Scaling and profiling dimensions of difference in the quality of learners' knowledge about teaching and learning

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*Constructivist perspectives propose that learners build new knowledge upon the foundations of their existing knowledge. Learners bring their existing knowledge to new learning in topic domains such as mathematics and science. Learners also possess knowledge about teaching and learning itself, including knowledge of learning strategies, learning environments, self-teaching, self-regulation, teachers' instructional intentions and activities, and so on. Such knowledge mediates learners' interactions with specific topic domains. In this paper we gather together previous research and create a Framework that can be employed to identify the quality of learners' knowledge about teaching and learning. The Framework contains 5 categories of quality of knowledge: Complexity, Structure; Foundedness; Contexts and Cognitive Representations of knowledge. We then describe the application of the Framework to 8 interview transcripts, from two diverse cohorts of learners, using NUD*IST, Correspondence Analysis and Profile Analysis. Four Dimensions of Difference in quality of knowledge about teaching and learning emerged, 1) Cognitive Schema: stockpiling to connecting; 2) Cognitive Richness: practical engagement to conceptual/abstract engagement; 3) Fruitful Learning Strategies: authentic practice to studying, and; 4) Learning Stance: incidental to intentional. Profile Analysis highlights the patterns of variables that contribute to individual differences.*

Key Words: Teaching; Learning; Quality of Knowledge; NUD*IST; Correspondence Analysis; Profile Analysis.

The importance of good quality knowledge for learning and problem solving

This research is predicated upon constructivist theory, that posits that students' existing knowledge forms the cognitive schemata into which new knowledge is networked (Nuthall, 1997).

> The strong assumption, then, is that problem solving, comprehension, and learning are based on knowledge, and that people continually try to understand and think about the new in terms of what they already know. (Glaser, 1984 p. 100)

Similarly, Sweller (1991) wrote that to ignore the contribution of an extensive knowledge base to successful problem solving is misguided:

> Our competent problem solver, rather than being a person with many powerful, general problem solving techniques at his or her fingertips, turns out to be a person with a large number of schemas allowing the classification of problems and problem states. (Sweller, 1991 p. 81)

Thus the importance of prior knowledge for facilitating the acquisition of new knowledge, in the constructivist paradigm, and in expert performance in the problem solving paradigm, has become increasingly recognised (Chi & Glaser, 1988; Eisner, 2000; Mayer, Larkin, & Kadane, 1984; Posner, 1988; Reimann & Chi, 1989; Sternberg, 1999b), and teachers are urged to employ strategies for eliciting students' existing subject matter conceptions (and misconceptions) prior to, and during, instruction (for example, Brown & Campione, 1996;

Donovan, Bransford, & Pellegrino, 1999; Faire & Cosgrove, 1988; McKeown & Beck, 1990).

Traditional evaluations of students' knowledge, such as short answer tests and application of learned algorithms to familiar problems, have targeted *what* students know. However, running parallel to attempts finding out what students know has been a continuous call for finding out *how well* students know (Novak, Mintzes, & Wandersee, 1999; White & Gunstone, 1992).

> Much recent work emphasises a new dimension of difference between individuals who display more or less ability in thinking and problem solving. This dimension is the possession and utilisation of an *organised* body of conceptual and procedural knowledge, and a major component of thinking is seen to be the possession of *accessible* and *useable* knowledge (italics added). (Glaser, 1984 p. 97)

Much earlier, Whitehead (1942) wrote about the importance of good quality knowledge and the unfruitfulness of teaching for students simply to acquire inert ideas that are functionally useless, that is, not available to be applied to problematic situations, or used to generate new knowledge. In the same vein, Kirby and Woodhouse (1994 p. 148) found that the quality of students' written summaries of texts was a powerful predictor of students' free recall of those texts. Thus good quality knowledge is important because of its direct relationship with functionality in subsequent recall and/or application tasks. Hogan and Fisherkeller (1999) proposed an interaction between reasoning processes and well-structured (good quality) knowledge:

> Knowledge and thinking are inextricably linked. A *well structured* knowledge base can sustain higher levels of reasoning than poorly structured knowledge (Novak and Gowin, 1984). Likewise, engaging in reasoning processes such as seeking information to support claims, can multiply and strengthen *connections* within a person's cognitive framework of ideas. Thus we use knowledge to reason and we reason to construct knowledge (italics added). (Hogan & Fisherkeller, 1999 p. 96)

Nickerson (cited in Boulton-Lewis, 1995) called for assessments that go beyond accessing students' recall of declarative and procedural knowledge and which, instead, tap into the level at which students understand subject matter and the quality of students' thinking. This is because

> researchers and educators have expressed concern, especially in recent years, that many students at all levels of formal education are unable to do the kind of thinking and problem solving that their school-work requires. (Nickerson, 1994 p. 411)

However, identifying *how well* students know, that is, the quality of students' knowledge, has been problematic. Indeed, it seems surprising to propose that theories or frameworks or even heuristics for identifying the quality of knowledge seem sparse. Following the seminal depth of processing work of Craik and Lockhart (1972), Jacoby and Craik (1979) pointed out that the proposition that more deep and meaningful analyses of perceptual events were accompanied by more durable memory traces was troubled by the fact that "some difficulty has been encountered in specifying exactly what is meant by 'deep' and 'meaningful' " (Jacoby & Craik, 1979 p. 1). In the same volume, J. R. Anderson and Reder (1979 p. 385) stated, "there exist no explicit rules, however, for measuring the 'depth' of a task." Similarly, Eysenck (1979) wrote

> in view of the vagueness with which depth is defined, there is the danger of using retention-test performance to provide information about depth of processing, and then using the putative depth of processing to 'explain' the retention-test performance, a self-defeating exercise in circularity. (p. 159)

Ten years later, Eysenck (1989) reiterated that "there is no adequate independent measure of the depth of processing" (p. 291). However, Eysenck pointed out the importance of Craik and Lockart's (1972) work in redirecting theorists' attention: "previous theorists had focussed largely on the stimulus-as-presented, whereas Craik and Lockhart (1979) quite correctly argued that it is the stimulus-as-encoded that is of fundamental importance to the memory theorist" (p 292). Chi and Bassock (1989) made significant progress in describing the interactive roles of monitoring understanding and self-explanation in developing understanding of principles used in text based examples. However, their research raised new questions:

> What does it mean to understand an example while studying it? How does understanding lead to cognitive monitoring? How does understanding relate to the way examples are used? Deeper analyses of our results hinge on our potential explication of *what understanding entails, how I can be represented, and how it should be assessed*. (italics added) (Chi, Bassok, Lewis, Reimann, & Glaser, 1989 p. 280)

Another ten years passed to find Mintzes and Novak (1999) asking, "What does it mean to understand …?" and "How will I know when my students have developed this ability?" (p. 42).

It is without question that educators want their students to acquire good quality, rather than inert, knowledge. Therefore, identifying the nature of good quality knowledge is an important part of planning, implementing and evaluating educational programs that have the acquisition of good quality knowledge as a goal. This paper links the imperative of identifying the nature of good quality knowledge to the general domain of knowledge about teaching and learning. This link is based upon research that highlights that knowledge about teaching and learning acts as a gatekeeper to acquiring knowledge in specific topic domains.

Teaching and learning as a knowledge domain

It seems reasonable to propose that knowledge about teaching and learning itself is a domain with which students in western educational institutions have many years of experience and hence, prior knowledge. Shulman (1986) and others (for example, Borko & Putnam, 1996; Calderhead, 1996; Putnam & Borko, 1997) have proposed various categories for classifying and investigating teachers' knowledge, and Lawson and Askell-Williams (2002) posited that learners also possess pedagogical knowledge that can be classified into categories such as General Pedagogical Knowledge and Pedagogical Content Knowledge (Shulman, 1986). Studies in the domains of self-regulation and metacognition have investigated students' knowledge about learning, particularly their own (Pressley, Van Etten, Yokoi, Freebern, & Van Meter, 1998; Winne & Hadwin, 1998; Zimmerman, 1995). Investigations into the content of students' knowledge in the form of approaches, conceptions, epistemologies, stance, goals and teacher-student congruence are predicated, either implicitly or explicitly, upon an assumption that a key goal of teaching is to ascertain the conditions that create better quality knowledge. For example, the surface-deep dichotomy clearly prescribes that *deep* approaches are better (Biggs, 1999). So are *higher* conceptions of learning (Marshall, Summers, & Woolnough, 1999; Marton, Dall'Alba, & Beaty, 1993), *congruence* between teachers' and learners' intentions (White & Gunstone, 1989), and *more effective* self-regulatory skills and attitudes (Zimmerman, 1995). In sum, the general domain of knowledge about teaching and learning is worthy of investigation because, during learning, such knowledge interacts with knowledge associated with specific topic domains (Elen & Lowyck, 2000; Pressley et al., 1998; Shulman & Quinlan, 1996; Winne & Marx, 1977; 1980; 1982). Before proceeding further, it is worth considering just what is meant by "knowledge."

A definition of knowledge

Previous writers have conceptualised knowledge in different ways. Calderhead (1996) referred to a common distinction between knowledge and beliefs:

> Although beliefs generally refer to suppositions, commitments, and ideologies, knowledge is taken to refer to factual propositions and the understandings that inform skillful action. (p. 715)

This distinction accords with the perspective that knowledge claims have to satisfy a truth condition, whereas belief claims do not (Munby, Russell, & Martin, 2001). However, as Calderhead admitted, some of what people might call beliefs are considered by other people to be fact-based knowledge, and vice versa. Philosophical questions of what is fact-based knowledge also enter this debate, for a radical constructivist would argue that there are no empirical facts, only viable interpretations (von Glasersfeld, 1998), whereas a realist would call upon the limitations of the physical world to provide potentially falsifiable scientific evidence (Phillips, 2000; Sternberg, 1999a). To the radical-realist debate we must add the diverse positions of social constructivist theorists, who stress that knowledge is constructed, and only has meaning within, its idiosyncratic social context (Prawat & Floden, 1994).

Alexander, Schallert and Hare (1991) adopted a broad definition of knowledge:

> Knowledge refers to an individual's personal stock of information, skills, experiences, beliefs and memories. This knowledge is always idiosyncratic, reflecting the vagaries of a person's own history. This use of the term knowledge contrasts with the use of the term in the field of epistemology, where knowledge often refers to justified true beliefs and is reserved for universal, or absolute truths. Rather…knowledge encompasses all that a person knows or believes to be true, whether or not it is verified as true in some sort of objective or external way. (Alexander et al., 1991 p. 317)

Alexander et al's (1991) definition seems suited to our research purpose of investigating what people actually say they know, for, in practice, there may be little difference in a person's actions that are based upon his or her beliefs, and actions based upon a tighter definition of knowledge. Therefore we have adopted Alexander et al's definition to underpin the research described in this paper. To this definition we must also add a qualifier, in that our research can only deal with knowledge that is functionally available to participants at the time of our research intervention. It is conceivable that participants might hold knowledge that due to situational (e.g., inappropriate contexts), physical (e.g., tiredness), emotional (e.g., anxiety), or other constraints, is not functionally available. Although our research procedures sought to authentically situate the data collection interviews, and to probe participants' knowledge to its fullest extent, we cannot claim that we are able to access all of any participant's knowledge. Thus our use of the word knowledge in this paper must be understood to be prefaced by the words "functionally available."

Prior research into the quality of knowledge

Researchers have addressed issues of quality of knowledge from different perspectives and using different terminology (e.g., depth of processing; levels of outcomes; connectedness; schemas). The criteria employed to determine the quality of knowledge in those various areas of interest have varied. From a philosophical perspective, Kerr (1981) posited that internal quality can be ascribed to an act only if a person's intentions are congruent with his or her plans, which in turn are congruent with his or her actions. Intentions, plans and actions are informed by knowledge, which, in turn, needs to meet a criterion of external quality through being grounded in the best available knowledge held by the relevant knowledge community.

From a research perspective, early depth of processing studies relied upon single indicators of quality, such as encoding information with "meaning." Meaningful encoding required more abstract and interrelated thinking that relied less upon perceptual input (Craik & Lockhart, 1972). Jacoby and Craik (1979) developed Craik and Lockart's conception of what was meant by "meaningful," adding, "greater degrees of elaboration of the stimulus {so as to} allow formation of a more distinctive, discriminable trace" (Jacoby & Craik, 1979 p. 19). McMurray and McIntyre (1981) appeared to employ a single criteria for establishing depth, namely, participants' identification of which task, in paired comparisons, required more conscious effort or attention for completion.

Another uni-dimensional approach, although based in a different research paradigm, emerged from Marton and Saljo's (1976a) analysis of participants' responses to meaning-based questions about selected text passages. Marton and Saljo's assessment of quality appears to rest upon participants' "conceptions of the intentional content of the passage" (Marton & Saljo, 1976a p. 8).

A related and substantial contribution to identifying the quality of students' knowledge was made by Biggs and Collis (1982) with their four-dimensional Structure of Observed Learning Outcomes (SOLO) taxonomy. Biggs and Collis' dimensions encompass 1) Capacity, which refers to working memory, 2) Relating operation, which refers to the way in which an instructional cue and the student's response interrelate, 3) Consistency and closure, which refers to the student's a) attempts at conclusions and b) consistency between data and conclusions or between different possible conclusions, and 4) Structure, which represents the relations between cue, data and response(s) in diagrammatic form. Biggs and Collis operationalised the SOLO taxonomy by providing exemplars of its application to different topic domains, thus providing a valuable resource for criterion-based assessment.

A multi-dimensional perspective of cognitive (memory) structure was proposed by White (1979) and White and Gunstone (1980). White's (1979) initial dimensions of the quality of memory structure were 1) extent, 2) precision, 3) internal consistency, 4) accord with reality, 5) variety of types of memory element, 6) variety of topics, 7) shape, 8) ratio of internal to external associations, and 9) availability. White's work highlighted the importance of a broad conception of what constitutes good quality knowledge:

> No one of these summary measures of extent … is by itself a sound measure of understanding. The point is that understanding is not identical with any one of these measures. Understanding is a complex multi-factor notion that cannot be described simply. (White, 1988 p. 72)

Since their early papers, White and Gunstone (Gunstone & White, 1986; White, 1988; White & Gunstone, 1992) and others (for example, Edmondson, 1999; Martin, Mintzes, & Clavijo, 2000; Mintzes & Novak, 1999; Pearsall, Skipper, & Mintzes, 1997) have made considerable progress with the evaluation of the quality of cognitive structure using techniques such as concept maps, epistemological vees, verbal protocols and word association tasks.

Indeed, cognitive structure (connectedness, linking, relating) has emerged as a possible chief indicator of quality of knowledge. For example, Wittrock (1990) wrote about understanding and comprehension, *constructing relations* between experience and new information, and generating interactive images *between* the old ideas and new events. He observed that researchers' interest in issues such as time on task and practice had waned because such constructs had not definitively proved to be mediators that influenced learning. Wittrock proposed a *generative* model of reading comprehension that involved the learner in creating meaning by *constructing relations,* a) among the parts of the text, and b) between the text and what learners already know, believe and experience. These processes would lead the learner to "good" reading, (and "effective" writing). The descriptors "good" and "effective" suggest that Wittrock also was interested in specifying the necessary conditions for achieving quality knowledge. A key point in Wittrock's analysis is that new knowledge is created through the construction of relations between, and organisation of, old and new information.

Pearsall, Skipper and Mintzes (1997) and Martin, Mintzes and Clavijo (2000) also investigated the organisation of knowledge:

> Research in the cognitive aspects of science learning has provided strong evidence that successful science learners as well as professional scientists develop *elaborate, strongly hierarchical, well-differentiated*, and *highly integrated frameworks* of *related* concepts as they construct meanings ….[and] the ability to reason well in the natural sciences is constrained largely by the *structure* of domain-specific knowledge in the discipline. {italics added} (Martin et al., 2000 p. 195)

Note the italicised words in the above Martin et al. quote: All describe a relationship between good quality knowledge and knowledge structure. Martin et al. scored the structural complexity of college students' domain specific concept maps according to six criteria, namely, concepts, relationships, hierarchy, branching, cross links and interconnectedness. By assessing change in the structural complexity of participants' concept maps, Martin et al. concluded that knowledge increases in quality in a stepwise, gradual and cumulative process, with periods of weak and radical change. Furthermore

> integration of new concepts does not keep pace with overall growth of the knowledge framework … students are adding concepts to the knowledge frameworks more rapidly than they are integrated, suggesting a significant amount of rote learning … [which may] place significant constraints on the ability of students to use knowledge in novel settings. (Martin et al., 2000 p. 321)

Similar thinking can be found in the work of Mayer and Greeno (Mayer, 1975; Mayer & Greeno, 1972), who wrote about internal and external connectedness between "nodes" in the memory network. Mayer and Greeno proposed that differences in learning outcomes might vary along three dimensions. The first would be a quantitative measure of the *amount* new nodes acquired by the learner during a learning event. The second dimension, internal connectedness, models the degree to which the new nodes are connected with each other in a single schema. Third, external connectedness, models the degree to which new nodes are connected to prior knowledge. Mayer's internal and external connectedness can be mapped onto Wittrock's (1990) connections between a) parts of the text and b) between the text and what the learner already knows, respectively. Mayer found that teaching that targeted either internal or external connectedness led to differential learning outcomes. Teaching that focussed upon internal connectedness led to better performance on near transfer problems. Teaching that focussed upon external connectedness led to better performance on far transfer problems. Such outcomes can be considered to be of better or worse quality, according to the objectives of the instruction.

Organisation of knowledge was addressed by Chi (1985) in her detailed studies of young children's categorisation of classmates' names and dinosaurs. Chi made three points that are of interest to this paper. The first, which connects with the work of Wittrock (1990), is that young children do appear to organise information into hierarchical categories (although these categories may not be the same as categories chosen by adults) and that such categorisation appears to facilitate recall. To support this, Chi provided the example of a 5-year-old child who could recall all of her classmates' names, based upon each child's classroom seating position. Furthermore, it was possible to train the child to successfully apply a new classification system (alphabetical) to the same content. (Chi extends this argument to propose that content knowledge {the children's names} interacts with strategy knowledge {categorisation} to facilitate recall).

A second observation made by Chi was that it is possible to make a distinction between information that is *linked* in memory (*robin* linked to *bird*) and information that is *hierarchically organised* (*robin* embedded in *bird* category) in memory. This distinction between *linked* and *hierarchically organised* appears to be a similar distinction to that made by Wittrock (1990) (above) when discussing *relations between*, and *organisation of*, information. A third proposition of Chi's was that children are able to categorise (pictures of dinosaurs) either by attending to perceptual features, such as duck bills, or by invoking higher order principles (based upon expert knowledge) such as plant or meat eater. The novice participants in Chi's study only used perceptual information to sort pictures of dinosaurs: expert participants were able to use both perceptual and abstract features to guide sorting. Furthermore, perceptual classification seemed to be subordinate to principled classification. This finding seems related to the work of Biggs and Collis (1982) and L. A. Anderson and Krathwohl (2001) (discussed below), which propose a concrete to abstract dimension in the quality of knowledge.

The original Taxonomy of Educational Objectives (cognitive domain) (Bloom, 1956), as well as its updated version, edited by L.W. Anderson and Krathwohl (2001), represent attempts to classify and align different levels of instructional objectives, instructional interventions and assessments. The 2001 revision of the taxonomy is two-dimensional and forms a neat matrix of cognitive processes as column headings (Remember, Understand, Apply, Analyse, Evaluate and Create), and types of knowledge as row headings (Factual, Conceptual, Procedural and Metacognitive). The cognitive process dimension moves from less to more complexity. The knowledge dimension moves from concrete to abstract representations. It would seem that both dimensions, concrete to abstract, and simple to complex, are designed to capture an intention to teach and assess in such a way as to promote the acquisition of high quality knowledge.

The four row headings in the revised Bloom taxonomy (Factual, Conceptual, Procedural and Metacognitive knowledge) highlight that different *types* of knowledge have been subjected to investigation. Certainly, more than four knowledge types have emerged from the work of various researchers, as documented by Munby, Russell and Martin (2001):

> Situated knowledge (Lienhardt, 1988), event-structured knowledge (Carter and Doyle, 1987), personal practical knowledge (Connelly and Clandinin, 1985; Elbaz, 1983). images (Calderhead, 1988, Clandinin, 1986), and knowing-in-action (Schon, 1983)…metaphors (Munby, 1986), voice (Richert, 1992), and craft knowledge (Grimmet & MacKinnon, 1992).…tacit understanding (Polyani, 1962), reflection (Schon, 1983, 1987), authority of experience (Munby and Russell, 1992, 1994), nested knowing (Lyons, 1990) and reframing (Munby and Russell, 1992).…novice and expert teacher (Berliner, 1986; Bullough, Knowles and Crow, 1991; Kagan and Tippins, 1992; Peterson and Comeaux, 1987; Shulman, 1987a…. (Munby et al., 2001 p. 887)

It is possible to add other types of knowledge to Munby et al's list, such as declarative and procedural knowledge (Anderson, 2000); Chi's (1985) fact- and rule-based knowledge; Tulving's (1972) semantic and episodic knowledge; Hiebert's (1986) and Rittle-Johnson and Alibali's (1999) conceptual and procedural knowledge; Flavel's (1979) metacognitive knowledge, and; domain expertise and topic specific knowledge (Sternberg, 1999b).

It seems reasonable to propose that a combination of types of knowledge would provide a quality dimension of richness, that would be superior to knowledge that is represented in only one way, for example, only as declarative knowledge, or knowledge represented only as mental images (Borko & Putnam, 1996; Munby et al., 2001). A similar proposition was put forward by White and Mayer (1980) who suggested four types of knowledge: intellectual skills (procedures), verbal knowledge (facts), images, and episodes (knowledge of past events; a subset of verbal and/or image). White and Mayer argued that possession of more than one type of productive knowledge, as appropriate to any specific skill, could lead to better understanding (or better quality knowledge). Productive knowledge might include analogies, concrete examples, definitions of concepts, and explanations of rules (p. 106). Later, White (1988) and White and Gunstone (1992) extended the idea of types of knowledge to propose seven types of *memory element:*

> The relative proportions of strings, propositions, skills, images and episodes affect the quality of understanding. A person whose knowledge of a concept is almost wholly propositional has a different form of understanding than someone with many images or episodes. Episodes may be particularly important in understanding, as they give a feeling of confidence in the accuracy or credibility of the knowledge. It is one thing to learn the proposition that metals expand when heated, another to see it happen, especially on a large scale such as gaps in railway lines or in the expansion plates of bridges. (White, 1988 p. 51)

By working within a classification system of different types of knowledge it is possible for educators to become aware of whether certain types of knowledge are being over-stressed or neglected during instruction, thus potentially affecting the quality of knowledge that students might construct (White, 1988; White & Mayer, 1980).

A detailed approach to judgements of quality of knowledge was reported by Hogan and colleagues (Hogan, 1999a; Hogan, 1999b; Hogan & Fisherkeller, 1999; Hogan, Nastasi, & Pressley, 2000) who produced a series of papers that documented eighth grade students' depth of cognitive processing in collaborative knowledge building groups. Hogan recorded students' verbal protocols as they jointly, through discourse, constructed mental models about the nature of matter. To assess students' reasoning complexity, Hogan created a rubric containing six criteria: generativity, elaboration, justifications, explanations, synthesis and logical coherence. The first five criteria vary along a quantitative dimension (none; some--one or two; multiple--three or more). The sixth criterion, logical coherence, varies along a continuum of vague--clear--solid. Interestingly, initially Hogan intentionally did not assess students' verbal protocols for the scientific "correctness" of their ideas. Instead, the teachers', and the researchers', intentions were to develop and investigate students' engagement in scientific reasoning processes (even if the students may have been, say, elaborating or justifying misconceptions). However, in a later paper, Hogan and Fisherkeller (1999) re-presented the reasoning complexity rubric, and also presented a bi-dimensional coding scheme for comparing students' statements to expert propositions. This scheme has seven levels, ranging from no evidence of compatibility to compatible. Compatibility with the scientific community seems to parallel Kerr's (1981) proposition that quality knowledge needs to be well-founded in the relevant knowledge community. Hogan's work to identify reasoning complexity and statement compatibility seems similar to our quest to explicate dimensions of quality of knowledge.

McKeown and Beck (1990) investigated the quality of fifth and sixth grade students' knowledge about the historical period leading to the American Revolution. McKeown and Beck argued that

> knowledge is not a one dimensional phenomenon and, thus, "having knowledge" is not a yes/no proposition; there are many subtleties in the character and arrangement of individuals' knowledge. (p. 689)

McKeown and Beck employed measures of correctness of responses, quantity of major ideas, quantity of elaborative ideas, relationships between ideas, and organisation of ideas, to ascertain the quality of students' knowledge. The researchers found that the students' knowledge was sparse, poorly connected and often confused into cognitive "stews." Interestingly, McKeown and Beck also uncovered that students held a considerable amount of informal knowledge (often incorrect), gained from general life experiences, and that the informal knowledge informed the students' schemas and subsequent hypotheses about events. It was also found that instruction could enhance the correctness of students' knowledge. However, if instruction was presented without an overall structure, it could contribute to the making of a cognitive stew.

Lawson, Askell-Williams and Murray-Harvey (2003) asked Teacher Education students, "What happens in my university classes that helps me to learn?" Two premises drove that question to students. The first was that the quality of students' knowledge about what helps them to learn would mediate the students' interaction with their own learning processes, which would in turn mediate their interaction with the topic of study. The second, was that in the case of Teacher Education students, the quality of their knowledge about their own learning could be expected to mediate their pedagogical interactions with their own (prospective) students. Lawson et al. created a *generative power* rubric, which was used to classify students' statements about one teaching and learning strategy: class discussions. The rubric contained four levels of generative power, ranging from propositions with no elaboration (level 1), through elaboration (level 2) and implication (level 3), to effects on learning and links with theory (level 4). Lawson et al. found that the generative power of students' knowledge ranged from very low to high. This has implications for the effectiveness of students' engagement with their own learning, and certainly would seem to have implications for their ability to generate productive learning experiences for their own students in a key pedagogical technique such as class discussions. The findings also raise questions about the degree of explicit teaching, rather than immersion, that is required so as to inform students about the strengths and weaknesses of different pedagogical techniques.

With the hindsight that the passage of time affords it becomes possible to draw together some of the previous research to look for commonalities between researchers in the identification of categories of quality of knowledge. The number of criteria and/or dimensions for assessing quality has ranged from one (Craik & Lockhart, 1972; Marton & Saljo, 1976a) to two (Anderson & Krathwohl, 2001), to four (Biggs & Collis, 1982; Mintzes & Novak, 1999), to six (Hogan, 1999a; McKeown & Beck, 1990), to nine (White, 1979; White & Gunstone, 1980). Our assessment is that good quality knowledge most likely is comprised of many categories, and that scope exists to build upon previous research so as to more fully differentiate and explicate those categories. With this in mind, in the next section we have organised the work of previous researchers into five categories.

Categories of Quality of Knowledge about Teaching and Learning

Complexity

Hogan's (Hogan, 1999a; Hogan, 1999b; Hogan & Fisherkeller, 1999; Hogan et al., 2000) and Lawson et al's (2003) work suggests that knowledge can range in complexity, from simple statements (perhaps declarative, linking to J. R. Anderson, 2002) to more complex statements, such as justifications and elaborations. The use of analogies and metaphors, making connections between components in a domain, and relating to prior knowledge, all suggest more complex cognitive schema (Anderson, 2000). Processes such as analysing, synthesising and re-conceptualising link, once again, to Anderson and Krathwohl's (2001) processes columns in their Taxonomy.

Structure

The SOLO (Biggs & Collis, 1982) construct of relating operation appears coherent with information processing models of cognition that include connected structures such as networks and schemas (Anderson, 2000), as well as with the work of Wittrock (1990), Chi (1985), Pearsall, Skipper and Mintzes (1997), Martin, Mintzes and Clavijo (2000), White and Gunstone (1980; 1992) and McKeown and Beck (1990). This suggests a connectedness, linking, or structural category.

Well-foundedness

In White and Gunstone's (White, 1979; White & Gunstone, 1980; White & Gunstone, 1992), Biggs and Collis' (1982), Hogan and Fisherkeller's (1999), Marton and Saljo's (1976a; 1976b), Kerr's (1981), and McKeown and Beck's (1990) work, there seems to be an argument for "quantity of *correct* propositions" as being a potential category of external well-foundedness. Well-foundedness can also be viewed from an internal perspective of congruence between a person's knowledge/beliefs, intentions, plans and actions (Kerr, 1981).

Contexts

The extended abstract level in SOLO (Biggs & Collis, 1982), which accounts for alternative conclusions according to possible modifiers and constraints, hints at issues of context, situational applicability and generalisation and transfer. Such issues have also been discussed by Mayer & Wittrock (1996) and Rittle-Johnson and Alibali (1999).

Cognitive Representations of Types of Knowledge

White and Gunstone's (1992) seven elements, J. R. Anderson's (2000) declarative and procedural knowledge, L. W. Anderson and Krathwohl's (2001) row categories, as well as the overview of knowledge types provided by Munby et al. (2001), suggest that knowledge can be held in diverse ways and that multiple types of representations might be qualitatively better than a single representation. Related to this is the work of researchers and theorists such as Lave (1988), Wenger (1998), Derry (1996) and Lakomski (1999), who highlighted the robust nature of knowledge gained through legitimate experiences and practice in authentic situations.

We have taken the five categories introduced above to create a Framework of Quality of Knowledge about Teaching and Learning (the Framework). The Framework is displayed in Table 1, where it can be seen that each category contains one or more variables that can be used to interrogate, in the present case, verbal protocols obtained from focussed interviews. For example, (reading down the column), the category *Complexity of statements during interview* contains the variables *interviewer questions and prompts, propositions, examples, pose questions, cause-effect statements, analogies/similes/metaphors*, and so on.

Table 1: Framework of Quality of Knowledge about Teaching and Learning

Complexity of statements during interview	Structuring of statements during interview	Foundedness of statements	Contexts of descriptions of learning activities	Cognitive representations of knowledge
Questions and prompts stated by interviewer.	Organising statements.	Congruent with teaching & learning theory.	Disengaged from learning.	Automated/ routine knowledge.
Propositions.	Summarising statements.	Congruent with the program of instruction.	Passive absorption of knowledge.	Knowledge embedded in authentic practice.
Examples.	Concepts.	Congruent with teachers' statements.	Learning through repetition.	Procedural knowledge (knowing how).
Cause-effect statements.	Cross-links.	Congruent with peers' statements.	Using mnemonics.	Declarative knowledge (knowing that).
Analogies/ similes/ metaphors.		Not congruent with teaching & learning theory.	Learning from texts.	Memories of episodes in time and place.
Analysing statements.		Not congruent with the program of instruction.	Learning from lectures.	Affective/ emotional knowledge .
Relate to prior knowledge.		Not congruent with teachers' statements.	Learning through discussions/ asking questions.	Mental images/pictures.
Relate topic components.		Not congruent with peers' statements.	Drawing/ using diagrams/ flow charts.	Mental aural representations.
Participant poses questions during interview.		Congruence between Knowledge/Beliefs, Intentions, Plans and Actions.	Learning through willing immersion in the work place.	Mental kinaesthetic representations.
Synthesise a bigger picture.			Awareness of situational affordances & constraints.	Metacognitive knowledge (knowing about knowing).
Reconceptualise.			Transferring learning to different situations.	Metacognitive experiences (feeling about knowing).
				Metacognitive goals (objectives of thinking).
				Metacognitive strategies (ways of thinking).

The remainder of this paper describes the application of the Framework in Table 1 to a sample of eight interview transcripts. Our purpose is to identify Dimensions of Difference in the Quality of Knowledge about Teaching and Learning (Dimensions of Difference) held by learners from different academic backgrounds. A brief summary of the procedure to be described in detail in the remainder of this paper is

1) Conducting in-depth, focussed interviews with targeted samples of learners from diverse academic backgrounds.

2) The use of NUD*IST (QSR, 1997) software to code, and then count, statements in the eight interview transcripts in accordance with the categories and subcategories in the Framework in Table 1.

3) The application of Correspondence Analysis (SPSS, 1995) software to the frequency data obtained from Step 2, so as to uncover Dimensions of Difference and Profiles.

4) Interpretation of the Dimensions of Difference and the Profiles.

Method

Participants and Sites

We selected two participant groups that seemed to have the potential to capture learners engaged in what might reasonably be considered to be different levels of academic achievement in learning, and for whom the press to engage in detailed analytical study could be expected to be different. The first group contained seven students enrolled in the third (clinical) year of a graduate entry, four year, medical education program run by a university in South Australia. Thus, these seven participants had all completed an undergraduate degree, in some cases had completed post-graduate qualifications, and one participant held a PhD in science. Furthermore, the seven students had undergone a further selection process, based upon interview and performance in the first two years of the medical degree, for entry into an innovative new program of rural, community-based, clinical placement. The high level of academic achievement that the participants in this group had achieved suggested that we could expect these students to have had considerable exposure to formal teaching-learning environments and to have developed knowledge and strategies to enable them to achieve success in such environments.

The second group in the study included 12 students taking a Certificate Level III in Community Services--child-care, run by a Technical and Further Education College in South Australia. This certificate is of one-year duration, and equips students to gain base-level (unqualified) employment as a child-care worker in a child-care centre. Participants' prior educational level ranged from minimal secondary schooling to completion of five years of secondary schooling, with the exception of one student who was concurrently enrolled in degree studies at university. Compared to the students in the medical sample, the students in the child-care sample could be expected to have experienced considerably less exposure to formal teaching-learning environments, and had not necessarily achieved success in such environments (as did become evident during the students' interviews).

All participants gave voluntary consent to be interviewed. Participants' ages in both groups ranged from mid 20s to mid 40s. They were of British and/or European heritage. All names used in this paper are pseudonyms.

Although the content of the medical course and the child care course was vastly different, the two courses had interesting similarities. The structure of the child-care course and the medical course was such that students spent Wednesday of each week in classroom based activities such as lectures, small group discussions, video presentations and, in the case of the medical students, problem-based learning sessions. The other days of the week required the students to attend rostered, on-the-job, training. For child-care students, this training was at a fully operational, metropolitan, public access, child-care centre. For medical students, training was at rural, community-based general practice surgeries and public, rural community hospitals. A second point of similarity between the two courses lies in the area of developing effective interpersonal relationships. Medical practitioners interact with patients, clients' immediate and extended families, related health and other professionals, community organisations (shelters, support groups) and so on. Child-care workers interact with the children in their care, and also with immediate (sometimes estranged) family, extended family, related human service and other professionals, community organisations (libraries, play groups, pre-schools) and so on. Thus the nature of the teaching and learning that the two participant groups engage with is both different, and similar.

Interviews

We reviewed the teaching and learning literature to compose a set of 18 focus questions to guide the direction of each interview. The focus questions and their broad theoretical foundations are included at Appendix 1. Each interview also included extra probing questions according to the idiosyncratic direction that each interview took.

In particular, our aim was to comprehensively capture each participant's understandings about their own learning *in action*. This, 1) was based upon our recognition of the importance of all three vertices of Bandura's (1997) cognition, environment and behaviour triangle of social-cognitive theory, 2) heeds the role that context plays in teaching and learning (Lave, 1988), and 3) adheres to Candy's (1991, p 457) suggestion that 'the person in context' be the main unit of analysis. Interviews were therefore conducted at participants' usual place of learning, either during a break in, or immediately after, a learning session. Each interview lasted from about 20 to 90 minutes, with the average being about 45 minutes. Interviews were transcribed verbatim.

It is possible to question the authenticity of data collected via interviews. Participants might espouse theories that may not reflect their actual behaviours (Argyris & Schon, 1974), or might account for their thoughts and behaviours according to their interpretations of the interview situation and the interviewee/interviewer relationship (Saljo, 1997). However, the fact remains that the only way to find out about what a person is thinking is to collect that person's personal account (Ericsson & Simon, 1993). Our assessment of the interviews conducted for this study is that all participants seemed to engage keenly in the interview process, and that they took care to attempt to tell as full and truthful an account of their knowledge as they could in response to the focus questions. Indeed, many participants indicated their appreciation of the interest that we were taking in their learning, and also the opportunity that the focus questions provided for them to reflect upon their own learning.

Coding the interview transcripts

Previous experience with in-depth coding of interview transcripts had alerted us to the time-consuming and resource-demanding nature of the coding task. Ideally, we would have preferred to code all 19 transcripts, however, we decided, at this stage of our investigation, to code eight transcripts that appeared to contain, with initial reading, responses that were quite diverse. By way of an illustration of the size of the coding task, the eight transcripts generated 35,683 data points. Each transcript took 30 to 40 hours to code.

Each interview transcript was segmented into statements of meaning. A statement of meaning consists of a word or a phrase that contains one identifiable idea. Next, each statement of meaning was coded, using NUD*IST software, according to the categories in the Framework (Table 1). It is important to note that any statement could be coded to more than one category, thus the total number of codes per transcript exceeds the total number of statements per transcript. This multiple coding procedure was selected after trials of both multiple and discrete coding. We assessed that multiple coding captured more of the richness in the data and also permitted us to interpret statements from multi-dimensional, rather than uni-dimensional, perspectives. Table 2 provides a sample of the statements of meaning and the coding, (for seven variables only), from Sally's (medical) transcript.

Reading Table 2 from left to right, it can be seen that statement 504 is coded B, proposition, as this is a simple statement of Sally's belief. Statement 504 is also coded E, organising, as Sally indicates that she is about to talk about more than one thing. Statements 506 to 508 are coded D, cause-effect, as Sally's view of PBL (problem based learning) as an "academic thing" affects her actions (which are recounted in later statements). It can be seen that statement 508 is coded C (examples). Statement 535 is another cause-effect statement describing the actions that flow from Sally's intention to make sure that she "covers everything she can" (527). Statement 535 is also a brief summarising and closing statement of the actions described above, and so is also coded F.

Three variables did not progress to further analysis. Two, *not congruent-peers* and *kinaesthetic representations* did not appear in any of the eight participants' transcripts. In the case of the third variable, *internal congruence between knowledge, intentions, plans and actions,* we assessed that each participant's statements of knowledge and beliefs did accord with their stated intentions and plans, which in turn accorded with their recounts of their actions. All transcripts were allocated *yes* in a dichotomous *yes/no* scoring of this variable. Therefore, the variable *internal congruence*, although conceptually important, clearly had no potential to differentiate between participants, and so was not included in further analyses.

Table 2: Sample of coding from Sally' s (medical) transcript

		Variables					
		B	C	D	E	F	G
ID	**Statements**	propositions	examples	cause-effect	organising	summarising	cross-links
504	The extra yards I am doing is..um...with...oh there's a couple of things	B			E		
505	With PBL cases, I see PBL cases as an academic thing			D			
506	that we are given time to do away from clinic			D			
507	so I'm expected to be at PBL on Wednesdays,			D			
508	it's not a day that I would go and see patients.		C				
509	So it's an academic day.						
510	It's rostered on as an academic day.						
511	So I feel that if I go into PBL and			D			
512	I have to do this sort of stuff on my own time,		C				
513	after work on the weekends,		C				
514	if I go in with the PBL having researched as much as possible,			D			
515	gone through the learning issues,			D			
516	done the extra reading.			D			
517	If I just focus on what I'm doing in my PBLs and			D			
518	maybe not so much of the things I'd like to research			D			
519	that I've seen in the clinic,			D			
520	like I'll put them on a list		C				
521	and wait later,		C				
522	that eventually the PBLs will catch up with a lot of what I'm seeing,			D			G
523	or touch on a lot of what I'm seeing and			D			G
524	if it happens after	B					G
525	or it happens before,	B					G
526	that's no big deal,	B					G
527	but by making sure that I cover everything I possibly can in the PBL,			D			G
528	then I know I've given myself a pretty good sort of academic lead up			D			G
529	into those sort of medical problems and						
530	I expect to catch up on the seeing the patient and		C				G
531	doing the sort of things I told you about,						
532	that sort of level of putting a real life situation and		C				G
533	mixing it with the text book,		C				G
534	academic side of it.		C				G
535	So I do that.			D		F	

Creating a contingency table

The coding procedure enabled the generation of a two-way contingency table representing the frequency of occurrence of each variable in each participant's transcript. A portion of the contingency table is presented in Table 3.

Table 3: Portion of contingency table: Raw frequencies of variables in 8 interview transcripts

	PROPOSITIONS	EXAMPLES	CAUSE-EFFECT	ANALOGY/ METAPHOR	ORGANISING	SUMMARISING	XLINKS	n=43
Josi:Med	62	406	482	45	26	44	378	5515
John:Med	99	318	250	25	12	29	200	3245
Rory:Med	173	539	723	50	40	57	285	7521
Sally:Med	112	485	1102	180	32	85	771	10446
Cait:CC	46	175	311	7	0	26	214	2930
Jay:CC	145	413	275	11	3	4	107	3575
Jen:CC	55	191	159	7	3	5	111	1725
Bec:CC	17	113	49	2	0	0	23	726
Margin totals	709	2640	3351	327	116	250	2089	**35683**

From Table 3 it can be seen that the statements in Josi's (medical) interview transcript were allocated 5,515 codes, of which, 62 were *propositions*, 406 were *examples*, 482 were *cause-effect statements*, and so on. A total of 35,683 codes were assigned to account for the 45 variables of quality of knowledge in the eight interview transcripts.

Comparing the totals of participants' responses permits a preliminary analysis of the data. Figure 1 is a plot of participants' coded statement totals (across 44 variables, with the exclusion of the variable *prompts,* which is a record of the interviewer's questions and prompts).

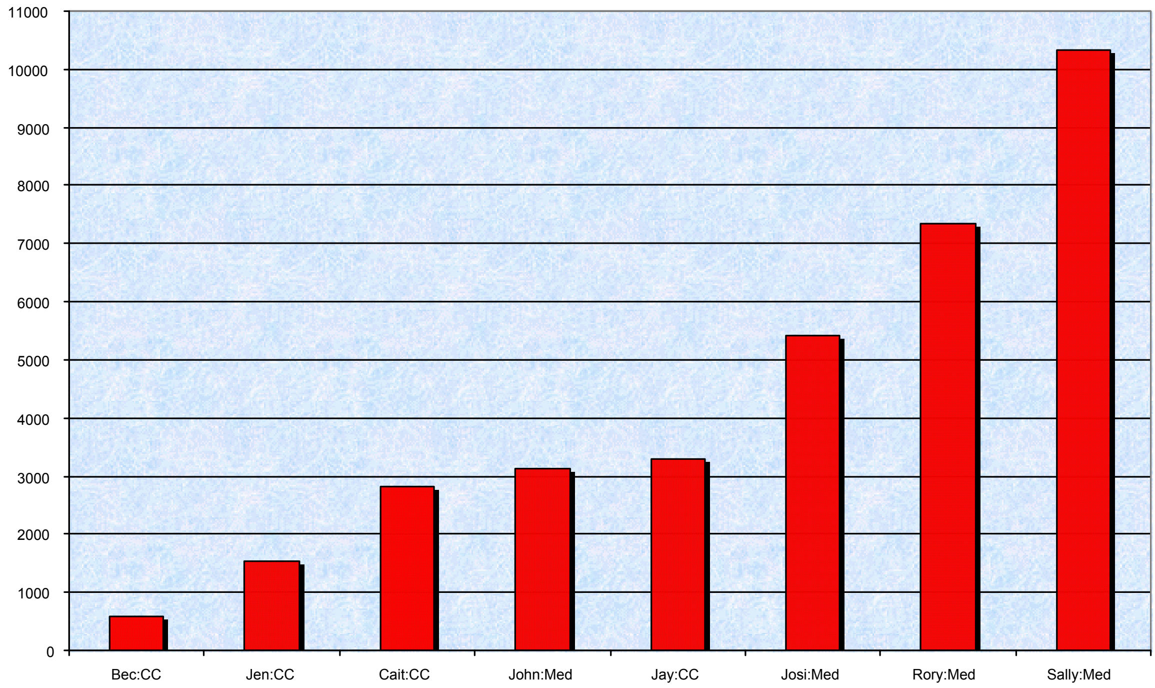

Figure 1: Participants' coded statement totals.

Clearly, from Figure 1, there is a large difference in the extent of individual participant's functional knowledge, ranging from under 1,000 coded statements to over 10,000 coded statements. The chart in Figure 1 also hints at group differences, with most of the child-care students at the low frequency end of the chart and most of the medical students at the high frequency end. It is worth restating at this point that each interviewee was presented with the same focus questions (Appendix 1), and each participant was prompted to expand his or her answers to each question as fully as possible. Nickerson's (1985 p. 235) observation, "the more one knows about a subject, the better one understands it," suggests that such differences between participants' levels of knowledge might be a vital indicator as to the potential quality of their knowledge.

As well as investigating frequencies, the data collected from the coding task has the potential to be explored more thoroughly. To achieve this, we turned to Correspondence Analysis.

Correspondence Analysis

Correspondence Analysis is an exploratory compositional technique that seeks associations amongst pre-determined categories (Hair, Anderson, Tatham, & Black, 1995). Correspondence Analysis employs chi-square distances to calculate the dissimilarity (or similarity) between the frequencies in each cell of the contingency table. The concept underlying the calculation of the chi-square distances is cell-independence. Cells (such as those for participants and variables in Table 3) whose observed and expected values are the same can be considered to be independent. Cells whose observed and expected values are different can be investigated further to ascertain patterns of interdependence. A major task for the researcher with Correspondence Analysis is to select the appropriate numbers of dimensions and to interpret the meaning of those dimensions. Correspondence Analysis contains an option that permits the placement of participants and variables in the same graphical representation, thus permitting comparisons between the relative placements of people and variables.

Different methods of creating the graphical representations has caused debate in the literature about the most appropriate choice of normalisation and methods of interpretation of the visual display (Gabriel, 2002; Greenacre, 1984; Hair et al., 1995; Nishisato, 1994; SPSS, 2001). Gabriel (2002) calculated goodness-of-fit for the various forms of graphical representation available in Correspondence Analysis. He concluded that researchers who have a specific interest in actual magnitudes of difference between rows (participants) or columns (variables) should choose the appropriate principal normalisation (row or column). However, researchers whose interest lies in comparing the general orientation of row points and column points, rather than visualising actual magnitudes, are well served by the symmetrical normalisation option:

> The symmetric biplot, in addition to its optimal fit of the data, proportionally fits the form and the variance almost optimally and is an excellent candidate for general usage, unless one requires representation of the actual magnitudes [Gabriel, 2002 #684 p. 435)

Our concern in the current project lies with interpreting the meaning of the dimensions extracted in the low-dimensional solution, and in interpreting the placement of participants relative to those dimensions. We therefore selected symmetrical normalisation for the graphical representations and analyses in this paper.

Assumptions

Correspondence Analysis is relatively free from assumptions about the nature of the data. It can work with counts (frequencies), and does not require data that conforms to a normal distribution (Greenacre, 1984). The main assumption, or limitation, of Correspondence Analysis is that all of the relevant variables are included in the analysis (Hair et al., 1995). If a key variable is overlooked in the design stage of the research, then the final scaling solution will be impoverished. The extensive review of the literature, and the multiple readings and codings of the interview transcripts undertaken for this study, encourages our belief that the variables included in the analysis are reasonably comprehensive.

Preliminary Analyses

We conducted a Correspondence Analysis for the eight participants and 45 variables (from Table 1). To begin, we ran the maximum possible number of dimensions (7, being one less than the minimum number of rows and columns) and removed four variables *(disengaged, automated, passive, mnemonics)* that achieved such extreme scores (greater than positive or negative 3) that they compressed the display of the remaining variables. This process can be compared to removing outliers from a principal components analysis (Nishisato, personal communication June 12, 2003). These extreme variables are interesting in themselves, (such as the low occurrence of mnemonics as a learning strategy), however, they fall outside of the essential aim of the Correspondence Analysis, which is to achieve data reduction.

The next step was to run the Correspondence Analysis in successively lower dimensions and to inspect each solution. We decided to investigate the 4 dimensional solution further. First we investigated the fit of each of the variables. (Fit is determined by the proportion of variance in each variable accounted for by the dimension). At Dimension 4, six variables achieved a total fit across all dimensions of less than 0.5 *(immerse, relate to prior knowledge, pose questions, affordances, reconceptualise, metacognitive experiences).* The reason for the poor fit of some variables is unclear, however it is possible that these variables do not vary in consistent patterns with other variables in the analysis (J. P. Keeves, personal communication, May 26, 2003). As with the extreme items that were removed, the poorly fitting items could be considered to have conceptual worth. In particular, the variable *relate to prior knowledge* is a key concept in constructivist theory, and it is interesting that it achieved a consistently low representation in all participants' transcripts. Also, the variable *awareness of situational affordances and constraints* achieved relatively high representation in all participants' transcripts, suggesting that all participants were aware of the opportunities and difficulties that were presented by their respective learning environments. For the purposes of the Correspondence Analysis, five of poorly fitting variables were removed from the analysis, and a sixth *(metacognitive goals)* was combined with a conceptually similar item *(metacognitive strategies)* and retained.

We also identified six variables that, although well fitted by the analysis, did not make a substantial contribution to the inertia (variance) of any of the four dimensions *(aural memory, congruent-peers, organising statements, summarising statements, cause-effect statements, metacognitive experiences)*. If all variables contributed equally to the variance in a dimension, each contribution would be 0.028 (1/36th given 36 variables remaining at this stage of the analysis). Removing non-contributing items is similar to removing items with low loadings in a factor analysis (W. C. Black, personal communication, June 12, 2003). Five of the low contributing variables were removed so as to simplify the final analysis. The sixth low contributing variable, metacognitive experiences, was combined with the conceptually similar metacognitive knowledge, and retained in the analysis.

Thus the final run of the Correspondence Analysis was with 29 variables (14 variables removed and 2 variables joined to conceptually similar variables). This 29 variable Correspondence Analysis is reported below. All 29 variables contributed more than expected to at least one dimension, and total fit for variables ranged from 0.595 *(congruent-teachers*) to 0.981 *(prompts)*. Total fit for one participant's scores, Josi (medical) was relatively low, at 0.417, while the fit statistics for the other participants' scores were high (0.689 to 0.996).

The 4 Dimensional Correspondence Analysis solution

To begin, the Correspondence Analysis program calculates the *row profiles*, which are the relative proportions of each variable within all of the variables mentioned by each participant. For example, Josi's (medical) statements that were coded as *propositions* totaled 62, which is 0.017 of the 29 coded variables in her profile. The row profiles permit a within-participant comparison of the variables.

Next, the Correspondence Analysis program calculates the *column profiles*. The column profiles are the proportion of each variable mentioned by each participant as a total of all participants' mentions of that variable. For example, Josi's *propositions* (62) as a proportion of all participants' mention of *propositions,* is 0.087 (or 8.7%). Profiling participants across the column variables permits between-participant comparisons. Participants who have similar profiles should appear close together in the graphical representation of low-dimensional space, while participants who have dissimilar profiles should appear further apart.

The next step in the Correspondence Analysis is to identify distances between the row profiles and between the column profiles. The Correspondence Analysis program standardises and transforms the frequency data by calculating chi-square distances from the row and column profiles (actual minus expected cell values as a proportion of margin totals). The program then reduces the complexity contained in the row and column profiles by creating a low-dimensional representation of the row and column profiles. It achieves this by factoring the basic structure (through a singular value decomposition) of the chi-square distance matrix, resulting in a set of row vectors, column vectors and singular values (Greenacre, 1984; Weller & Romney, 1990). Finding a low-dimensional solution is conceptually the same as finding the principal components, with the qualification that Correspondence Analysis is able to deal with frequency data (Greenacre, 1984; Nishisato, 1994; Weller & Romney, 1990). Finally, the Correspondence Analysis scales the vectors to create scores for each participant and each variable. These scores are plotted in a visual display (Weller & Romney, 1990).

Results and Discussion

The Correspondence Analysis solution

Table 4, taken from the Correspondence Analysis (symmetrical normalisation) output for the eight participants and 29 variables, contains the singular values, inertia, and proportion of variation explained for one to seven dimensions.

Table 4: Dimensionality of the Correspondence Analysis solution

Dimension	Singular Value	Inertia	Proportion explained	Cumulative proportion
1	0.33787	0.11416	0.496	0.496
2	0.20503	0.04204	0.183	0.679
3	0.16250	0.02641	0.115	0.794
4	0.14229	0.02025	0.088	0.882
5	0.10876	0.01183	0.051	0.934
6	0.09756	0.00952	0.041	0.975
7	0.07573	0.00574	0.025	1
Total		0.22993	1	1

From Table 4, the singular values indicate the relative contribution of each dimension to an explanation of the variance in the participant and variable profiles. Hair et al. (1995) recommended that singular values of greater than 0.2 indicate that the dimension should be included in the analysis. However, this cut-off point must be balanced against the proportion of variance explained by each dimension, as well as achieving a balance between the interpretability of multiple dimensions and a model that fits the complexity of the data (Benzecri, 1992). The singular value and the inertia are directly related ($I=SV^2$): the inertia is an indicator of how much of the variation in the original data is *retained* in the dimensional solution (Bendixen, 1996). The proportion explained by Dimension 1 (from Table 4) is 0.496, and by Dimension 2 is 0.183, which together explains 0.679 (or 67.9%) of the variation in the data. The placement of participant and variable scores along these two dimensions is represented in Figure 2. Variables that are highlighted by italics and/or underlining contribute more than expected, and are therefore most important, to the dimension (Clausen, 1998; Hair et al., 1995; Nishisato, 1994).

From Figure 2 it can be observed that Dimension 1 variables range from *prompts, examples, propositions* and *episodic memory* at the left, to *congruent-program*, *diagrams/flow charts, synthesise, relate components, and cross links* at the right. This continuum finds ready parallels with the multi-structural and relating constructs proposed by Biggs and Collis (1982), the links and hierarchies in evaluation tools such as concept maps (Martin et al., 2000; McKeown & Beck, 1990; White & Gunstone, 1992), and discussions about the organisation of knowledge (for example, Anderson, 2000; Chi, 1985). It is also possible to interpret Dimension 1 as ranging across different degrees of *complexity,* with *propositions* and *examples* at the left, and *analogy/metaphor, relate components and synthesise* at the right. Taken together, the variables along the Dimension 1 continuum suggest a *Cognitive Schema* dimension of *stockpiles of knowledge* at the left, to *connected knowledge* at the right.

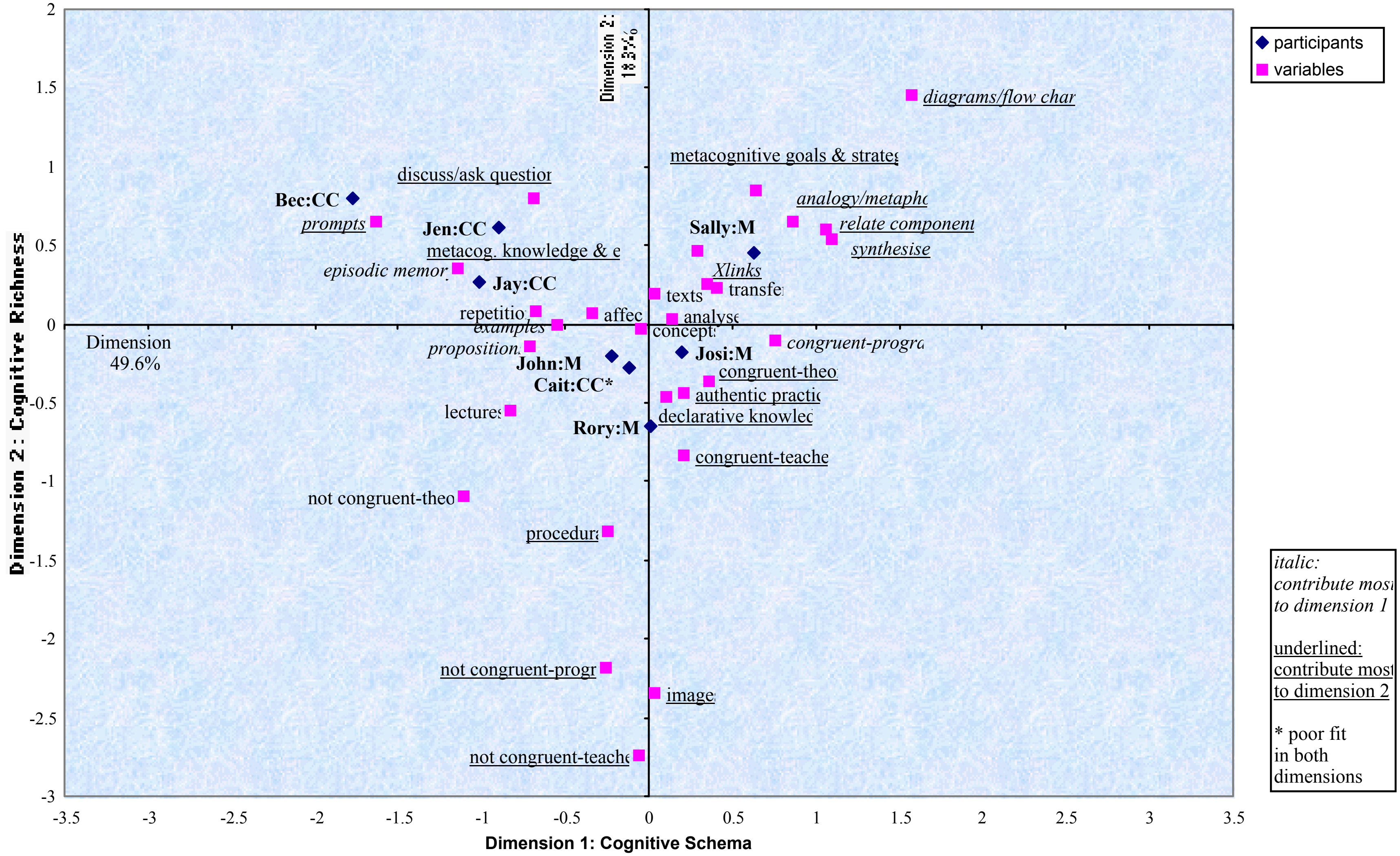

Figure 2: Dimensions 1 (Cognitive Schema) and 2 (Cognitive Richness)

The variables in Dimension 2 range from *prompts, diagrams/flow charts, discussions/ask questions, metacognitive goals and strategies, metacognitive knowledge and experiences, cross links, analogy/metaphor, relate components, discuss and synthesise* at the top of the chart, to *not congruent* with *teachers* and *program*, *images, procedural knowledge, declarative knowledge, authentic practice* and *congruent with theory and teachers* at the bottom of the chart. These variables suggest a dimension of *Cognitive Richness*, ranging from *conceptual* or *abstract engagement* at the top of the chart, to *practical engagement* at the bottom of the chart. In particular, the bottom of the chart seems to capture "knowing that" and "knowing how" (Anderson, 2000). It is interesting that these two types of knowledge cluster at the same end of Dimension 2, perhaps illustrating the interpretive strength of a multi-dimensional solution compared to a dichotomous perspective.

The Correspondence Analysis solution also locates participants' scores on the chart. There appear to be substantial individual differences. For example, Bec's (child-care) score is situated to the far left of Dimension 1, and Sally's (medical) score occupies the furthest position to the right. Clusters of participants' scores are also apparent, with the child-care students' scores clustered in the left side, middle to upper quadrant. The medical students' scores are spread out across the remaining three quadrants. However, caution must be exercised in interpreting the graphical display. For example, it appears from Figure 2 that Cait's (child-care) score is located closer to the medical students' scores than to the child-care students' scores. However, a cross-check to the statistics of fit for participants' scores indicates that both John's (medical) and Cait's scores are very poorly fitted by Dimensions 1 and 2 (less than 10% fit in both dimensions. Further analysis (below) will demonstrate that John's and Cait's scores are located in another plane (dimension).

The most interesting part of the Correspondence Analysis emerges with the *relative* placement of participant and variable scores to the interpreted dimensions. Hence it can be seen from Figure 2 that three of the child-care students' scores are located at the *stockpiles of knowledge* end of Dimension 1, two medical students' scores are located around the centre of *stockpiles* to *connected*, and Sally's score (medical) is toward the *connected knowledge* variables. In Dimension 2, Sally's (medical) and Jay's (child-care) scores are located closer to the *conceptual/abstract* pole, and Rory's (medical) and Jose's (medical) scores are located closer to the *practical* pole.

Although this is a small sample, it seems reasonable to suggest the possibility of between-group differences, in particular along Dimension 1. Hence the medical students spoke more about the need to "join ideas together", and to "make it into a big picture." Conversely, the child-care students were able to make declarative statements, and to give examples, but showed less evidence of integrating the various strands of their knowledge into a more connected schema.

Along Dimension 2, the child care students cluster towards the positive pole, but the medical students range from positive to negative, perhaps reflecting the concurrent practical and theoretical emphases of their clinical training year. It is interesting that the child-care students' scores are located at the *conceptual/abstract* pole of Dimension 2, suggesting that their "learning about" looking after children was more salient to them than the "hands on" component of their training. One interpretation of this difference along Dimension 2, drawn from our reading of the transcripts, is that the practical part of the medical students' training was perceived by the students as being quite demanding, whereas the practical component of the child-care training was perceived as being routine and/or second nature by many of the child-care students.

Returning to Table 4, it can be seen that, following the extraction of Dimensions 1 and 2, Dimension 3 accounts for 0.113, and Dimension 4 accounts for 0.086, of the remaining variance. Although these amounts are relatively small, we consider that in an exploratory study such as this it is worth investigating those additional dimensions. In particular, Dimensions 3 and 4 pick up some of the idiosyncratic variance in the profiles of Cait (child-care), Josi (medical) and John (medical), whose scores contributed less than the scores of the other participants' to Dimensions 1 and 2. Therefore, Figure 3 is a graphical display of Dimensions 3 and 4.

In Figure 3 it can be seen that variables at the left of the chart range from *repetition, discussions/ask questions, transfer, cross links, affective, images and not congruent-theory,* to *declarative knowledge, analyse, congruent-teacher* and *metacognitive goals and activities* at the right of the chart. Thus Dimension 3 appears to capture a sense of the *fruitfulness* of various *strategies for learning*, ranging from strategies that are particularly suited to learning in *authentic practice* at the left-hand pole, to strategies that are particularly suited to *learning by studying*, either alone or in class at the right. Strategy knowledge, such as *repetition,* or *ask questions,* can be categorized as a type of knowledge. Furthermore, as the strategy knowledge appears to be embedded in learning in different situations, it can also be categorised as contextual knowledge, thus suggesting an interaction, or relationship between *type* and *context.*

Dimension 4 is more difficult to interpret, as each higher dimension accounts for smaller amounts of residual variance. However, it is possible that it reflects a dimension of learning *Stance,* with *intentional* or *deliberate learning* represented by *congruent with teachers, not congruent program, lectures, discussions/ask questions, metacognitive knowledge and experience, affect, concepts and propositions* at the top of the chart, and *incidental learning* represented by *episodic memory, texts, authentic practice, congruent-program, declarative knowledge, not congruent-theory* and *prompts* at the bottom of the chart. Stance describes the way in which a learner positions him or herself in relation to the learning environment. The term stance is borrowed from the work of Evensen (2001), who used it in relation to medical students' self-regulatory self-positioning. Bereiter and Scardamalia (1989) discussed the difference between intentional learning and leaving learning to happen perchance as a result of exposure to learning activities. It is possible that this fourth dimension taps into motivational or "hot" cognitions that have tended to be overlooked or downplayed in information processing accounts of learning (for example, Anderson, 2000). Alternatively, it could reflect students' conceptions (Marton et al., 1993) or epistemologies (Hofer & Pintrich, 1997) of learning and knowing.

The grouping of participants in Dimensions 3 and 4 differs to that in Dimensions 1 and 2. Cait (child-care) occupies an extreme position to the left of Dimension 3, and is the only participant located in that half of the chart. John (medical) and Bec (child-care) take opposite ends of Dimension 4. Contribution statistics indicate that Dimensions 3 and 4 reflect specific individual differences.

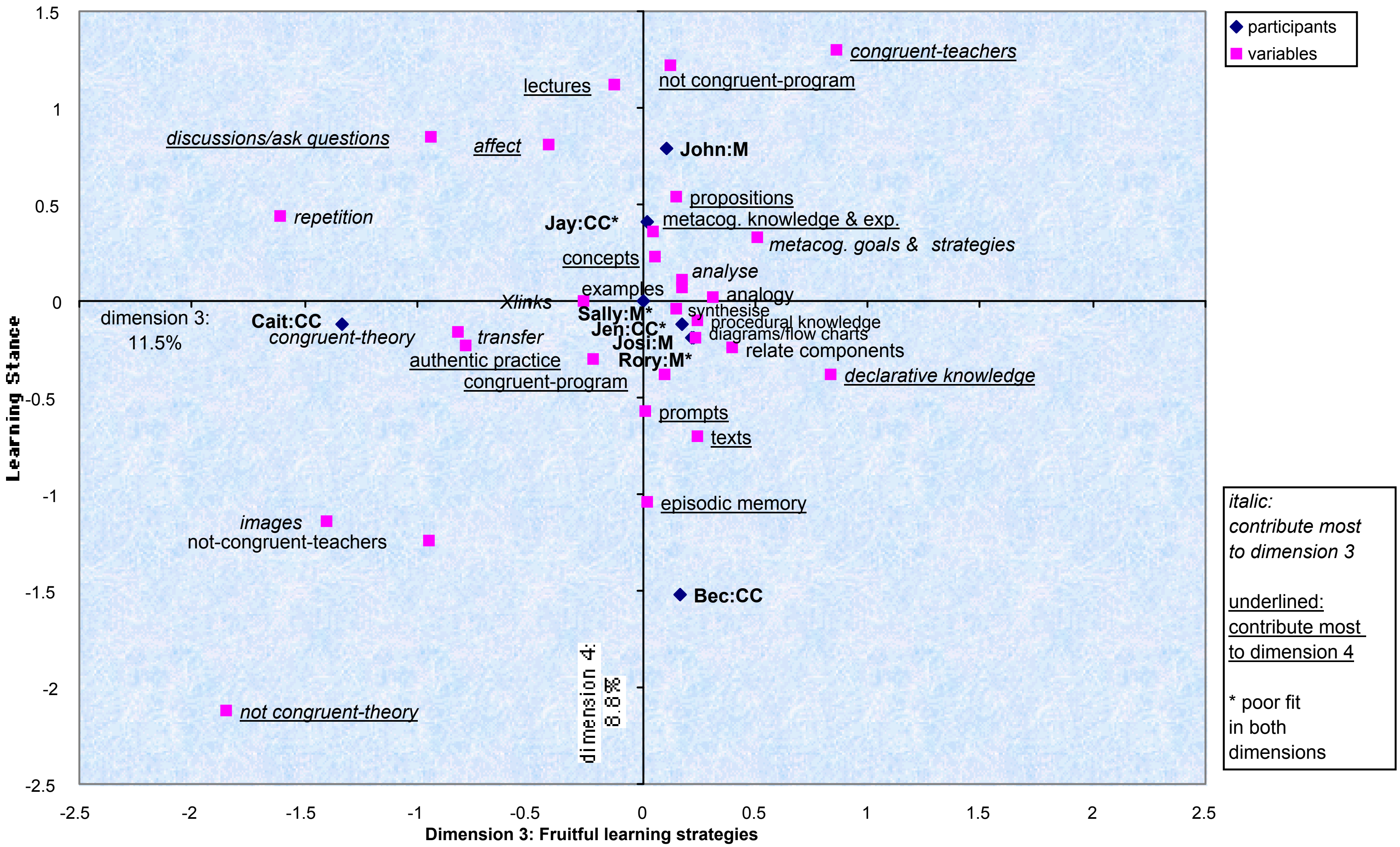

Figure 3: Dimensions 3 (Fruitful learning strategies) and 4 (Learning Stance)

Profiling the Dimensions of Difference

Nishisato (1994) suggested that one approach to overcoming difficulties (with relative distances) with joint visual displays of participants and variables in a Correspondence Analysis would be to represent participant profiles (patterns of responses) rather than single points (x, y coordinates) in the graphical display. Clusters of similar profiles could then be identified. In another strand of research, Davison (1983) proposed that the vector of scores along a scaled dimension (in that case, multi-dimensional scaling) can be conceptualised as a profile. Later, Davison (Davison, Gasser, & Ding, 1996; Kuang, Bielinski, Kim, Davison, & Ernest C. Davenport, 1998) developed the concept of vector profile to propose that the profile of a Dimension can be conceptualised as the profile of a prototypical person who ideally resembles that Dimension. Comparisons could then be made between the prototypical profile and individual participant's profiles.

It seems potentially fruitful to combine Nishisato's and Davison's suggestions. By extracting the participant profile information, and the scores of each variable on a dimension, from the Correspondence Analysis solution, a participant's profile across all variables can then be compared to, for example, the profile of the prototypical Dimension 1 person. The purpose of such a comparison is to go beyond identifying a participant's position on a chart, to consider how the complete set of (in the present case) 29 variables combine to describe a participant's pattern of responses. The various computational stages of the Correspondence Analysis procedure provide the information necessary for such a comparison, namely, participant profiles across variables, dimensional coordinates, and measures of fit between each participant and each dimension.

Thus, it is informative to compare the profiles of the participants with the two highest fit statistics for Dimension 1. These are Sally (medical) (strong positive Dimension 1 score, fit 0.748) and Jay (child-care) (strong negative Dimension 1 score, fit 0.801). It would be expected that Sally's profile would closely match the profile of Dimension 1, and that Jay's profile, through her negative Dimension 1 score, would be a close mirror image of the Dimension 1 profile. From Figure 4 and Figure 5 it can be seen that this is indeed the case. Figure 4 is the plot of Sally's profile across all variables against the profile of Dimension 1. Figure 5 is the plot of Jay's profile across all variables against the mirror image (signs reversed) of Dimension1.

In Figure 4 it can be seen that Sally's (medical) profile accords quite well with the Dimension 1 (Cognitive Schema) profile. Sally is relatively strong on *diagrams/flow charts, relate components, analogy/metaphor, synthesise, metacognitive goals and strategies, congruent with program* and *transfer,* and relatively weak on *images, lectures, procedural knowledge,* the three *non congruent* variables*, episodic memory* and *repetition.* Also, Sally relied much less upon interviewer prompts as she recounted her knowledge during the interview. From Figure 5, Jay (child-care) is relatively strong on *episodic memory, repetition, discussions/ask questions* and *lectures* and relatively weak on *images, synthesise, diagrams/flow chart,* and *metacognitive goals and activities*. Jay relied heavily upon interviewer prompts to bring out her knowledge during the interview. In short, Jay's profile is opposite to Sally's.

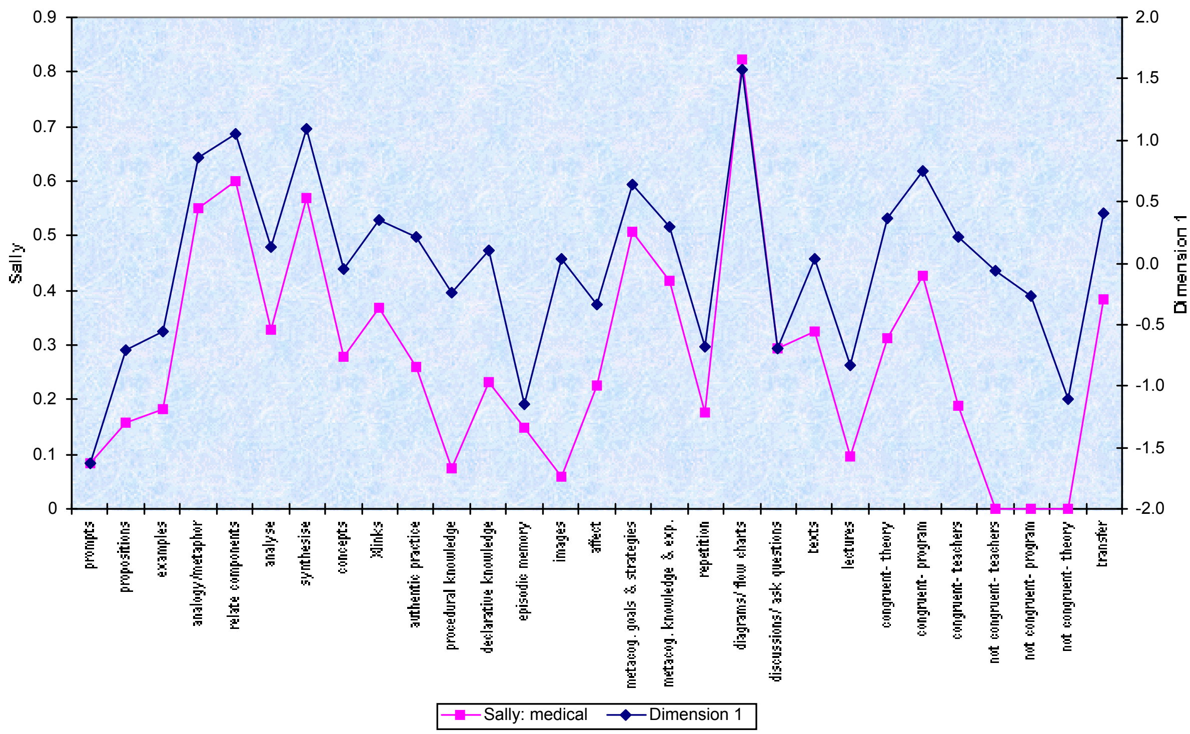

Figure 4: Profile comparison: Dimension 1 (Cognitive Schema) and Sally (medical)

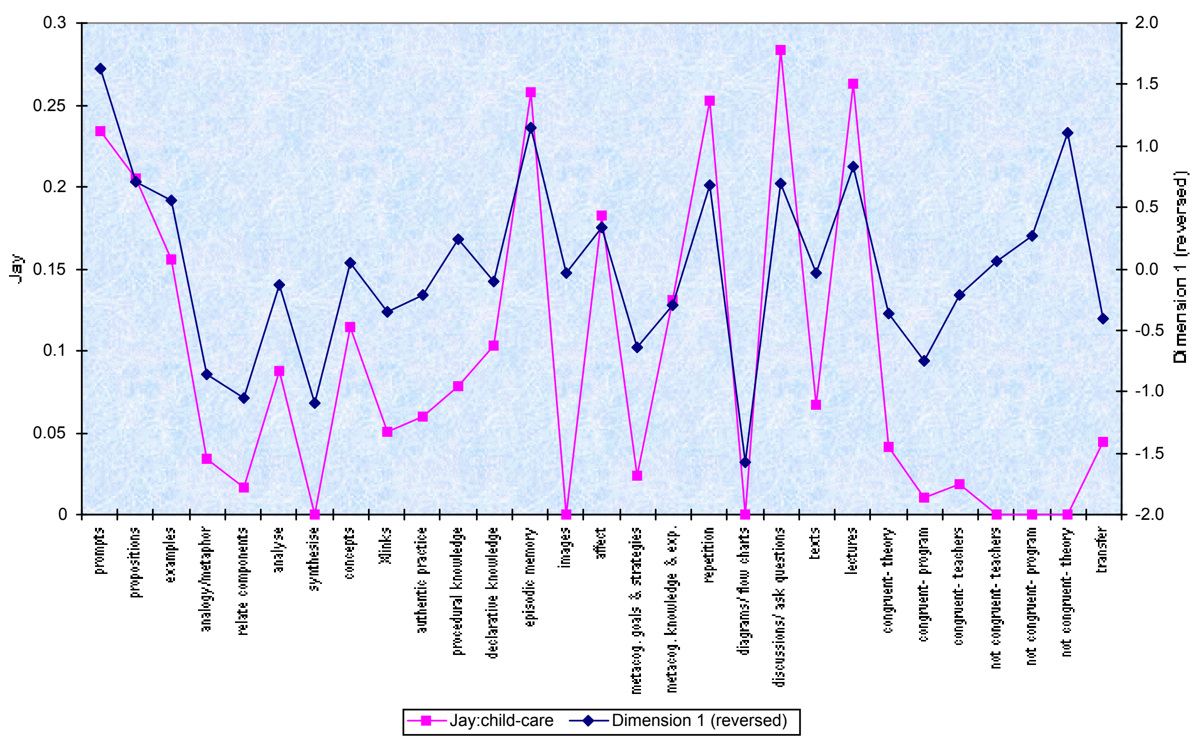

Figure 5: Profile comparison: Dimension 1 (Cognitive Schema) (reversed) and Jay (child-care)

The profiles also allow a deeper analysis. Note in Figure 5 the relatively low scoring cluster of Jay's score for the six *congruence* and *non congruence* variables, suggesting that Jay spoke relatively little about issues that might align with other people's knowledge about teaching and learning. It might be unreasonable to expect Jay to have knowledge that aligns with researchers' and theorists' contemporary knowledge about teaching ad learning. However, it would be hoped that she would possess knowledge that is congruent with that of her teachers with whom she has regular contact, and with the course designers as represented in course handbooks and statements of outcomes. In addition, interesting comparisons can be made between Sally's and Jay's profiles. For example, Sally's profile is high across the variables of *connecting* (*relate components, synthesise, transfer, diagrams/flow charts*), while Jay's profile is relatively low across these variables. Note also Jay's relatively low score on the two *metacognition* variables at the right hand end of Figure 5.

A perspective of the relative level, or extent, of knowledge held by each participant can be gained by plotting Sally's and Jay's profiles on the same chart, as in Figure 6.

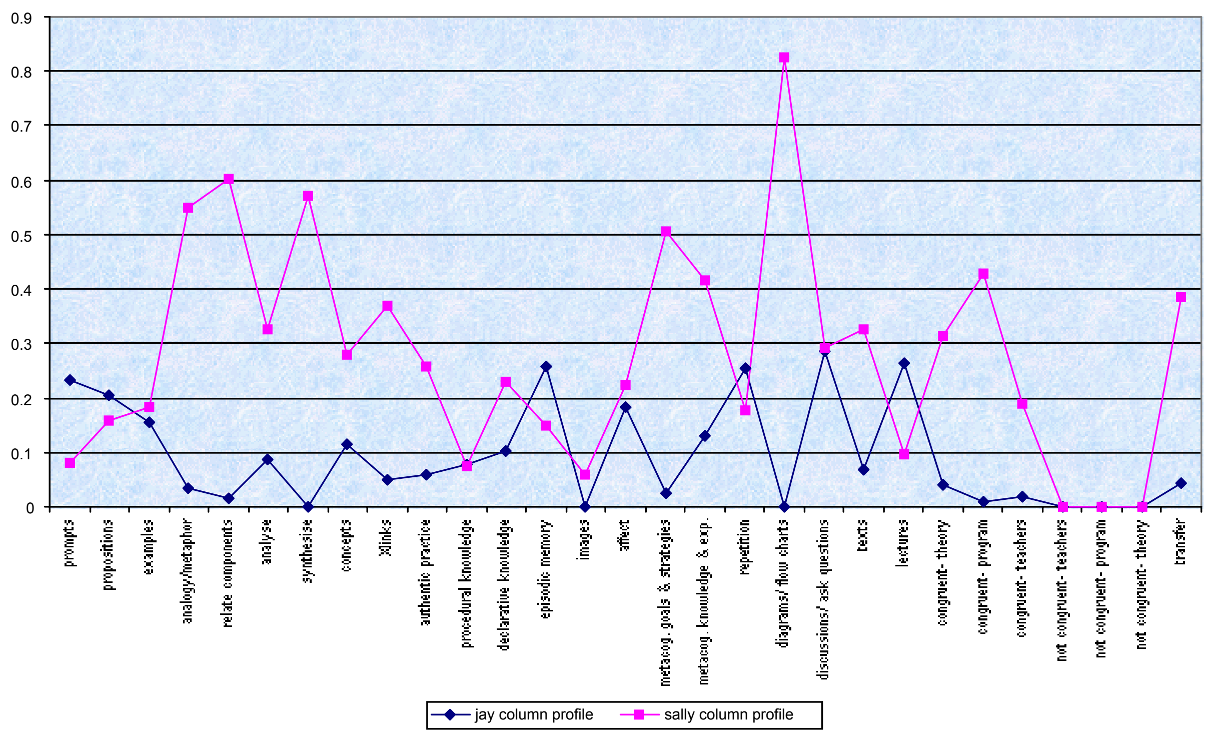

Figure 6: Profile comparison: Sally (medical) and Jay (child-care)

It is immediately apparent, with the exception of the variables *propositions*, *lectures, repetition, episodic memory and prompts*, that most of Sally's scores are at a higher level than Jay's. This accords with Sally' marginal profile (0.268), compared to Jay's (0.110), and demonstrates graphically that Sally was able to express considerably more knowledge across most of the variables of quality. Therefore, even when Sally's profile dips as Jay's rises, for example at *metacognitive knowledge and experiences* and *analyse*, Sally's functionally available knowledge level is still higher than Jay's. It is also possible to identify comparative patterns between Sally's and Jay's profiles. For example, whereas Sally's profile rises across the first five variables of complexity (*prompts* to *relate components*), Jay's profile falls. As these variables are ordered from less complex to more complex, this indicates that Sally's profile reflects relatively more of the higher level variables of complexity.

We interpreted Dimension 1 as a *Cognitive Schema* dimension, ranging from *stockpiling* to *connecting*. It seems reasonable to classify Sally as a relatively more connecting person, and Jay as a relatively more stockpiling person. In addition, from the profiles, it is possible to highlight the variables that contribute to these classifications by observing the peaks and troughs on the chart. Thus, the profiles provide a tool for diagnosis of possible areas of intervention to improve the knowledge about teaching and learning that both Sally and Jay hold. Suggestions might include a program that provides Jay with explicit instruction in strategies for creating connections between pieces of knowledge, such as concept mapping (White & Gunstone, 1992). Jay might also benefit from instruction in metacognitive skills of monitoring and evaluation of progress (Winne & Hadwin, 1998). In Sally's case, the value of imagery as an encoding and retrieval tool (Anderson, 2000) might be a useful addition to her already strong knowledge base about teaching and learning.

Turning to Dimension 2 (Cognitive Richness), the participant with the highest fit statistic to Dimension 2 is Rory (medical) (fit = 0.789). From the two-dimensional chart in Figure 2 it can be seen that Rory obtained a negative score on Dimension 2. Therefore, it would be expected that Rory's profile would show a substantial mirror image to Dimension 2. As illustrated in Figure 7, reversing the scores of Dimension 2 permits a ready comparison between its profile

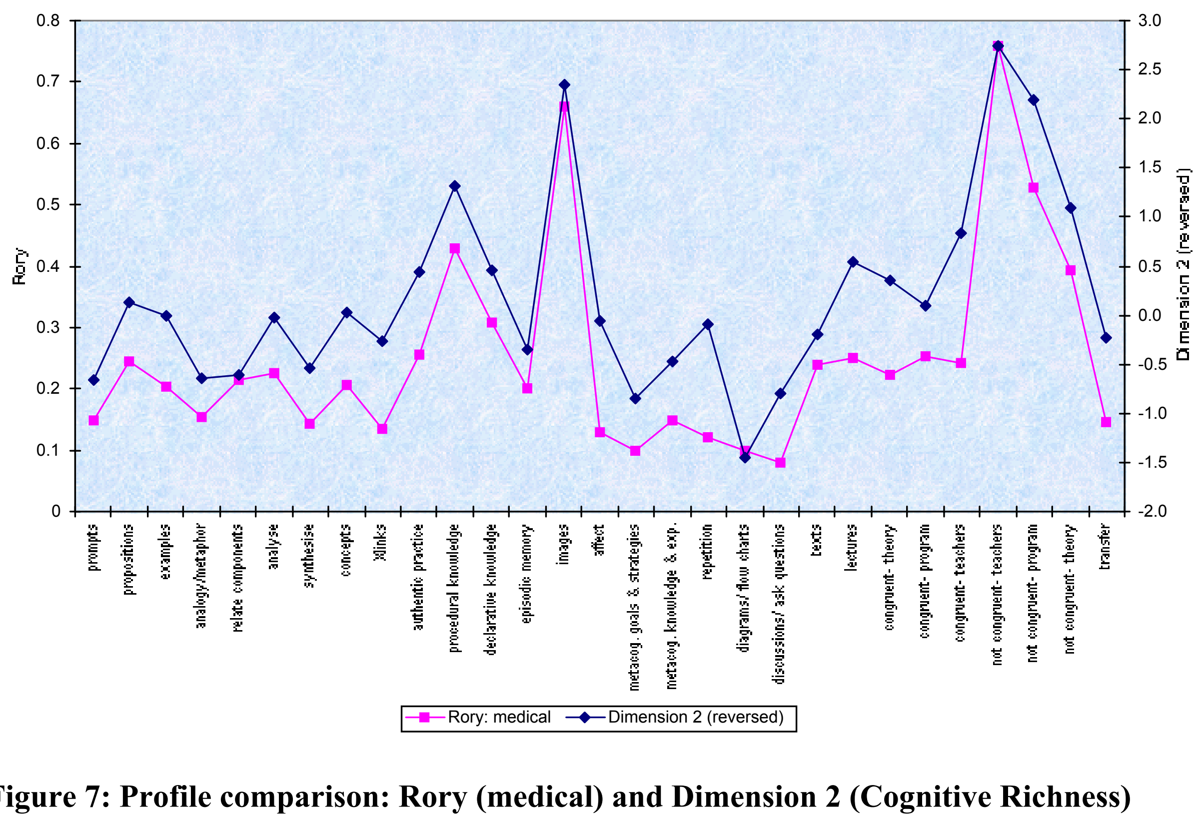

Figure 7: Profile comparison: Rory (medical) and Dimension 2 (Cognitive Richness) (reversed)

and Rory's, where it can be seen that Rory scored relatively strongly on *procedural knowledge*, *images* and *not congruent-program* and *not congruent- teachers*. This profile highlights Rory's concern in his interview with the procedural training that he was receiving in his clinical year, and his plans to make a career in surgery. Note however that Rory is relatively weak on variables such as *diagrams/flow charts, metacognitive goals and strategies, discussions/ask questions* and *transfer*. He also appears to be relatively less knowledgeable about generating connected schemas of knowledge (*cross links, synthesise, analogy/metaphor*). During interviews, many of the medical students spoke at length about the difficulty of finding the correct balance between "learning medicine" and "doing procedures." This balance was seen to be salient for passing exams, as well as for becoming a good doctor in the future. One question that is raised by an inspection of Rory's profile is whether he is achieving a good balance between the *conceptual/abstract* and *practical* components of his learning.

A different picture is provided by Figure 8, which is the graphical display of the profile of Cait's (child-care) scores and Dimension 3 reversed.

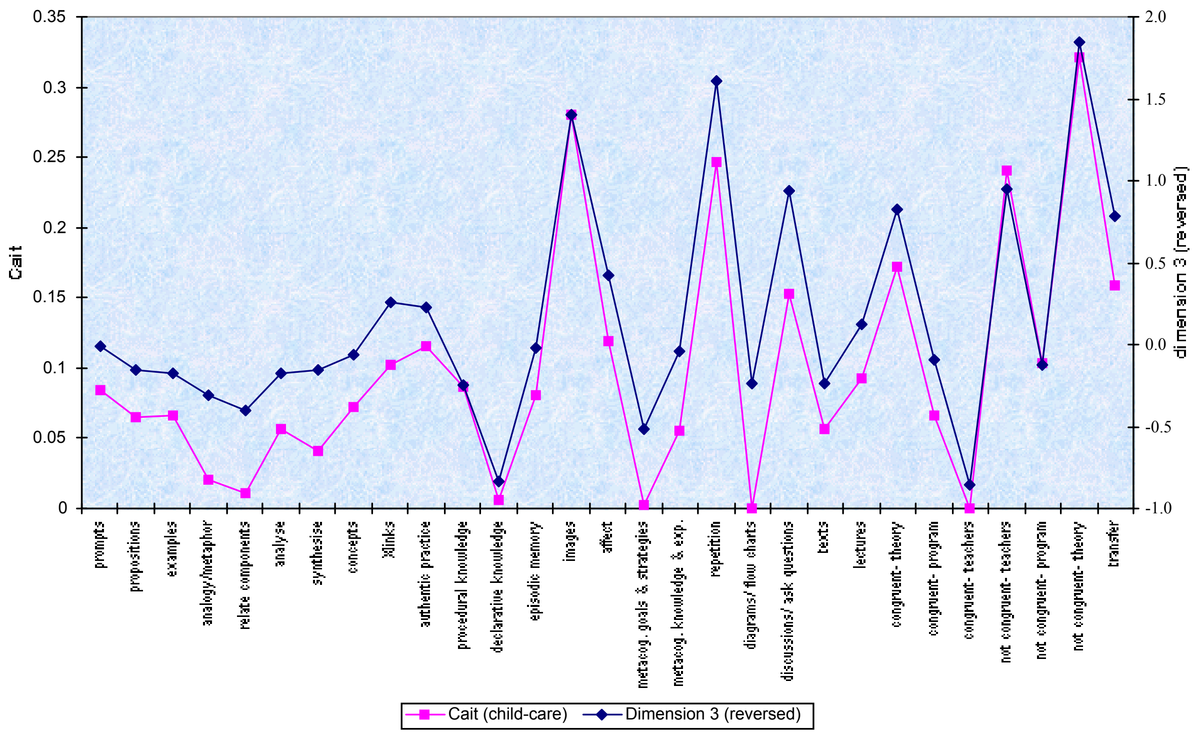

Figure 8: Profile comparison: Cait (child-care) and Dimension 3 (Fruitful Learning Strategies) (reversed)

Dimension 3 (Fruitful Learning Strategies: authentic practice to studying) accounts for 92.4 per cent of the variation in Cait's transcript, and from Figure 3 it can be seen that Cait's score is located at the *authentic practice situated* pole of this Dimension. Cait is relatively strong on *images, repetition, authentic practice, not congruent-teachers, not congruent- theory,* and *discussions/ask questions.* She is relatively weak on *relate components, declarative knowledge, metacognitive goals and strategies, diagrams/flow charts* and *congruent-teachers.* It is informative to compare Cait's profile with her original interview transcript. Cait tells about how when asking questions in class she feels intimidated, but she has no trouble asking questions in the child-care centre, which is mainly one-to-one interaction. Cait also recounts how she takes lots of notes in class. She "goes over" her notes, but she doesn't give an account of how she might add to the value of those notes with strategies such as drawing diagrams or flow charts, making headings, creating outlines and so on. Cait describes herself as a "hands on" person:

> Cait: I'm more of a hands-on person … I just find it easier if I'm actually in there doing something to learn um…yeah er…just um…wiping down benches and you know cleaning the kitchen or something like that. 'Cause I'm actually doing it um…it's easier than watching a video and thinking oh yeah, that person's doing a good job, you know I'd rather get in there and be doing it rather than sitting there and watching somebody else doing it … Yeah I feel like I'm learning more. You do, you feel, or I do, I feel like I'm learning more because I'm actually doing it, whereas the person on the video, I look at a video and think oh that person's learning more, kind of thing, 'cause they're doing it. So…I don't know um…I just…you know I like actually having your hands-on approach to everything. It's sort of easier.

Cait's self-assessment seems to match the Correspondence Analysis solution that extracted Dimension 3, which accounts for Cait's more- and less-fruitful learning strategies. Such strategies could be expected to both grow from, and contribute to, a preference for learning in situated, authentic practice.

A final example is provided by Bec's (child-care) scores. Dimension 1 (Cognitive Schema) and Dimension 4 (Stance) achieved the highest fit with Bec's profile (0.637 and 0.196 respectively). Figure 9 is a plot of Bec's profile and the profiles of Dimensions 1 and 4 (reversed).

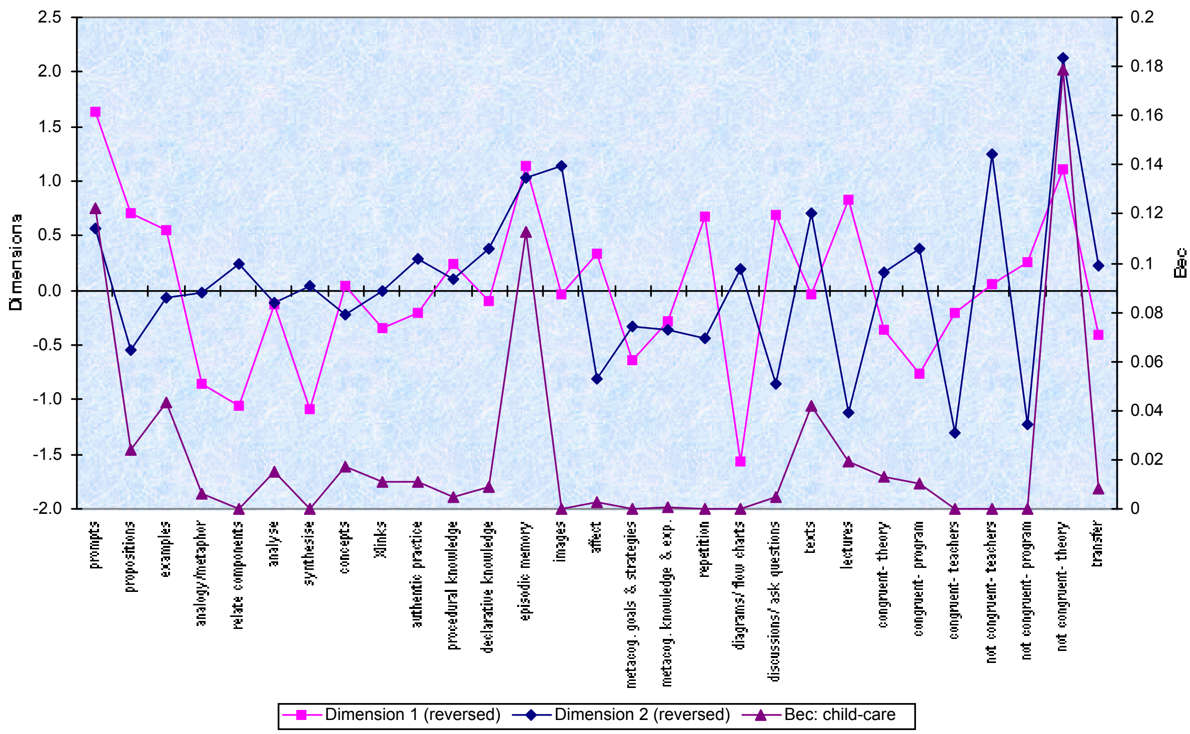

Figure 9: Profile comparison: Dimension 1 (Cognitive schema) (reversed). Dimension 4 (Learning Stance) (reversed) and Bec (child-care)

It is immediately apparent from Figure 9 that Bec's profile follows a combination of Dimensions 1 and 4 (reversed). However, what is more salient about her profile is the low level of nearly all variables, other than *episodic memory*, and *not congruent-theory*, which are relatively high. Also high is *prompts*, which is an indicator of how much work the interviewer, rather than Bec, needed to put into the interview in order to access Bec's knowledge about teaching and learning. It seems that, rather than assessing Bec's profile as at the *stockpiling* end of Dimension 1, or the *incidental learning* end of Dimension 4, Bec's knowledge about teaching and learning is relatively seriously impoverished. For example, 10 of the variables achieve totals of 0, and only four rise above 0.04 (or 4% of all participants' accounts of a variable). Potentially, a student with a profile such as Bec's could appear in any class. Thus the teacher has to address considerable issues, not necessarily with prior knowledge about the topic of study (for example, Bec was already employed as a live-in nanny), but with the quality of such a student's knowledge about teaching and learning.

Summary and Implications

We have proposed that good quality knowledge in the domain of teaching and learning is as essential as good quality knowledge in a student's chosen topic domain. We have built upon a broad range of previous investigations about the nature of good quality knowledge to propose a Framework of Quality of Knowledge about Teaching and Learning containing five categories: Complexity, Structure, Foundedness, Contexts and Cognitive Representations. Using NUD*IST and Correspondence Analysis, that Framework was applied to eight interview transcripts to identify Dimensions of Difference of Quality of Knowledge about Teaching and Learning between participants from different academic backgrounds. Four major Dimensions of Difference emerged which were interpreted as, 1) Cognitive Schema: stockpiling to connecting; 2) Cognitive Richness: practical engagement to conceptual/abstract engagement; 3) Fruitful Learning Strategies: authentic practice to studying, and; 4) Learning Stance: incidental to intentional. Correspondence Analysis also provided information that permitted comparisons between individual participant Profiles and the Prototypical Profiles of the Dimensions of Difference.

It is clear that substantial individual differences occur, both in participants' placement along the Dimensions of Difference and in the peaks and troughs of participants' Profiles. Some participants, such as Sally (medical), possess relatively extensive knowledge across nearly all variables, and especially, relatively more knowledge about variables identified with *connecting* knowledge. Other participants, such as Bec (child-care) appear to possess impoverished functional knowledge.

There are also suggestions of group differences. For example, although both clinical medicine and child-care studies contain substantial practical components, the child-care students expressed relatively less knowledge about the practical component of their learning. Interestingly, the *stockpiling* pole of the Cognitive Schema dimension attracted relatively more participants than the *connecting* pole. Furthermore, child-care students dominated the stockpiling pole. One possible response to this might be that the nature of the child-care course subject matter precludes a connecting cognitive schema. However, interviews with the child-care course director and lecturer indicated that this was not the case. For example, one aim of the child-care course is to foster the integration of students' knowledge of theories of children's physical and psychological development with the implementation of best practice in child-care centres. A second aim is for students to develop interpersonal and management skills that facilitate effective relations with diverse groups of people. Both of these aims would require child-care students to engage in complex cognition about theory and practice.

It is worth mentioning some of the variables in the Framework that did not occur differentially between participants or groups of participants in the present study. For example, the various indicators of *well-foundedness (congruent and not congruent with program, teachers, theory*) did not form discrete clusters or dimensions themselves, but rather seemed to disperse amongst dimensions. In some instances, congruent and not congruent with the same indicator appeared at the same pole of a dimension (for example, *congruent* and *not congruent with teaching and learning theory* at the negative pole of Dimension 3). Our re-reading of the transcripts with this discovery in mind evidenced that congruence and non-congruence seemed to be situation specific, applying to one particular unit of work, or one teacher's interpretation. For example, John (medical) questioned the relevance to himself of the personal, reflective writing task that was included in the clinical course program. Similarly, Rory (medical) questioned the amount of explicit direction that one supervising General Practitioner felt necessary to give to clinical students such as himself whose prior work history included ambulance and nursing experience.

Another interesting observation is the number of variables that might be assumed to be mainstream strategies in current educational practice, such as *relate to prior knowledge, using mnemonics, creating mental images, drawing diagrams/flow charts* and *discussions/ask questions,* but which occurred with relatively low frequency in participants' transcripts. This might point to a need for explicit teaching of what are considered to be key learning strategies in a constructivist teaching and learning environment.

It is also possible that the application of the Framework to other cohorts of learners with alternative histories to those chosen for the present study might generate alternative Dimensions of Difference. One hypothesis might be that a study of learners from different cultural backgrounds might activate a Dimension of Difference that spotlighted congruence and non-congruence between teacher and learner statements. Another hypothesis might be that a cohort of disaffected teenagers might generate a Dimension of Difference that highlights affective/emotional knowledge, or where Dimension 4 (Stance) becomes the principal dimension.

The implications of our research can be assessed from four directions, two theoretical, one practical and one methodological. The first, theoretical, is to propose that the Framework provides a tool that can be used to identify categories of quality of knowledge that people hold. The application of Correspondence Analysis to participants' scores on the subcategories in the Framework has illustrated that the categories and sub-categories in the Framework do have potential for identifying the quality of participants' knowledge. Thus we are able to go beyond a simple statement such as "deep" knowledge, to propose specific variables that might contribute to the assessment "deep". For example, it is possible to investigate students' statements that *relate components*, students' *analogies* and *metaphors*, *cross-linking* statements and so on.

The second theoretical perspective is that the use of the Framework in conjunction with Correspondence Analysis has enabled the identification of Dimensions of Difference between learners from different academic backgrounds. We proposed that medical students and child-care students could be expected to have experienced different degrees of academic press: a combination of exposure, pressure and success within academic environments. The four Dimensions of Difference uncovered in this study provide a theoretical perspective of the differences between learners that can result from, and contribute to, different histories of academic press.

The third, practical, implication comes from the potential that the Framework and the four Dimensions of Difference have to influence educational practice. We proposed that learners' knowledge about teaching and learning mediates their interactions with topics. Therefore, educators need a way of knowing about the quality of the knowledge that learners bring to educational settings, otherwise educational programs will be poorly targeted. It can be seen that a teacher faced with, say, the four medical student participants in this study, has to deal with students with different quality knowledge about teaching and learning. Sally might be drawing diagrams, relating components to each other, analysing and synthesising, while Rory might be concentrating upon willingly immersing himself in gaining experience with cutting and stitching. Of course, these are all valuable activities. The question arises as to what extent they are the appropriate activities for the learning task at hand, and to what extent learners' knowledge is deficient in learning areas that require alternative knowledge.

The need for teachers to know about what their students know is particularly highlighted by the case of Bec. Without knowledge about Bec's knowledge, Bec's teacher is placed in a position of having insufficient information to effectively proceed, either with teaching and learning in the topic, or with teaching and learning about teaching and learning. An informative perspective is provided by Sternberg (Sternberg, 1987; Sternberg, 1994; Sternberg, 1999b; Sternberg, 2000) who has developed an argument in many papers over the years that intelligence is best viewed as domain specific developing expertise. If knowledge about teaching and learning is a form of domain specific expertise, it would seem that Bec's understandings about teaching and learning are undeveloped and that this state will hinder her further learning. In contrast, the quality of Sally's knowledge about teaching and learning places her in good stead for maximising her learning opportunities. Furthermore, the clustering of the three participants from the child-care cohort at the stockpiling end of Dimension 1 suggests that this is a more general issue than one of occasional, or rare, individual differences. Our findings point to the importance of avoiding assumptions that adult learners necessarily come to formal educational settings pre-equipped with a range of high quality knowledge about teaching and learning.

Also, our illustrations of participants' Profiles highlighted that learners' knowledge can be characterised by patterns of variables of quality. Such patterns can be employed as tools for diagnosis and to design and implement targeted instructional intervention. Other instructional interventions have tended to focus upon one or a few variables, such as teaching students to construct visual images to strengthen cognitive networks, teaching metacognitive strategies for self-monitoring, keeping journals so as to develop and engage in reflective thinking, using problem based learning scenarios so as to develop self-regulation, and engaging students in dialectical activities. The Framework, the Dimensions of Difference and the Profiles uncovered in this study provide a new way of looking at such interventions, with a view to grounding future interventions in a theoretical framework, targeting interventions to individual differences, and providing a multi-dimensional perspective to the range of knowledge that such interventions might enhance.

The fourth perspective for viewing this study, methodological, highlights the use of Correspondence Analysis as a technique that provides elegant graphical representations to assist in understanding the complexity contained in large data sets. Furthermore, Correspondence Analysis is particularly suited to the type of data that is commonly available in the social sciences: frequency data. In particular, extending the use of Correspondence Analysis beyond the graphical displays of the low dimensional solutions to create prototypical and individual participant Profiles is a valuable technique for representing the fine detail of participants' knowledge.

Limitations and future directions

The research described in this paper is of a small sample, and of course, we make no claims that our specific findings can be directly transferred to other settings. Rather, our contribution is to provide a *way of looking* at issues of quality of knowledge about teaching and learning. Cobb (2001 p. 549-460) captured the spirit of this kind of research in his discussion of the generalizability of design experiments: "This is generalization by means of an explanatory framework rather than by means of a representative sample."

Finally, it is clear that not many, if any, educators will have the financial and time resources to conduct in-depth interviews with each of their students, and to assign thousands of codes to interview transcripts, as we did. Whereas this stage of our research has been to propose the

Framework, and to identify Dimensions of Difference, the next steps in our research will be to refine these constructs for more general applicability.

Appendix 1: Interview questions for Learners

Domains of teaching and learning
1: The nature of the learning environment (authentic practice; classroom/text based)
2: The nature of the learner (motivation; management; metacognition)
3: The nature of teaching and learning (transmission--reception; construction)
4: The nature of the subject matter (curriculum content and purpose)

Domain	**Background theory**	**Interview questions for learners**
2	Achievement goals (mastery, performance, strategic)	What do you want to achieve from what you are doing in this lesson/topic/course? Why do you want to achieve this?
2	Self-efficacy, expectancies for success and attributions for success/failure	How well do you expect to perform in this lesson/topic/course? Why do you have those expectations? Can your performance be changed and if so, how?
2 and 3	Cognition and Metacognition	What thinking processes will you be using in this lesson/topic/course?
2 and 3	Management	In what ways are you responsible for the learning in this lesson/topic/course? In what ways is your teacher responsible for the learning in this lesson/topic/course? ?
2 and 3	Assessment/ feedback/ self-regulation (reflection, metacognition)	How will you know that you have learned what you are meant to?
4	Curriculum content	What specific things are you meant to learn from this lesson/topic/course? What broad understandings or ideas do you think you are meant to get from this lesson/topic/course?
4	Curriculum purpose	Why are you learning this? When, where and how will you use the learning in this lesson/topic/course?
1 and 3	Teaching and learning strategies	How does what you are doing help you to learn what you are meant to?
2	Value and Interest	Is this what you want to learn? Why, or why not, do you want to learn it?
1 and 3	Psychological and social constructivism. Teaching and learning strategies.	Who and/or what helps you to learn? How do they/it help you to learn?

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