there might be, which provides part of the rationale for this book. Second, these various accounts do not score well in terms of integration or synthesis. Although these specifications are valuable, when taken together they constitute a somewhat unwieldy listing of features that could be more explicitly organized. In the next section we set out a framework that is advanced as a systematic and parsimonious structure for considering the range of features of high quality knowledge .

Dimensions of quality of knowledge representation

We have organised the features of good quality knowledge representations and learning actions into a broad framework containing the six dimensions set out in Table 1: (a) extent; (b) well-foundedness, (c) structure, (d) complexity, (e) generativity, and (f) variety of representational format. The framework is designed to consolidate the main indicators of good quality reviewed in this chapter, thus providing a structured basis for future research.

The dimensions are proposed to make both direct and indirect contributions to the quality of learning actions and quality of knowledge representations. In some cases, the dimensions need to interact to constitute high quality knowledge. For example, a more extensive store of knowledge would not, on its own, be guaranteed to result in a better quality knowledge representation or better quality problem

solving. However, if the learning actions of the students all rated well on other dimensions, then a more extensive network of relevant knowledge would be predicted to result in a better quality knowledge representation and better problem solving performance. The framework set out here is broad and identifies dimensions of quality. It does not identify measures associated with each dimension, although measures have been developed in use of an earlier version of the framework described in Askell-Williams (2004).

Extent

The extent, or quantity, of knowledge is included in most of the accounts of knowledge quality reviewed in the previous section. For example, analyses of expertise have built upon the research of Chase and Ericsson (1982), who showed that expertise involved the ability to recall more task-relevant patterns and patterns that differed in structure from those of novices. Extent of knowledge is an explicit feature of the SOLO taxonomy, of Alexander's (2005) analysis of expertise, and of White's (1979) analysis of the quality of cognitive structures. J. R. Anderson (2010, p. 311) argued that extent of task-relevant knowledge is more important for problem solving than native ability. Extent can be seen as an implicit feature of descriptions of deep learning. As the extent of transformation of knowledge increases it is reasonable to argue that the amount of prior task-relevant knowledge that is activated will increase.

Well-Foundedness

In each of the accounts of White (1979) and White and Gunstone (1980), Biggs and Collis (1982), Hogan and Fisherkeller (2000), Marton and Säljö (1976a; 1976b), Kerr (1981), Chi and Roscoe (2002), and McKeown and Beck (1990), there is explicit concern to make judgments about the correctness of propositions and also the

correctness of relationships between propositions. This judgment of correctness, or well-foundedness, is made with respect to the degree of congruence between a person's knowledge and the knowledge of the relevant knowledge community. Well-foundedness can also be viewed from an internal perspective of congruence between an individual's knowledge/beliefs, intentions, plans and actions (Kerr, 1981). Marton and Säljö (1976) showed a relationship between deep processing and well-foundedness, described by Entwistle and Smith (2002) as "a logical and inevitable relationship between a deep approach and thorough understanding" (p. 328).

Structure

Structure is used here to refer to the organisation of knowledge in a configural sense, including the economy of that configuration and its efficiency of operation. This configural property of students' knowledge (Goldsmith & Johnson, 1990) is often depicted in network or graph models as a pattern of node and links (e.g., Collins & Quillian, 1969). A straightforward distinction in terms of structural quality can be made between knowledge that is fragmented and that which is connected. Other research suggests a need to represent the connectedness or structure of knowledge as a dimension of quality, including the work of Mayer and Greeno (1972), Wittrock (1989), Martin, Mintzes and Clavijo (2000), White and Gunstone (1979; 1992), and McKeown and Beck (1990). In this dimension, the structure of hierarchical and heterarchical configurations of knowledge elements (such as nodes, or concepts, or schemata) are in focus. Both connectedness within a knowledge schema and connectedness between different schemata are of interest (Mayer, 1975). In particular, well connected knowledge representations are more economical and efficient at facilitating knowledge retrieval, and so have advantages for problem solving (J. R. Anderson, 2010; Karmiloff-Smith, 1992). In J. R Anderson's (2007) ACT-R model,

knowledge compilation is a means by which knowledge elements are assembled and refined into more economical structures. Efficiency in structure is also described as a process of encapsulation, so that encapsulated structures generated through practice require minimal attention (Brown & Carr, 1989). Compiled or encapsulated structures could be seen as having a smaller cognitive *footprint*.

Descriptions of deep approaches to learning do implicate structure, though they link this closely to the dimension of complexity, as indicated in the discussion of a deep approach by Kember et al. (2004): "Relating ideas together results in a more integrated view, which contrasts to the fragmented knowledge that commonly results from a surface approach" (p.272). A similar contrast between the characteristics of deep and surface approaches was drawn by Entwistle and Peterson (2004).

Complexity

Complexity refers to the nature of the transformation or abstraction of the knowledge representation. As noted earlier, discussions of deep learning identify complexity in the sense of good quality understanding, and of relating, as key features of depth of processing, or of a deep strategy. This sense was critical in Chomsky's (1957) initial descriptions of deep and surface structures and was explicit in Craik and Lockhart's (1972) description of depth of processing as involving a "greater degree of semantic or cognitive analysis" (p. 676). Complexity is also assumed to be associated with differences in reflective, metacognitive activities, which contribute to the precision of a knowledge representation. The range of characteristics identified by Hogan and colleagues, such as logical coherence, focussed on ways in which knowledge representations differ in complexity (Hogan, 1999a, 1999b; Hogan & Fisherkeller, 2000; Hogan et al., 2000; see also Hmelo-Silver & Pfeffer, 2004). For

example, one student's knowledge might be limited to simple propositional relationships, while another student may provide more complex elaborations and justifications, perhaps through the use of analogies and metaphors.

Whereas the structure dimension focuses on the configural arrangement of knowledge elements, the complexity dimension captures differences in the *qualitative nature* of the relationships, or in Biggs and Collis' (1982) terms, differences in the "relating operations" that have been established between the knowledge elements. With reference to node-link structures noted above, complexity is an indicator of the nature of the links themselves.

Generativity

The extended abstract level in the SOLO taxonomy (Biggs & Collis, 1982) implies situational variation, generalisation, and transfer. This sense that more valued knowledge is able to generate a greater range of potential responses during problem solving has also been discussed by Perkins and Salomon (1994), Mayer and Wittrock (1996), and Bereiter (1997). Such knowledge is more robust, or in Bruner's (1966) terms more powerful, or of better quality, in the sense of being more widely applicable across a range of problem contexts and in the face of possible disturbances (Taatgen, Huss, Dickison & Anderson, 2008). When the relationship between this dimension and deep learning is considered, it might be argued that the emphasis on learning for understanding in descriptions of deep strategies implies transfer: that is, deep understanding will support transfer. However, this feature of quality does not seem to be tapped directly in items used as indicators of deep strategies.

Variety of representational format

Knowledge can be held in different representational formats. White and Gunstone (White, 1979; White & Gunstone, 1980) identified this in their proposed variety of types of memory elements. Descriptions of representational formats such as images (Kosslyn, Thompson & Ganis, 2006), declarative and procedural knowledge and embodied cognition (J. R. Anderson, 2010), L. W. Anderson and Krathwohl's (2001) types of knowledge representations, and the knowledge types reviewed by Munby et al. (2001) all suggest that knowledge can be held in diverse representational formats, and that multiple cognitive representations are more likely to be applicable across a wider range of problem situations than a single representation. This is also the position adopted by dual-code theorists who argue for the operation in cognition of interconnected, and additive, verbal and non-verbal systems (e.g., Sadoski, Goetz & Rodriguez, 2000). As argued by White and Mayer (1980), it seems likely that a combination of types of knowledge representation would provide a quality dimension of richness that would be superior to knowledge that is represented in only one way. Recent research on the use of multiple external representations for learning provides some further support for this view (e.g., Kolloffel, Eysink, de Jong, & Wilhelm, 2009).

An earlier version of framework shown in Table 1 has been used to examine differences in the quality of knowledge, in particular, in the quality of students' knowledge about teaching and learning itself (Askell-Williams, 2004; Askell-Williams & Lawson, 2006). In those studies, which did not include the dimension of extent, students from different fields of post-school education were interviewed about a wide range of their study tasks, both in class tasks and in practical workplace learning situations. Indicators of the dimensions of knowledge quality were developed

and used to code the students' interview transcripts. Askell-Williams (2004) used the statistical technique of correspondence analysis to develop multidimensional displays and profiles that showed different patterns of relationships between indicators of knowledge quality between groups of students that had very different post-school formal learning experiences. In Figure 1, an example is shown of a comparison of the profiles of the quality of knowledge of two of the participants in that study, a child care student and a medical student. These analyses provide not only a way to represent predicted differences in students' knowledge quality, but also provide a more detailed and nuanced description of differences in knowledge quality than a description that relies on a single dimension like deep-surface. In addition, the analyses of students' profiles showed that the framework can be used to identify relative strengths and weaknesses in students' knowledge about, and use of strategies for learning, and so provides a basis for generating teaching actions that could address any identified weaknesses. Our ongoing concern for strengthening this quality of knowledge about learning itself is the focus of the final section of this chapter.

The need to foster students' good quality knowledge about learning

Black (2004) observed a set of 24 lessons in a Year 5 classroom in north-east England, and as part of her analysis found that in whole-class discussions across the set of 24 lessons, students averaged 20 interactions with the class teacher: just less than one interaction per lesson. Again in the UK, Galton, Hargreaves, Comber, Wall, and Pell (1999) carried out a detailed observational study of types of interaction in the classrooms of 28 teachers of students in their final year of primary school, in a repeat of a study carried out in 1976. In the 1976 study, across 58 classrooms, it was found that teachers, on average, engaged in around six minutes of individual interaction with each child per day. In the 1976 data, on average, a student was observed to spend

"84% of the time working on his/her own without interacting with either the teacher or another pupil" (p. 23). In the 1996 results, the level of teacher interaction with individual students had declined, from 72% of all interactions in 1976, to 48% of all interactions 20 years on. Unless things have changed since the 1996 results, the broad pattern of current student life in UK classroom is unlikely to involve a much greater level of interaction with teachers. We can expect this pattern to extend beyond the UK, because in most classrooms in most schools, teaching is a large group activity. The arithmetic is not complicated: With one teacher and 25 students in a one hour lesson, a teacher who was determined to spend an equal amount of time with each student would need to switch attention from student to student each 2.4 minutes!

This simple arithmetic reminds us that learning is, to an important extent, a solitary activity, even when the learner is in a group setting. Of course, the context of learning set by a teacher or parent will be an important influence on a student's learning, but within these contexts students must direct their own learning for much of the time. They must decide what to select, what to transform, what parts of their existing knowledge they should activate, and what to recall later when solving a problem. In other words, learning in classrooms and in individual study involves an important element of self-teaching. This begs the question of how well students know how to do this self-teaching.

In a recent study that investigated the extensiveness of students' knowledge about a range of learning actions that relate to some of the categories of knowledge quality identified above, we administered questionnaires to students attending three metropolitan secondary schools in Adelaide in 2007 and followed these same students across the next two years in high school (Askell-Williams, Lawson, & Skrzypiec, 2010). The three schools were located in low to upper-middle class socio-economic catchments. The questionnaires included items about cognitive and metacognitive

strategy use which were factored into a single scale of learning strategies. Examples of metacognitive strategy items included:

- When I don't understand something in this subject I go back over it again

- I make plans for how to do the activities in this subject

- When I have finished an activity in this subject I look back to see how well I did.

Examples of cognitive strategy items included:

- I draw pictures or diagrams to help me understand this subject

- I practise things over and over until I know them well in this subject

- I discuss what I am doing in this subject with others

The levels of learning strategy use reported by students across the three years is shown in the group profiles in Figure 2. The reported frequency of learning strategy use in the three schools did not change significantly across the three years.

We had expected some increase in frequency of strategy use as the students progressed through secondary school. However, it is reasonable to ask whether such an expectation was justified. Early research on metacognitive knowledge suggested that knowledge of memory strategies did increase with age (Kreutzer, Leonard & Flavell, 1975). There is more recent evidence that well-designed learning tasks can be associated with growth in strategy knowledge in early secondary school (Spörer & Brunstein, 2009). However, such growth in strategy knowledge does not appear to be an automatic outcome of all classroom learning. Koriat and Bjork (2006) and Herzog, Price and Dunlosky (2008) have argued that growth in learning strategy knowledge requires appropriate metacognitive activity, so that the generation of more precise knowledge about strategy effectiveness will be stimulated by performance monitoring and by linking the outcomes of monitoring to the prior strategy knowledge (Winne, 1996). In the light of this, our expectation of a different pattern to that shown in

Figure 2 suggests that we were being optimistic about the nature of teaching-learning interactions in our sample.

The pattern of strategy use shown in Figure 2 could be influenced by a range of factors. Perhaps learning strategy use was not an explicit focus of classroom lessons in these schools, or the students or teachers did not realize the value of these strategies. Perhaps the learning tasks that students undertook did not stimulate them to generate more complex strategy knowledge about learning, or students did not actively monitor their performance in use of such knowledge. Whatever the factors related to the pattern of findings in Figure 2, we think that there are reasonable grounds to suggest that value could be generated by working with teachers and students in similar circumstances to increase explicit cognitive and metacognitive strategy use by students in all lessons, to provide suitable conditions for the generation of high quality knowledge representations. The dimensions of knowledge quality set out in the framework Table 1 indicate areas for explicit attention during cognitive and metacognitive strategy instruction.

The grounds for this suggestion are strengthened by our in-class interviews with some of the Year 9 students whose data are included in Figure 2. Our research confirmed that, at the class level, students' verbal reports about their knowledge and use of cognitive and metacognitive strategies for learning were quite limited. Few strategies could be reported, the selection of strategies was not always well-founded, there was very limited use of strategies for structuring and developing complex relationships, and lack of spontaneous transfer across classroom tasks (Askell-Williams et al., 2010). So we feel confident that the level of strategy use shown in Figure 2 should be increased.

At a broader level, findings such as those shown in Figure 2 are not all that surprising, based on our interactions with university and school students and teachers.

It still seems that there is too little recognition by practitioners of the value to be derived from teaching about cognitive and metacognitive strategies in classrooms (Kistner et al, 2010). This seems at odds with the message coming from reviews of research set out in the texts we use with our teacher education students, and from the meta-analysis by Hattie (2009), that knowledge and use of good quality cognitive and metacognitive strategies has practically significant effects on student achievement (e.g., Bransford, Brown & Cocking, 2000; Bruning, Shraw, & Ronning, 2011; Mayer, 2008; Seifert & Sutton, 2009).

Conclusion

We see the goal of generating good quality knowledge as central to the efforts of most students, teachers and educational researchers. There is good reason to work at enabling all three groups to develop explicit and detailed knowledge about the nature of good quality knowledge representations, and of the learning actions that will generate such knowledge. In this chapter we have proposed a framework that helps to bring together a rather fragmented field of ideas about how to represent the nature of good quality knowledge and good quality learning actions. A major motivation for our pursuit of this topic is that we see evidence in schools and universities that teachers and students do not accord sufficient weight to the development of explicit, good quality knowledge in the domain of learning.

Although the dimensions set out in the framework above are broad, they encompass the multiple descriptive terms identified as indicators of good quality knowledge representations and learning actions reviewed in the earlier part of this chapter. The dimensions bring together and make explicit some features of learning quality that are either not explicit, or not present, in other discussions of learning quality. Consideration of the range of dimensions suggests that uses of *deep* as a

single synonym for high quality learning, such as that in the earlier quote from Tagg (2003), could act to limit both the theoretical analysis of quality and the more practical concerns that students and teachers have when working on ways to construct, encourage and assess good quality knowledge. As indicated in Table 1, deep is used to describe several dimensions of quality of learning. Further consideration of the role of different representational formats in the generation of good quality learning is one area for further research and instructional intervention, and the relationship between structural quality and complexity of knowledge representations also invites further investigation. Concern for a wider set of dimensions of quality suggests that each dimension should be a focus during teaching and study, including in assessment of student learning.

Karmiloff-Smith (1992) argued that explicit knowledge can be inspected and discussed by both the individual and others. Students and teachers who do not have a suitable explicit metalanguage about learning will find it hard to engage in detailed discussions about ways to generate high quality learning actions. The framework presented in this chapter consolidates a body of well-founded knowledge derived from research and provides a structure to generate and support discussions about high quality learning actions. The challenge is to work to increase the application of such good quality knowledge about learning in the actions of teachers and students.

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Table 1.

Dimensions of knowledge quality

Dimension	Descriptions in literature
Extent	Extent, extensive, quantity of major ideas, scope of knowledge, (deep).
Well-foundedness	Accurate, accord with reality, accord with the relevant knowledge community, relevant data, correctness of responses, thorough understanding (deep).
Structure	Structure, economy, capacity, well integrated (deep), organisation, shape
Complexity	relating operation, (deep) understanding, complex, precise, adequacy of justification; adequacy of explanation; elaborated, degree of synthesis, logical coherence, consistency and closure, internal consistency, integration, coherence with prior beliefs
Generativity	supportive of transfer, flexible, power, transfer appropriate processing, robust encoding, extended abstract, availability, generativity
Representational format	variety of types of memory element, imagery, knowing-in-action and personal practical knowledge, declarative, procedural, semantic, episodic, verbal/visual

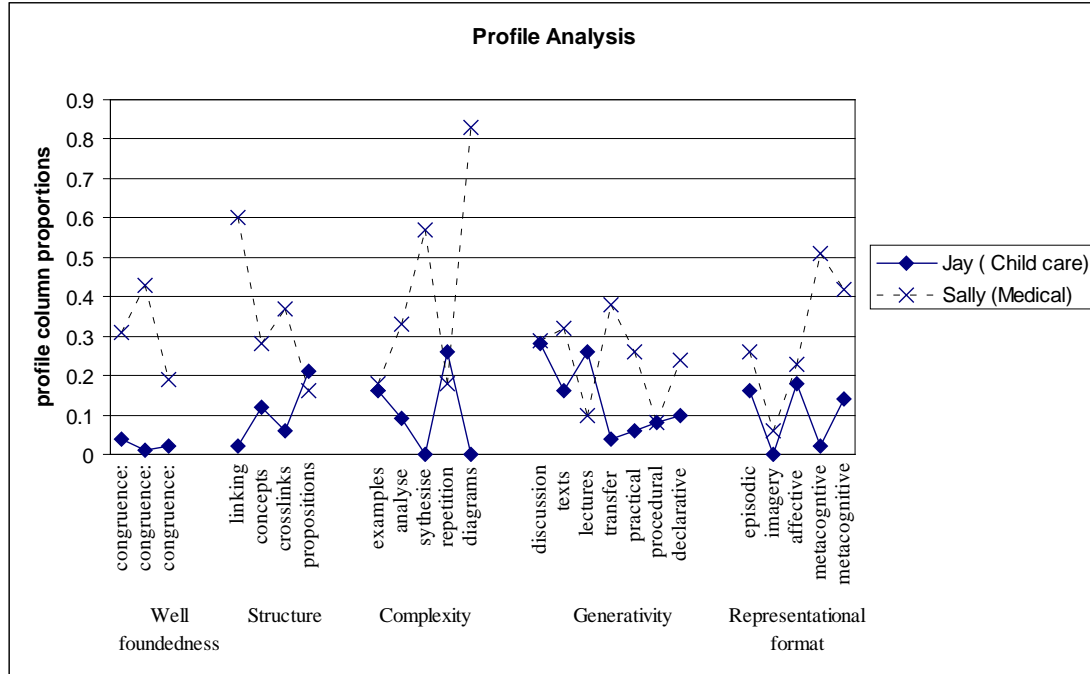Figure 1: Profile comparison using indicators of dimensions of knowledge quality.

Figure 2: Mean learning strategy use for the same students tracked across Years 7, 8

and 9.