Bifocal Assessment in the Cognitive Age: Thinking Maps for Assessing Content Learning and Cognitive Processes

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The Bifocal Lens

Among his other revolutionary accomplishments, Benjamin Franklin invented bifocals to allow us to see things more clearly—that which is right before our eyes as well as that which typically requires closer inspection—with the same tool. The most effective revolutionary tools are elegant in their simplicity, leading to complex applications. Thinking Maps®, as a fundamental language of cognitive patterns, have shown promise to become a model for transforming educational assessment. This set of visual tools allows us as teachers to see student content learning *and* thinking processes through the same bifocal lens—viewing the content at the surface and the cognition more in depth. Our cognitive age requires that our assessment tools keep pace with our new understanding about how the brain learns and processes information. In this piece, we offer tools for educators and learners to determine not only "what" is learned but also "how" it is learned.

Non-Linguistic Representations, Visual Tools, and Assessment

How can teachers and students, as self-directed, self-assessing learners, look through a bifocal lens to determine what factual and conceptual content knowledge students have gained while simultaneously looking down deeper at the thinking processes that are the drivers of higher-order learning? We may seek a unifying lens that draws together content and process through a third dimension: the "form" of knowledge represented using Thinking Maps. In *Concept-Based Curriculum and Instruction,* Erickson (2002) visually shows that many concepts are structured in the form of a hierarchical tree, with the guiding theory at the top of the tree, supported by generalizations, concepts, topics, and facts cascading down like branches to an isolated knowledge base. This reflects what actually happens when students draw out a Tree Map, one of the eight Thinking Maps; they simultaneously show their factual content knowledge, their process of either inductive or deductive categorization, and conceptualization, while also representing the visual form of the synthesis of contents and processes. Students are building content knowledge as conceptual understandings in these cascading general-to-specific categories and are actively forming complex mental models (Senge et al., 1990) grounded in complex visual patterns of thinking. When students create such visual models, teachers and students alike can scan quickly and see deeply. This provides what all effective teachers need—an efficient, useful assessment tool that allows us to see both the content and process through the same unified lens.

Different types of visual tools, from brainstorming webs for creative thinking to graphic organizers for analytical thinking to thinking process maps for conceptual thinking, have been used extensively across classrooms over the past thirty years and have been comprehensively documented by Hyerle in *Visual Tools for Transforming Information into Knowledge* (2009). In recent years, comprehensive research has shown that "nonlinguistic representations" (Marzano, Pickering, & Pollock, 2001; Marzano & Pickering, 2005) are highly effective for improving instruction and learning, directly impacting comprehension and writing across all disciplines. Cognitive scientists, brain researchers, and learning theorists are now working off the same page; the brain networks and maps information, the unconscious mind builds schemata or linked associations about ideas and concepts, and fundamental cognitive processes enable all learners to transform static information into active, useful knowledge.

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A rich history of "theory into practice" shows us how to use visual tools for learning, but applications of this wide range of tools for assessment purposes are scant. Attempts have been made to integrate simple graphic organizers into standardized tests and scaffolds that students may use in order to respond to formal writing prompts. Some teachers now use ubiquitous graphic-organizer templates and those included in structured reading programs and content area textbooks as handouts. But students don't need more handouts. They need tools they can use on their own when the teacher isn't there. Despite many of the hundreds of graphic organizers that may be helpful as tools for certain tasks of teaching, learning, and assessment, many of the pre-structured boxes and ovals are merely replicating standardized worksheets that students "fill in" rather than allowing individual students to create their own maps of learning by hand and mind. Most of these graphic organizers have a glass ceiling, preventing students from independently going outside the box beyond preordained structures. This glass ceiling is not clear enough to allow us as teachers to see the students' thinking at a higher level.

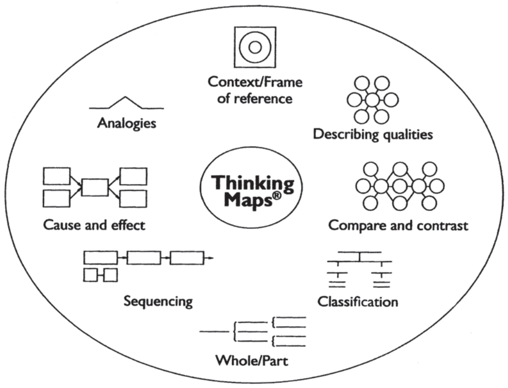
One of the most significant and well-researched mapping approaches, "concept mapping," was developed for integrating teaching, learning, and assessment and is detailed in a groundbreaking book, *Learning How to Learn* (Novak & Gowin, 1984). Teachers and students learn how to create hierarchical maps on a white board and/or from blank paper. Using simple ovals and curved lines for showing interrelated links between different levels of the maps, all students are trained in this model until they fluently create evolving visual representations of what and how they are thinking. This is the heart of formative assessment; the teacher can walk around the room and look down on each student's map and, in the moment, question students based on three criteria: how are you expanding, clarifying, and assimilating new information and concepts into your new understandings? These independently created student maps are thus used as formative assessments as teachers check for any factual concerns and misconceptions.

Early studies demonstrated how, at the end of a term, teachers and students score maps as summative assessments using the same criteria. The significance of this approach is that each student creates his or her own maps. There is no one correct map for any given concept. The focus is on developing content knowledge, thinking processes, and, ultimately, the differentiated forms of unique concepts. Though well researched, dynamic, and highly effective, concept mapping may have theoretical and practical limitations preventing extensive use in classrooms. The model is based on a view that all knowledge is hierarchical, so that all factual information and cognitive and metacognitive knowledge is subsumed within a highly complex, single map form. Because of this theoretical view, teachers and students must go through extensive training to learn how to integrate multiple forms of thinking into a unified, complex weave of interrelated concepts. Nonetheless, concept mapping provides a rich starting point for the use of visual tools in better understanding students' thinking processes and content knowledge.

Thinking Maps: A Synthesis Language of Visual Tools Based on Cognitive Processes

Over the past twenty years, drawing from the full range of visual tools and guided by the rich background concept mapping offers, a new visual language has evolved, called Thinking Maps (Hyerle, 1990, 1993, 2004). Thinking Maps are a learner-centered model that brings together the dynamism of hand-drawn maps with eight consistent graphic structures that are each, respectively, grounded in eight fundamental cognitive processes. These interrelated cognitive processes, as shown in Figure 1, are based on a theoretical model of six thinking processes originally developed by Dr. Albert Upton (1960) in the early 1960s. This model was

Figure 1



refined in the mid-1980s, based on current cognitive science research, models of cognitive processes developed for psychological testing, and, most importantly, the added representation of cognitive processes defined as visual patterns.

The eight cognitive skills have been foundational to our understanding of human thinking from early developmental psychology up through present-day neuroscience research. If you look back to early tests of cognition (and even early intelligence tests), through to Jean Piaget's research and to existing models of thinking skills, these cognitive processes are identified as follows:

Defining in Context	(labeling, definition, context)
Describing Qualities	(properties, characteristics, attributes, traits)
Comparing and Contrasting	(comparison, similarities, differences)
Categorizing	(classification, both inductive and deductive)
Part-Whole	(spatial reasoning, physical structures)
Sequencing	(sequencing, ordering, seriating)
Cause-Effect	(causality, prediction, systems feedback)
Seeing Analogies	(analogies, similes, metaphors, allegories)

While cognitive scientists and educators have understood these cognitive processes and used the processes for testing, mediation, remediation, and even establishing "standards," (and standards-based assessment), the essential transformational quality of Thinking Maps is that eight cognitive processes are defined visually using eight unique graphic starters, or primitives. Concretely, this means that students don't just talk about classification, they learn to draw a top-down or bottom-up Tree Map from a blank page that displays the category structure driving their thinking. Consider a clear analogy to any mapmaking, such as handheld print road maps or GPS systems: the mapmaker must create a very simple legend of essential graphic primitives that becomes the code for any reader to interpret what often turns out to be a very complex map. Large dots are for cities, double bold lines for major roads, and icons are noted for important information, such as hospitals and airports. The universality of the legend means that not only can anybody read the maps, but also that any other person can create his or her own map using this common symbol system regardless of language and cultural background.

The Thinking Maps model is based on five qualities that are aimed at universal transfer of the theory in practice: (1) graphic consistency, (2) flexible expansion of each map, (3) developmental growth from novice to expert use, (4) integrated use of multiple maps within and across disciplines, and (5) reflective, as learners use the maps to assess how they are thinking. When used together as a language, these tools lead immediately and directly to more complex, higher-ordered thinking, such as problem solving that involves evaluating, thinking systemically, thinking analogically, and creating new knowledge and understanding. When students are given common graphic starting points, every learner is able to detect, construct, and communicate different patterns of thinking about content concepts. And every teacher (including the learner himself or herself) can see these patterns and assess what they mean. The discrete verbal and visual definitions of each tool and the five qualities noted above, along with the extensive research on each of the eight types of cognitive processes, establish the internal validity of Thinking Maps as a strong theoretical model for thinking as well as a practical language for facilitating thinking, learning, instruction, and assessment.

Assessment Using Thinking Maps

Developing Fluency with Thinking. Since 1990, Thinking Maps have been implemented in over 5,000 schools in the United States, England, New Zealand, and Singapore. Through this training, teachers are offered processes for directly teaching their students to use all eight maps within and across every discipline and within interdisciplinary projects. Once introduced, modeled, and reinforced over several years, students develop fluency with each map. They are also able to transfer multiple maps into each content area, becoming spontaneous in their ability to choose and use the maps for whatever content information and concepts they are learning.

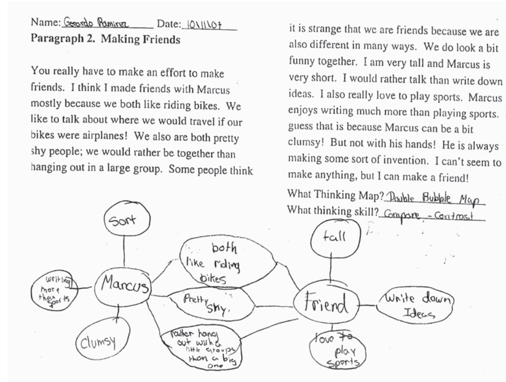
The first step that teachers take is to teach the maps to students. This is done through the very simple activity of applying each map to an object, such as an "apple," or guiding students to use each map for an autobiography. Ideally, the next step would be to assess students' fluency with each cognitive process and their abilities to apply the map in a specific content area.

In Figures 2a–c, we see excerpts from an activity based on using the maps for reading comprehension. In this example, students are given eight separate paragraphs about a boy named Marcus. Each paragraph is carefully constructed to reflect, respectively, a text structure based on one of the eight cognitive patterns. In the area of reading comprehension, the research on text structures is conclusive; there are a limited number of basic structures that inhabit any given text, such as comparing and contrasting, theme, problem/solution, and description. It should be no surprise that these text structures are each based respectively on these fundamental cognitive patterns: comparison, categorization, causality, and describing attributes.

In the three examples by a fifth grade student who has developed fluency with the maps, we can see that he is able to identify correctly the thinking process and the map for each paragraph: the Double Bubble Map for comparing (2a), the Multi-Flow Map for Cause and Effect reasoning (2b), and the Bridge Map for building analogies (2c). Remember, the purpose of this assessment is for both the students and their teacher to assess their abilities to abstract an obvious cognitive pattern from the text, identify the thinking processes, and draw the map, starting with the common graphic primitive for each map.

Developing Transfer of Thinking for Content Learning. While the fluency activity is focused on assessing basic use with each Thinking Map, the next step in the process is the use of the maps for learning and formative assessment. This is analogous to the way educators define the transition from "learning to read" to "reading to learn." Once students have learned to use Thinking Maps, they use the tools to think and learn and thus are able to see their own thinking patterns for self-assessment. They can also share their maps in paired discussion or combine them with peers in cooperative groups, which offers an effective way for teachers to effectively assess individual and collaborative content knowledge and concepts. Teachers may ask students to use the map before, during, and after a lesson or unit of study. For example, in Figure 3, the student was asked to "think about" what she knows about the United Nations (UN) using a Circle Map. From a blank page, the student created the concentric circles and defined the UN in the outside circle with what she considers to be important ideas *(helps nations, bring harmony, stick together, democracy, etc.).*

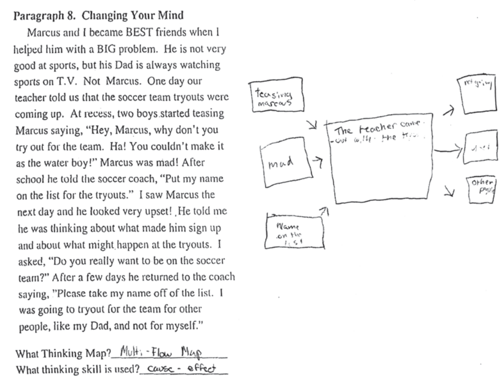
Figure 2a


Paragraph 2. Making Friends

You really have to make an effort to make friends. I think I made friends with Marcus mostly because we both like riding bikes. We like to talk about where we would travel if our bikes were airplanes! We also are both pretty shy people; we would rather be together than hanging out in a large group. Some people think it is strange that we are friends because we are also different in many ways. We do look a bit funny together. I am very tall and Marcus is very short. I would rather talk than write down ideas. I also really love to play sports. Marcus enjoys writing much more than playing sports. I guess that is because Marcus can be a bit clumsy! But not with his hands! He is always making some sort of invention. I can't seem to make anything, but I can make a friend!

What Thinking Map? Double Bubble Map
What thinking skill? Compare - Contrast

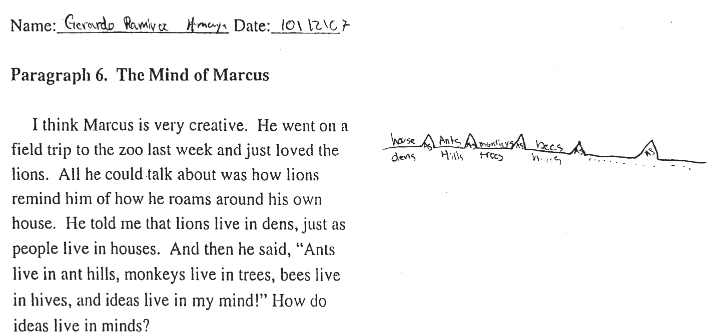
Figure 2b


Paragraph 8. Changing Your Mind

Marcus and I became BEST friends when I helped him with a BIG problem. He is not very good at sports, but his Dad is always watching sports on T.V. Not Marcus. One day our teacher told us that the soccer team tryouts were coming up. At recess, two boys started teasing Marcus saying, "Hey, Marcus, why don't you try out for the team. Ha! You couldn't make it as the water boy!" Marcus was mad! After school he told the soccer coach, "Put my name on the list for the tryouts." I saw Marcus the next day and he looked very upset! He told me he was thinking about what made him sign up and about what might happen at the tryouts. I asked, "Do you really want to be on the soccer team?" After a few days he returned to the coach saying, "Please take my name off of the list. I was going to tryout for the team for other people, like my Dad, and not for myself."

What Thinking Map? Multi-Flow Map
What thinking skill is used? cause - effect

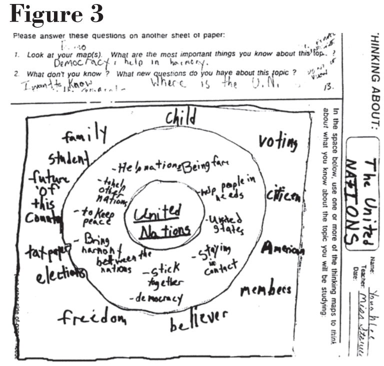
Figure 2c


Name: Gerardo Ramirez Date: 10/12/07

Paragraph 6. The Mind of Marcus

I think Marcus is very creative. He went on a field trip to the zoo last week and just loved the lions. All he could talk about was how lions remind him of how he roams around his own house. He told me that lions live in dens, just as people live in houses. And then he said, "Ants live in ant hills, monkeys live in trees, bees live in hives, and ideas live in my mind!" How do ideas live in minds?

Figure 3


Please answer these questions on another sheet of paper:
1. Look at your map(s). What are the most important things you know about this topic?
2. What don't you know? What new questions do you have about this topic?

THINKING ABOUT: The United NATIONS

In the space below, use one or more of the thinking maps to think about what you know about the topic you will be studying

Figure 4

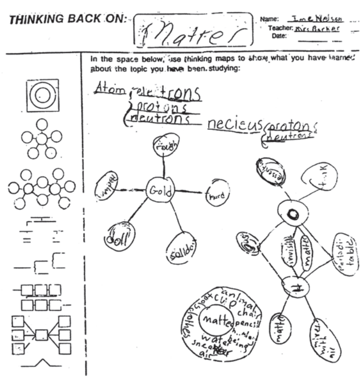


Figure 5

	Minimum	Attending	ParticiPating	Effective	Reflective
EXPAND	• very few connections • use of only one Map	• multiple connections • few supporting details are shown	• multiple concepts are shown with details • multiple Maps are used	• thematic and interdisciplinary connections are shown	• personal, interpersonal, and social implications are recorded
CLARIFY	• bits of information are isolated, unorganized • irrelevant information is included	• different kinds of information are provided • details are shown in relation to general concepts	• patterns in Maps are developed • details are sorted • general concepts are fully supported with relevant details	• connections are shown between multiple Maps • central ideas are highlighted for application	• frame is used to establish point of view and value of Map • hypotheses are generated
ASSIMILATE	• one perspective or solution is shown • rote repetition of information is presented	• alternative way of presenting information is initiated • points of confusion are highlighted	• integration of prior knowledge and new information is shown • fundamental misconceptions are resolved	• several Maps are coordinated for use in final product • novel applications are created	• multiple perspectives are shown • limitations of Map(s) are suggested • self-assessment is initiated
DESCRIPTION	The student is demonstrating a simplistic level of understanding of content and/or limited effort.	The student is attending to the task and demonstrates a basic grasp of content and information.	The student is actively engaged with thinking about content and is beginning to integrate and initiate new ideas.	The student is strategically synthesizing information with a focus on organizing central ideas and details for meaningful applications.	The student is seeking a deeper understanding of knowledge by recognizing multiple interpretations, implications, and limitations of work.
	1	2	3	4	5

The rectangle around the Circle Map is the "frame," and it may be used around any of the eight maps to guide learners to reflect on their frame of reference for critical reflection. This is an essential part of the Thinking Maps model. While each of the cognitive processes and respective visual patterns supports students as they draw out descriptions, comparisons, causes and effects, sequences, etc., a key dimension of thinking goes beyond these cognitive processes toward a metacognitive perspective on what and how we all gather, organize, process, and reflect on the content we are learning. Costa (in Costa and Kallick, 2008) has described these maps as "displayed metacognition," for as students look down on their maps, they see a snapshot reflection of their thinking. With the frame added to each cognitive map, students are engaged in explicit metacognition. In this case, the student noted in the outside frame that there are at least a dozen different frames at work: she is a *child,* the *future of this country, freedom, American,* etc. All of these are reference points that the student identified as possible influences on her thinking.

This example shows the use of a single Thinking Map, which is often only a starting point for using multiple other maps that reflect the pattern of content being taught through text or teacher.

No single cognitive map can hold the richness of any concept. In Figure 4, after a short unit on "matter," a science teacher asked students to show what and how they know about this topic on one page. The student in the example used four maps: the *Brace Map* for analyzing the physical parts of the whole atom, the *Bubble Map* for describing the properties of gold, the *Double Bubble Map* for comparing hydrogen and oxygen, and the *Circle Map* for generating examples of "matter." This evidence shows that this student has moved beyond basic fluency with each map to a new level of being able to independently apply and transfer multiple Thinking Maps to show factual knowledge networked within conceptual displays. Importantly, all other students in the classroom also are able to select which Thinking Map(s) they wish to use for the content and processes embedded in the text, much like carpenters selecting multiple tools out of a toolbox according to the task at hand. To extend this analogy, a foreman on a construction job tells the master carpenters what they are suppose to build but cannot be responsible for telling each worker which tools to use for the actual building of the final product. Once students gain basic mastery over Thinking Maps, the teacher can observe which kind of thinking the students chose to do, the tools they used, and the conceptual products that they constructed. The teacher, like the foreman, can thus see the products of work and student choices of tools and assess the outcomes while looking at the formative development of thinking.

Developing Reflective Assessment of Content and Thinking. In the examples above, we have looked at student-generated Thinking Maps that show a progression from fluency to transfer. In these examples, we mostly looked at how teachers may use Thinking Maps for formative assessment on a daily basis. Once students are fluent with and can transfer the maps within and across disciplines (which can happen easily with eight-year-old students), teachers have an alternative way of structuring formative assessments. At the end of a unit of study, teachers may create assessments that ask students to draw comprehensive maps of the content they have learned. Oftentimes, content concepts are assessed by asking students to write down their answers in the form of multiple choice, short-answer questions, essays, and reports. These traditional assessment formats are linear representations (our written code) of what are mostly nonlinear concepts, thus lacking congruency of form. What happens if a student is a very good thinker and a very poor writer? The outcome is exasperation by all; the teacher often knows the student can do the conceptual work but cannot deliver on a test that requires him or her to choose from multiple-choice options, fill in a word, or write out nonlinear concepts in the linear form of an essay. The student is frustrated as well.

If Thinking Maps are used as formative and summative assessment, how does one give value, or a grade, to the Thinking Maps created by students? Returning to Novak and Gowin's (1984) research on concepts and concept mapping, they identified three criteria for assessing and grading the student-generated maps: expanding, clarifying, and assimilating. As shown in Figure 5, the five-point M-A-PP-E-R rubric (Hyerle, 1996) offers a holistic framework for assessing Thinking Maps developed by students. The five dimensions across the top reflect the cognitive engagement of the student with content knowledge leading toward final products and a metacognitive, reflective stance. The three dimensions down the left side reflect the dynamic criteria for transforming information into useful knowledge established by Novak and Gowin. Note that the first cell at the top left of the three-by-five matrix is the minimum level—a student using only one map with very few connections. As you view this matrix, read across the cells and notice that as students are expanding the amount of information in the map, they must also work to synthesize the maps they create, as well as clarify ideas by supporting general concepts with relevant details (see the center cell: "clarify" and "participating"). As an example of scoring, return to the "matter" example in Figure 4. Let's say that this student created only one map, a Circle Map, showing basic factual knowledge about "matter." This student probably would receive a score of "1" as shown in the simple five-point scale for holistic scoring. If the student completed the four maps as shown in Figure 4, then the score may rise to a level "2" or "3" (depending on the context), as he has shown a basic grasp of knowledge and is actively integrating ideas together. This rubric is at this time a tool that may be used by teachers and students alike to reflect on and discuss the growing sophistication of not only their content knowledge but their own growth as autonomous thinkers within and across disciplines.

Importantly, all other students in the classroom also are able to select which Thinking Map(s) they wish to use for the content and processes embedded in the text, much like carpenters selecting multiple tools out of a toolbox according to the task at hand.

Seeing through the Bifocal Lens

When a teaching faculty brings the Thinking Maps across the entire school, or a school system brings the maps across the feeder patterns from elementary to high school in their wider learning organization, a common visual language for thinking develops and the focus becomes trained on higher-order thinking, creative and analytic thinking, and supporting students in becoming autonomous, reflective learners. There is a transformation in the minds of teachers about what is possible to teach because they have a dynamic way to assess students' thinking at a different order beyond content knowledge and skills. The students have been offered a language that nurtures and facilitates continuous cognitive development, problem solving, and fundamental Habits of Mind (Hyerle, 2009, in Costa and Kallick). Like any language, they have been given graphic starting points through which they creatively analyze content knowledge, spinning new patterns of thinking, consistent with how the brain learns. When given tools to show not only what they know but how they know it, teachers can truly look through their integrated bifocal lens and determine both the content that students have learned as well as the thinking they used to process what they know. All can see the formative nature of thinking evolving before their eyes. And looking through this revolutionary new lens, a teacher may say to a student, with delight and depth, "I see what you mean."

Thinking Maps is a registered trademark of Thinking Maps, Inc. Specific training authorized by Thinking Maps, Inc. is required before implementing Thinking Maps in the classroom. For more information, visit www.thinkingmaps.com.

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