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Uncovering students' thinking about thinking using concept maps

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Abstract A method for uncovering students' thinking about thinking, specifically their meta-strategic knowledge, is explored within the context of an ongoing, multi-year intervention designed to promote the development of students' thinking dispositions. The development of a concept-map instrument that classroom teachers can use and an analytic framework for interpreting students' responses is presented. In a preliminary study, the concept map instrument is piloted to evaluate changes in students' conceptions of thinking after a year's participation in classrooms where their teachers actively sought to make thinking more visible by noticing and naming the thinking observed as well as introducing and using thinking routines (Ritchhart and Perkins. Educational Leadership, 65(5), 57–61 2008). Concept maps from 239 students from grades 3 through 11 were analyzed. Results suggest that students' conceptions of thinking do improve with age but also can be substantially developed through a classroom culture where thinking is modeled and rich opportunities for thinking are present. The concept map instrument itself proved to be a robust instrument for uncovering students' thinking about thinking.

Keywords Metacognitive assessment · Program evaluation · Concept maps · Metacognitive development · Thinking dispositions · Meta-strategic knowledge

In the Cultures of Thinking Project, we seek to develop students' dispositions toward thinking by working with teachers to create classrooms where thinking is valued, visible, and actively promoted as part of the regular, day-to-day experience of all students. Because we believe that thinking dispositions are not so much learned as they are enculturated over time, our project focuses on helping teachers to understand the culture of their classrooms

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and working with them to shape that culture in a way that supports students' development as thinkers. In practice, this means attending to a set of eight cultural forces (Ritchhart 2002) we have identified as important shapers of group culture: 1) the physical environment of the classroom, 2) the use of language, 3) student and teacher interactions, 4) the allocation of time, 5) the creation of learning opportunities, 6) the use of structures and routines to scaffold and support thinking and learning, 7) the modeling of thinking, and 8) the setting of expectations for thinking. These forces can be found in any setting where learning is a component of the group's activity (Ritchhart 2007). An exploration and understanding of these eight cultural forces provides both the conceptual and practical backbone for our work with teachers.

Our most recent work is centered in Australia in the form of a 5-year professional development project at Bialik College, a private Jewish day school in Melbourne. The Cultures of Thinking Project, under the patronage of Abe and Vera Dorevitch, involves teachers from kindergarten to grade twelve in ongoing professional learning communities focused on an exploration of thinking and classroom culture. Working in mixed grade and subject-area groups, teachers begin their learning by discussing and identifying the kinds of thinking dispositions they value as being integral to students' disciplinary understanding. Teachers then learn how to use "thinking routines," simple structures that help to scaffold and support students' thinking, and various documentation techniques that help to make students' thinking visible. Teachers' ongoing learning is supported through weekly meetings with colleagues to discuss student work and explore ways that students' thinking can be promoted. Our approach to professional development provides conceptual frameworks for understanding classroom culture (the eight cultural forces), instructional tools in the form of thinking routines (Palmer et al. 2005; Ritchhart and Perkins 2008), and protocols for discussing student work and classroom practice. However, we do not prescribe a set of practices to implement or a structured program to follow. Rather, teachers' integrate their learning about thinking and classroom culture into their teaching according to their own understanding and unique approach to teaching at their particular grade level and subject area.

In working with teachers to understand classroom culture and its role in supporting thinking, we seek to make classrooms cultures of thinking. In creating classrooms that are cultures of thinking, we in turn seek to develop students who are themselves more thoughtful, self-regulating, and self-initiating in their learning. Clearly, our approach is not a linear process of simple instructional inputs yielding a set of well-identified outcomes but rather an organic process that recognizes and honors the complexities of teaching, learning, and thinking. Nonetheless, we do see shifts in the culture of the classroom as well as changes in students as a result of our efforts (Ritchhart and Perkins 2008). As researchers, as well as professional developers, one of our goals has been to develop measures that can capture these changes. In this paper, we report on one such effort focused on identifying changes in student's conception of thinking over the first year of the project.

Specifically, we discuss the use of concept maps as a potential tool for uncovering students' thinking about thinking and explain the development of a coding scheme for making sense of such an individualized and open-ended measure. Applying this methodology, we then look at students' conceptions of thinking within the Cultures of Thinking project in order to examine developmental differences as well as measure changes in those conceptions as a result of immersion in the project. However, it should be noted that our goal in this paper is not to prove the effectiveness of our intervention, to do so would require a different type of study. Our intent is to show that concept maps can: 1) be an effective tool for capturing students' thinking about thinking, 2) reveal developmental differences, and 3) capture changes in students' conceptions over time. The implications and limitations of our findings for educators interested in promoting students thinking and metacognition are explored within this limited context.

Conceptions of thinking

As schools increasingly take on the mission of cultivating students' thinking dispositions and enculturating the habits of mind that can support life-long learning, the issue of how students construe thinking and their general metacognitive awareness comes to the fore. The important function of awareness in metacognition was highlighted by Biggs (1987) who stated, "To be properly metacognitive, then, students have to be realistically *aware* of their own cognitive resources in relation to the task demands, and then to plan, monitor, and control those resources" (p. 75). Biggs refers to this awareness of one's own learning processes and one's control over them as meta-learning, a subcomponent of metacognition. This view is reiterated by Baird (1990), who describes metacognition as "knowledge, awareness and control of one's learning" (p. 184). Drawing on this work, Case and Gunstone (2006) put forth "knowledge and awareness of learning" (p. 52) as the first stage in their four-part model of metacognitive development. While we believe that this focus on awareness is well placed, we would take issue with a focus on "learning" as the central tenant of metacognition. Although learning broadly construed is clearly central as a *product* of metacognition, we assert that metacognitive awareness must first and foremost be centered on thinking. It is the focus on the cognitive actions of learning that separates metacognitive development from other closely related constructs, such as, self-regulated learning, conceptions of learning, and approaches to learning. Furthermore, we belief learning is but one product of metacognition. Consequently, we belief metacognitive awareness is most productively characterized as the awareness of "the *thinking processes* that facilitate learning, problem-solving, decision making, and judgment."

Within the context of our study, then, we are interested in exploring students' explicit awareness of the process of thinking without limiting it solely to the realm of learning. Furthermore, we wanted to focus our attention on students' conceptions of what it means to think rather than their beliefs or theories about thinking or the purpose of thinking. Specifically, we were interested in uncovering students' awareness of thinking moves they might undertake that can facilitate their learning, problem solving, decision-making, and judgment. Zohar and Ben David (2008) refer to this as meta-strategic knowledge. Although this includes study skills and the recognition of memorization and knowledge retrieval strategies, it goes beyond them to look at students' awareness of thinking strategies that can build understanding. This would include such mental moves as looking at material from a different perspective, making connections with one's prior knowledge, generating alternative hypotheses, and so on.

Clearly, there is a wide range of thinking strategies students might employ in their learning, as well as in other domains. Although many possibilities exist for how such strategies might be classified, identifying strategies by their level of processing has a long history. Craik and Lockhart (1972) suggested that depth of processing effects recall and proposed a continuum ranging from the shallow to the deep to classify students' processing. Marton and Saljo (1976) use this same notion to classify the approach students use in processing text as either deep or surface. Biggs (1987) builds on this work in proposing a framework for understanding students' motives and strategies for learning. Biggs proposes three levels: surface, deep, and achieving, with achieving being characterized as focusing on the behavior consistent with being a good student. Van Rossum and Schenk (1984) use different language to refer to similar constructs, calling surface-level strategies "reproductive" and those that build understanding and require greater depth in processing, "constructive." In our work with teachers, we have found the simple language of "surface" and "deep" thinking moves to be intuitively useful. Surface strategies focus on memory and knowledge gathering whereas deep strategies are those that help students to develop understanding.

Although changes in students' conceptions of thinking, or development of their meta-strategic knowledge, are not the end goal of efforts to promote thinking or enhance metacognitive development, they can serve as one marker of students' development. Just as students' conceptions of learning are associated with their approaches to learning, we postulate that when students' conceptions of thinking are limited to knowledge retrieval and memorization strategies, then they may be more likely to try and adopt these kinds of strategies when their teacher asks them to "think." Studying teachers, Ritchhart (2002) found that teachers' conceptions of thinking shaped the way they tried to promote students' thinking. Teachers with well-elaborated conceptions of thinking comprised of specific thinking strategies were more able to support and scaffold thinking in their students than were those teachers having more general and global conceptions. Like Biggs (1987), we see a connection between students' meta-strategic knowledge and students' ability to engage, control, and monitor those strategies. Although, we do not assume that merely increasing students' meta-strategic knowledge will cause students to think differently, we do believe that nurturing the development of students' thinking dispositions, which would include metacognition, is informed by teachers becoming more aware of students' conceptions of thinking. But, how do we uncover students' thinking about thinking? How do we unearth their conceptions of what thinking is and the mental moves it encompasses? How do we do this in an open way that captures individual responses and growth over time rather than constraining students' responses to a pre-determined set of categories?

Concept maps as tools for making thinking visible

In trying to uncover students' thinking about thinking, we wanted to find a measurement tool that was non-threatening, open-ended enough to allow for rich and detailed responses, and manageable for teachers to administer. Since this task would be one of the first done in classrooms participating in the project, we had further goals. Specifically, we wanted the probe into students' thinking to: 1) feel authentic to the classroom and not a test or exercise done for outsiders, 2) be an opening for discussion of thinking with students, 3) not feel like a test with right or wrong answers, 4) be relatively transparent so that teachers would come to see themselves as researchers into their students' thinking. With these goals in mind, we pursued concept maps as a tool for making students' thinking about thinking visible.

Concept maps are a graphic organizing technique designed to help learners explore their knowledge or understanding of topics that are highly elusive and mystifying (Novak and Gowin 1984). In this sense, concept maps act as metacognitive tools used to illuminate one's thinking. Early uses of concept mapping was largely in the context of science classrooms while more recent uses have broadened to explore the nature of learning in a variety disciplines and contexts (Kinchin and Hay 2007).

Concept mapping is largely credited to Joseph Novak (Novak 1998; Novak and Gowin 1984). Novak's original rules of concept mapping are quite straight forward: the learner first writes her ideas in text boxes that are arranged hierarchically on a page; the learner then links these concepts with arrows pointing in explicit directions to convey meaning between concepts; lastly, concepts are listed only once but the learner can make multiple links between concepts (Hay and Kinchin 2006). Researchers have noted the various benefits that this approach yields, including: classroom shifts in the epistemological authority from the teacher to the student, less emphasis on right and wrong answers, creation of visual entry points for learners of varying abilities, and reduction of cognitive load to support learning (Fisher et al. 2000; O'Donell et al. 2002; Roth and Roychoudhury 1993). With its emphasis on actively engaging learners in depicting the conceptual relationships they perceive, concept mapping is considered to be consistent with constructivist epistemology (Edmondson 2000).

In classrooms, the practice of concept mapping can vary widely in terms of rules, structure, purpose, and how they are evaluated. In some cases, they are little more than lists arranged in a circle. In other instances, they reveal the interrelationship among ideas. In whatever way they are used, concept maps offer a structure on which to hang one's ideas, even if those ideas are not yet clearly fleshed out, or perhaps cannot yet be fully articulated or performed in action. Furthermore, concept mapping can range from very simple to complex, which makes it useable by a wide range of learners.

Due to their familiarity, accessibility, and flexibility, we felt that concept maps had the potential to be useful tools for teachers to initially uncover students' conceptions of thinking and begin a discussion of thinking. Owing to their potential for uncovering nascent ideas and to reveal interrelationships and connections, we felt that concept maps could be useful tools for us as researchers to uncover students' conceptions of thinking and chart their development over time. However, because of the widely divergent ideas on how to construct concept maps among both students and teachers, we needed to develop a standardized method for creating concept maps that all teachers and students in the project could easily use and that would provide consistency across grade levels and subject areas. For our purposes, we chose a free-range style of concept mapping (Adamcyzk et al. 1994) that we explain further in the instruments section below.

Method

Participants

Participants in this study included 239 students from Bialik College, a Jewish day school in Melbourne, Australia. Of these students, 39% were girls and 61% were boys, 177 were from the elementary division in Grades 3–6, and 62 were from the secondary division in Grades 7–11. The relatively smaller number of secondary students reflects both the proportionately smaller number of secondary teachers participating in the project at the time and the fact that some secondary teachers felt they could not give over class time to participate in the concept map activity.

All students were in classrooms of teachers actively involved in the Cultures of Thinking Project. As participants in the project, each of these teachers participated in a professional colleague group with seven other teachers over the course of the school year. The groups met once a week for a semester to: a) explore the role of the eight culture forces (mentioned in this paper's introduction) in shaping classrooms' culture, b) look collectively at student work for evidence of thinking, and c) explore the use of thinking routines as structures for promoting thinking (Ritchhart and Perkins 2008). The second semester, the teacher groups met twice montly to engage in personalized action research projects aimed at understanding how classroom culture influenced students' thinking.

Students participated in the creation of concept maps as part of their regular classrooms and under the direction of their teachers at both the beginning (February) and end (November) of the school year. Thus, there was a 9-month interval between students' first (pre-test) and second (post-test) concept maps. During this time, teachers participated in their professional learning groups to discuss student thinking and explore the cultural forces. It should be noted that, by design, each teacher's application of the ideas behind building a culture of thinking was unique and the student participants did not receive any standardized treatment; rather they were merely students in the classrooms of teachers who were striving to make thinking valued, visible and actively promoted in the classroom.

We did not establish a control group in our initial pilot of the concept map measure. An in-school control would have been politically untenable as our efforts were meant to be school wide. Furthermore, we actively promoted teacher sharing with colleagues beyond their professional groups. Because of the uniqueness of the student population, a matched sample would have been difficult to obtain. To deal with the lack of a control for evaluating potential changes in students' conceptions of thinking, we planned to identifying a developmental trajectory for students within our sample based on their pre-test concept maps and to use this trajectory for our baseline of comparison. To the extent that students' performance on the post-test concept maps exceed what would be expected based on developmental trends observed in the pre-test concept maps, we have a partial indicator of the effects of the project. Of course, this is not as strong an indicator of program effects as a control group would provide. However, it is important to keep in mind that our primary goal, which we report on here, was to develop and test an instrument with the potential to capture students' developing conceptions of thinking rather than to evaluate our project. Once such a measure is established, it is our hope that it can then be applied more rigorously in measuring program effects, both our own and that of others.

Instrument

As previously discussed, we chose to use concept maps as our tool for uncovering students' thinking about thinking for the potential they afforded the teachers for instruction and investigation of thinking as well as the rich data it was likely to provide us as researchers. An important first step in using concept mapping as a measurement instrument was to refine the concept map prompt. We decided to use a prompt that was purposely general in an attempt to support and not inhibit students' responses. The prompt asked students: "What is thinking? When you tell someone you are thinking, what kind of things might actually be going on in your head?" Two examples were given: "making a mental picture of things" and "comparing one thing with another." The term "thinking" was written in the middle of the page and students were asked to record their ideas about thinking. We specifically chose the phrasing, "What is going on in your head?" as opposed to, "What are you doing?" to focus students on cognitive actions rather than physical ones. We chose two specific examples that likely would be familiar to students in order to further promote a focus on cognitive acts.

In trial runs of this prompt, we noticed that the open-ended prompt still left room for interpretation and for students to respond in different ways. For example, many students still responded with physical actions as part of their map and others asked their own questions about thinking. Other responses seemed to answer different types of questions, such as, where do you think? Students' choices about what implicit questions about thinking they asked and answered in writing their maps largely defined the final categories in our analytic schema.

To elicit the highest-level response we could from students, we provided three further prompts that would encourage additional thinking about thinking and possibly induce new thoughts about thinking that were not as close to the surface as their initial responses. These prompts were: 1) Think of a time when it was difficult or hard for you to think. What kinds of things did you do then? 2) Think about times when you knew you were doing some good thinking. What were you doing then? 3) Think of someone you consider to be a good thinker. What kinds of things does this person do that makes him or her a good thinker? These prompts were given to students individually once they indicated they had run out of ideas to put down on their maps.

In administering the instrument, teachers were given a protocol to follow (see Appendix). This protocol led students through a whole-class experience of making a concept map so that all classes would have the same expectations of a concept map. The example asked students to brainstorm ideas about a topic. "Holiday" was chosen since this was just after the summer holiday and the word, as used by Australians, can be very action oriented, have personal as well as global meaning, and can be literal as well as affective in nature. The mapping focused on the collective brainstorming of ideas as the teacher placed the ideas on the maps and made connections as they occurred. Thus, students saw the open-ended and free form nature of mapping as well as models of the connection between ideas and the use of one thought to stimulate another. Figure 1 gives an example of a Grade 5 student's concept map. Figure 2 provides an example of a Grade 9 students' concept map.

Coding the concept maps

A team of six researchers worked with an initial set of 172 "pre-test" concept maps from students in grades three to eleven. Since there were no existing analytic scoring schemes available, we employed an inductive coding approach (Strauss and Corbin 1998). This

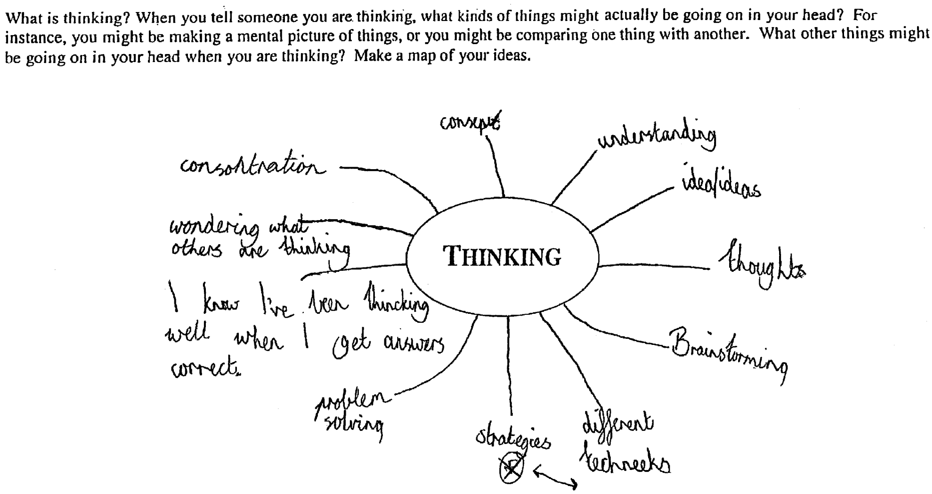

Fig. 1 Female, Grade 5 student's concept map of thinking

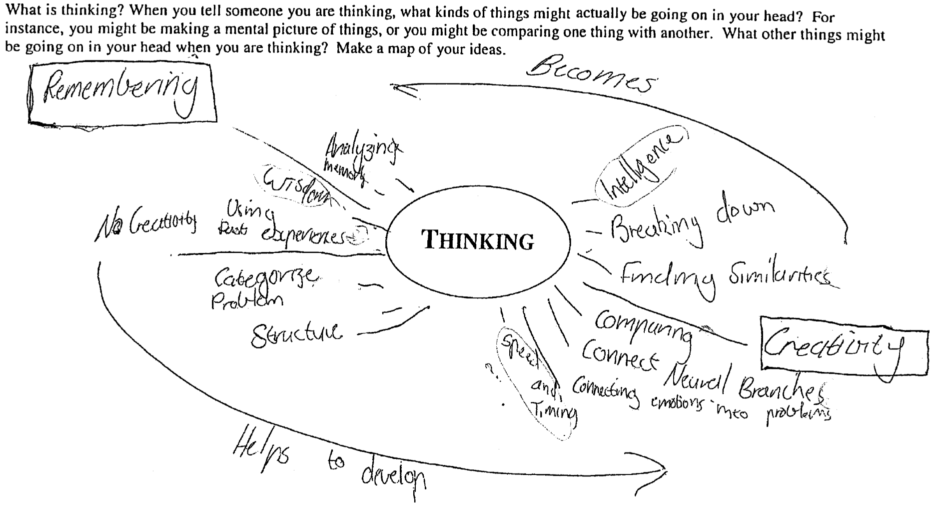

Fig. 2 Male, Grade 9 students' concept map of thinking

allowed us to best represent all of the data from the maps, as well as to articulate a new frame for understanding students' conceptions of thinking.

We began by individually identifying "types of responses" in a common set of twenty concept maps and then came together to compare notes and agree upon a list of preliminary categories of responses. A second set of twenty maps was then reviewed to determine the usefulness of these categories and to look for the emergence of any new kinds of responses. Throughout these iterative reviews, we noticed that the open-ended concept map prompt left room for students to offer different types of responses. While most all responses were related to thinking, it was as if students were implicitly asking themselves, and responding to, a variety of questions about thinking such as: When and where do I think? How do I feel when I am thinking? How to I prompt myself to think? Students' choices about what implicit questions about thinking they asked and answered in writing their maps helped define the emerging types of responses. After three iterations of our review process we identified ten categories of responses and grouped them into four main response types: Associative, Emotional, Strategic and Meta.

Associative Responses. In our first round of analysis, we immediately noticed many comments that seemed to be associated with thinking but not descriptive of the actual act of thinking. Comments such as "in math class", "when I'm traveling" and "what will happen next" spoke to the when or where of thinking, as well as what I am thinking about. These comments did not describe actual thinking processes or the nature of thinking but rather actual people, places and things. Other associative remarks included very general comments about what I think with, or how I think, such as: "thoughts in my mind" or "brainwaves". Three categories of responses comprised this Associative set of responses: Events/Occasions for Thinking (e.g., "in maths class"), Objects of Thought (e.g., "my friends"), and General Observations and Connections to Thinking (e.g., "my brain").

Emotional Responses. The number of comments revealing an affective connection to thinking struck us. Students included affective words such as: "unsure", "joy", and "hard when there is time pressure." We suspected early on that a category of emotions was emerging but clearly it was not reasonable to code comments such as "nervous" and "exploring emotions and feelings linked to the task" as being the same. We devised codes for two distinct categories of emotional responses: Reactive Emotions, that is, those initial responses to calls for thinking such as being "scared" or "unsure," and Cognitive Emotions (Scheffler 1991), that is, those emotions that arise as a result of thinking such as, "being excited that I solved it" or "confusion as a result of trying to solve the problem."

Strategic Responses. A clear set of responses that emerged from analyzing students' maps related to the concept of strategies. These comments stood apart from the other types of categories in that they mention either a specific or general action one takes when engaging in thinking processes. These were the kind of responses we were targeting in our probe of thinking as they helped us to see what strategies for thinking students were familiar with in their own thinking and, thus, most likely to apply. This set of responses mapped on to deep/constructive and surface/reproductive approaches to learning.

We noticed four categories into which students' responses might be grouped: 1) Memory and Knowledge-Based Strategies. These related to surface learning and focus on storage and retrieval of information, such as, "look in books" or "practice it over and over again." 2) General and Non-Specific Strategies. These can relate to either surface or deep learning, but they stood out as a category due to their very general nature. Items in this category often sounded good, but did not reflect specific actions one could take. For example, "think logically" is clearly related to thinking but it is ambiguous in terms of its actions when coming from a fifth grader. So too items like: "problem solve," "metacognition," or "understand." 3) Self-Regulation and Motivation Strategies. This category of responses reflected students' understanding that thinking needs to be motivated and managed, and included responses such as, "clear your mind of all other worries" and "tell myself I can do it." 4) Specific Thinking Strategies and Processes. This category relates to deep or constructive approaches to learning that are about making meaning, building understanding, solving problems, and making decisions. These included such responses as: "consider different perspectives" or "expand on other questions that may arise from the previous one."

Meta Responses. Lastly, there were a few responses on students' concept maps that spoke to a greater awareness of the nature of thinking. Rather than specifying an action, these comments focused on epistemology, the nature of understanding, and conceptualizations of building knowledge. This Meta type of response included comments such as: "There is always more to learn," "You can't ever fully understand something," and "Remembering helps to develop creativity." Although we did not attempt to solicit these kinds of responses, some students provided them on their own.

These ten categories of responses grouped across four main types provided the coding schema for the research team. Since the maps were so varied in format and clarity, we also created guidelines to help align researchers in coding. For example, some maps had very clear lines and arrows showing the students' understanding about how their ideas were linked (see Fig. 2), others had lists of ideas with inferred connectedness, while others had many one-word responses with no clear juxtaposition (see Fig. 1). The guidelines helped us to determine when to count an item as a single response or as a multiple response. For instance, we decided not to count a 'label' or top-level category that is elaborated but to count each new elaboration as a response. Therefore, if the item on the map was "Formulate: formulate ideas, formulate opinions," it was counted as two responses, not three.

Once our guidelines and schema were finalized, we scored all of the maps and reached an inter-rater reliability of at least 80%. With reliability established we divided the maps among the six researchers and scored the entire set. For our post-test maps we reconfirmed reliability and once a minimum of 80% reliability across the set of all scorers was established, we divided the maps among the researchers and coded all of the post-test maps.

Analysis

We examined the students' maps via two modes of inquiry. First, each map received a "score" that represents the total number of comments per category of response. These were summed in order to create scores for the four types of responses: Associative, Emotional, Strategic, and Meta. An additional variable that summed the total number of responses per grade was also created for both the pre and post-test concept maps. As the percentages were created, we wanted to see the distribution of responses for the whole population as a "snap shot" of the maps. Hence for each category we computed the percentage of total responses for each grade level, for pre-test and post-test separately. That is, all pre-test responses across all categories for each grade were counted. The percent of responses for each of the four sets of responses was also calculated. For example, the total number of responses for the Associative set of responses for each grade level divided by the total number of responses for that level.

Secondly, a "Sophistication" score was computed for each student's concept map. Each response type was assigned a weighted numeric value. Associative, Emotion, and Meta responses were awarded 0 points. Although informative of students' understanding of thinking, these did not reveal the mental moves of thinking that students had at their disposal. For this, we had to focus on the responses that fell in the Strategic set. Within this set of responses: Knowledge-Based and General Strategies, which were reflective of surface learning or were non-actionable in nature, were given one point. Self-Regulation and Motivation Strategies were given two points, as these strategies are important for activating and sustaining thinking, whether deep or surface. Thinking Strategies, which reflected deep learning, were given three points. Points were summed so that a high score equated to a "more sophisticated map". Under this scheme, a student with a well-developed set of strategies for surface learning was rewarded for the number of specific strategies he or she was able to generate but not as much as a student who was able to generate a more modest amount of deep strategies. Thus, our sophistication score rewarded deep thinking over surface thinking, as this has been associated with more advanced development (Marton et al. 1993).

For our analysis, we grouped students into three groups according to curriculum and developmental differences. These were Grades 3 and 4, Grades 5 and 6, and Grades 7–11, which encompassed the secondary school. These groupings allowed us to create larger data sets for analysis since in some cases only a single class of students completed the maps in the secondary school. We used chi square tests when analyzing developmental and pre-post differences for percents of responses. We used ANOVA and regression models when analyzing concept maps sophistication score.

Results

Developmental differences

Table 1 displays developmental differences on students' initial concept maps. Younger students' maps (grades 3–4) predominately focus on what they think about, when they think, and other general responses (*Associative*=71.51%). As students mature, the number

Table 1 Developmental differences for students' initial thinking concept maps

Response types	Grades 3–4 (*N*=46) Percent of responses	Grades 5–6 (*N*=63) Percent of responses	Grades 7–11 (*N*=62) Percent of responses	χ2	Sig
Associative	71.51	68.00	45.87	173.97	*P*<.01
Strategies	16.47	23.09	41.02	43.75	*P*<.01
Emotions	12.02	8.68	11.40	0.21	N.S
Meta	0.00	0.23	1.70	0.06	N.S

of *Associative* responses lessens, though this is still the single largest category of responses (*Associative* grades 5–6=68.00%, *Associative* grades 7–11=45.87%). All grade level differences were significant ($\chi2(2)=173.97$, $P<.01$). Developmentally we also see that older students report significantly more *Strategies* than younger students ($\chi2(2)=43.75$, $p<.01$). Responses coded *Strategies* for grades 3–4=16.47%, grades 5–6=23.09%, and grades 7–11=41.02%. Students at all levels show an awareness of the role of emotions in thinking though there was no significant difference between grades in either *Emotions* or *Meta* thinking comments. We found similar developmental tendencies in the post-test maps reported in Table 2.

Pre- post test differences

By examining pre-post differences in students' concept maps, we wanted to see if students' conceptions of thinking became more strategic and less associative as a result of their teachers working to create classrooms in which thinking was valued, visible, and actively promoted. It should be noted that teachers did not actually teach students about thinking or introduce a set of thinking strategies; rather they focused on getting students to think as part of everyday learning while making them more aware of their thinking as it was happening.

Analysis of pre-post changes across all groups is reported in Table 3. For all grade level groups, there is a significant decrease in *Associative* responses and a significant increase in the category of *Strategies* reported. Across the three grade-level groups, the percentage of *Strategic* responses increased by an average of 23.88 percentage points. In grades 7–11, there was a significant decrease in responses related to *Emotions* and a significant increase in *Meta-Comments*. Changes in *Emotions* and *Meta-Comments* were not significant for grades 3–4 or grades 5–6.

For the map *Sophistication Score*, reported in Table 4, developmental differences were found to be significant on both pre and post maps. These differences show that on average younger students' maps tend to be less sophisticated than older students' maps. For each grade level separately, as well as for all grades combined, students' post concept maps show

Table 2 Developmental differences for students' post-test thinking concept maps

Response types	Grades 3–4 (*N*=95) Percent of responses	Grades 5–6 (*N*=82) Percent of responses	Grades 7–11 (*N*=37) Percent of responses	χ2	Sig
Associative	51.20	48.20	26.88	81.28	*P*<.01
Strategies	39.54	43.93	68.77	64.57	*P*<.01
Emotions	7.91	5.52	1.45	3.75	N.S
Meta	1.35	2.34	2.91	0.17	N.S

Table 3 Pre-post conception of thinking differences divided by grade

Conception of thinking categories	Percent of responses			Percent of responses			Percent of responses		
	Grades 3–4			Grades 5–6			Grades 7–11		
	Pre	Post	χ2	Pre	Post	χ2	Pre	Post	χ2
Associative	71.51	51.20	25.28**	68.00	48.20	116.2**	45.87	26.88	42.46**
Strategies	16.47	39.54	21.79**	23.09	43.93	8.12**	41.02	68.77	12.44**
Emotions	12.02	7.91	0.17	8.68	5.52	0.48	11.40	1.45	4.04*
Meta comments	0.00	1.35	0.00	0.23	2.34	0.40	1.70	2.91	0.26*

*$p<.05$, **$p<.01$

a shift toward a more complex conception of thinking as evidenced by their *Sophistication* scores.

Because we did not have a control group of students with which to compare these results, we contrasted our observed findings with the predicted growth for this group of students based on the developmental differences observed in the pre-test. To compute an estimate of average yearly growth, we performed a regression analysis on the pre-test sophistication data. "Grade" was found to be a significant contributor to the change in sophistication score ($F\ (1,169)=41.64$, $P<.01$) with an expected growth in sophistication of 2.051 per grade. Our findings indicate a mean gain in sophistication score of 3.24 across all grades. Theses gains show that the pre to post growth observed may not only be a consequence of development, but also might be attributed to the teachers' involvement in the project.

Discussion

Our intent in this paper has been to report on our efforts to develop a measure that can be used to effectively uncover students' thinking about thinking. Our examination of hundreds of concept maps has shown that they are indeed rich vehicles for uncovering students' conceptions of thinking in a way that is accessible both to teachers and students. In most classrooms, after the concept map task, teachers engaged students in a discussion of thinking in which strategies were shared and discussed. The map task also provided teachers the opportunity to show as well as tell students that the class would be focusing on thinking throughout the year and that thinking about thinking was a worthwhile and important part of learning. This, in and of itself, may help to move students from a surface to a deep approach to

Table 4 Pre-post concept maps sophistication score by grades

Grade	Pre-test sophistication score		Post-test sophistication score		F	Sig
	Mean	S.D	Mean	S.D		
Grades 3 & 4 (N=141)	4.02	4.78	8.85	6.81	18.61	$P<.01$
Grades 5 & 6 (N=145)	10.50	9.67	14.23	10.99	4.52	$P<.05$
Grades 7–11 (N=99)	12.25	12.02	18.78	8.51	8.37	$P<.01$
Across grades	9.39	10.16	12.63	9.66	9.84	$P<.01$
Developmental differences	F Sig	10.27 $P<.01$		18.65 $P<.01$		

learning. Dart et al. (2001) found that students' conceptions of learning do not dictate an approach; rather students' conceptions are mediated by the context of their learning. Teachers alerting students to a different type of learning, a learning that is more investigative, participatory, and personal, can affect students' approaches to learning regardless of their conceptions of learning (Dart et al. 1999). To the extent that students' engagement in thinking is dependent on their understanding and beliefs about how thinking happens, then the very act of unpacking what it means to think can help students become more metacognitive, more self-directed as learners, and better thinkers.

In our design of the concept map protocol, we wanted to focus students' attention on thinking strategies. However, despite our initial prompt, examples, and secondary prompts, students' concept maps still displayed a high propensity to give Associative responses. On one level, this seems to be worrisome and perhaps a sign that the prompts need adjustment. Another perspective, suggested by the very nature of free-style concept mapping itself, is that the open-ended and accessible nature of concept mapping allows individuals to depart from a narrow script. Furthermore, having the freedom to record responses that are not strictly limited to the prompt might keep thinking open and preclude a premature finishing of the task. In this way, Associative responses might be seen as a soft mental pause, rather than a full stop, in the concept map process.

Due to their individuality, concept maps are largely a qualitative measure. Nonetheless, we have shown that it is possible to code students' responses in a way that illuminates their current mental model of thinking. Furthermore, this coding connects with and provides a foundation for better understanding conceptions of deep and surface learning found in the literature on learning. The mental models emerging from the concept map process can provide the basis for future teaching, as well as baseline data for researchers. It is interesting to note that students' conceptions of thinking frequently recognized the affective, emotional, and motivational aspects associated with thinking, all areas receiving increased attention in the field of metacognition. The emergence of these types of responses across all grade levels, alerts us to the fact that promoting thinking should not be viewed as a strictly cognitive activity, but must also address the emotional and motivational side of thinking.

The fact that we were able to see growth in students' conceptions of thinking after a year of indirect instruction that sought to make thinking more valued and visible in classrooms suggests that a focus on creating a classroom climate conducive to and supportive of thinking effects students, at least to the extent that it broadens their conception of thinking and their meta-strategic knowledge. It also provides evidence that students' conceptions of thinking are malleable and can be advanced beyond expected developmental progress. From a research perspective, efforts to promote student thinking have traditionally suffered from a lack of clear evidence of their effectiveness (Ritchhart and Perkins 2005; Ritchhart and Perkins 2008). This is in part due to the fact that broad-based efforts to promote thinking dispositions offer diffuse benefits to students that are not easy to capture in on-demand testing situations that focus on surface learning outcomes. Although our intent in this paper was not to prove the effectiveness of our particular program, we have shown the potential for using concept maps to demonstrate how students' conceptions of thinking shift. This provides us, as well as our fellow researchers, with one potentially useful measure for capturing the effects of interventions that promote students' thinking.

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Appendix

Protocol for Thinking Maps

1. Tell students you are interested in their thinking or that this year you will be doing a lot of things to get them to think. Tell them you are interested in finding out what they think thinking is and what they think is involved in thinking.
2. Tell students you will ask them to do a concept map about thinking. Ask students if they have done a concept map before. Tell them there are many ways of doing concept maps, so you want to just do a quick one so that they are clear about this way of doing a map. Do the "HOLIDAY" example concept map. Point out that this map is about brainstorming ideas and making connections when they seem obvious, but there is no one right way or no answer. You are just interested in their ideas.
3. Pass out the Thinking Maps sheet and read the directions. Ask students to fill out the information at the top before they start. Ask students to work quietly without talking about their ideas yet. Ask them to raise their hands when they have come to a stop.
4. Pass out the second prompt sheet and ask students to read it and use it to add to their maps. With younger children you can read it to them if you think that is best. If students have questions, you can clarify them but point out that the sheet is just questions to help them generate more ideas and they don't have to actually be answered.
5. When everyone seems to be done, or as small groups finish, ask students to try and add at least 2 more items to their maps.

Possible ways to debrief the activity

1. Have students compare their maps with a partner and look at similarities and differences.
2. Create a whole class concept map drawing on students' ideas.
3. Focus the discussion on subject specific types of thinking by asking students what kinds of thinking from their lists, ways of thinking, or thinking actions they think they will be using in your class this year.

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