IMAGINATION IN THE NATURAL SCIENCES: PATTERN RECOGNITION, TRANSFORMATION, AND EXPRESSION

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ABSTRACT. This paper discusses a simple conceptual framework that can help foster imaginative learning in the natural sciences. As a visual tool, it aids perception of relationships in the learning process. The framework involves the transformation of pattern from encountered forms to personally and culturally meaningful forms, i.e. from natural pattern (sensed in nature), through ideal pattern (a poietic cognitive schema), to abstract pattern (kinetic expression into a cultural form). These understandings are enriched via consideration of theory emerging from research on imagination in learning and pattern recognition and transformation, as will be discussed toward the end of the paper. We will illustrate the pattern transformation framework using plant identification and naming, with reference to how learning in the natural sciences involves perceiving relationships among the three types of pattern. For example, identification of the fern species Matteuccia struthiopteris involves connecting the mature plant's natural pattern (a feather-shaped frond) through ideal pattern (an ostrich feather) to abstract pattern (the epithet struthiopteris from Latin 'struthionis' for ostrich, and 'pteris' for feather). In comparison, the English name 'fiddlehead' idealizes the natural pattern of the immature plant as the curved handle of a violin, and the Mi'kmaq name 'Mte'skmwaqsi' idealizes the same natural pattern as a snake. In that this model allows respectful inclusion of different cultural knowledge systems, this presentation will interest educators in the areas of natural sciences and science as understood in different worldviews. This paper is based on a presentation delivered at the 4th International Conference on Imagination and Education ("Opening Doors to Imaginative Education: connecting theory to practice") held in Vancouver, Canada, during July 2006. This written version differs from the actual presentation in that during the presentation numerous animated visuals were used to illustrate an oral explanation. This research is funded and guided by Cheryl Bartlett, Canada Research Chair in Integrative Science, Cape Breton University, with additional guidance provided by Mi'kmaq Elder Mrs. Murdena Marshall of Eskasoni First Nation in Unama'ki-Cape Breton.

KEY WORDS: science education, imagination, natural sciences, patterns, models and modeling, conceptual framework, metacognition, plant names, scientific nomenclature, cultural context, Integrative Science, Indigenous science, Western science, worldviews, knowledge systems.

IMAGINATION

Creativity and imagination have an important role to play in natural science education. Creativity is acknowledged to be a 'core element' of Western science, which is often required for scientists when they imagine new scientific models, as well as test and evaluate them (Gilbert 2004). And, Gregory Cajete, Indigenous scientist and educator, places creativity at the center of his model science curriculum from a Native American perspective (1994).

Faced with the challenge of teaching science in a Western, Indigenous, or cross-cultural perspective, educators embrace the concepts of creativity and imagination but also struggle to reconcile them with other core concepts of the natural sciences, such as objectivity and empiricism. This may in part be due to the way imagination is defined in some educational contexts, where the definition of imagination differs little from the common usage, as in dictionary definitions which associate imagination with illusions, fabrications of the mind, fancy, fantasy (eg. WNCD 1969). It is true that both creativity and imagination may suggest a personal origin of understanding that cannot be systematized. Yet that does not mean that imagination is not partly derived from perception and observation. Vygotsky, for example, emphasized the link between imagination and reality, describing imagination as a faculty that draws on experience yet transforms it (Lindqvist 2003). In this definition, imagination is viewed as having a poietic component in which new meaning is generated from old experiences and observations.

In this paper we will describe a Pattern Conceptual Framework which is a model of learning in the natural sciences and which inherently references the role of the learner as an engaged participant in the learning process who is able to imaginatively draw in meaning from nature and express outward understandings of nature which are personally and culturally relevant.

CONTEXT

This paper describes the rationale behind the development of a Pattern Conceptual Framework and its application in cross-cultural science education. This research and development occurred in the context of the Integrative Science Program at Cape Breton University, which is located on Cape Breton Island, in Eastern Canada. Cape Breton, known as *Unama'ki* in the Mi'kmaq language, is part of the Mi'kmaq First Nation traditional territory (which also includes mainland Nova Scotia, New Brunswick, Prince Edward Island, and parts of Quebec and Maine). Mi'kmaq students from several Mi'kmaq communities attend a variety of programs at Cape Breton University.

The Integrative Science Program is a unique four-year science degree that brings together Indigenous and Western science in the undergraduate science classroom and laboratory. This program was developed at the initiative of a group of Mi'kmaq Elders from Cape Breton who collaborated with university faculty and administrators to conceptualize a science degree in which there would be a welcome place for Mi'kmaq traditional knowledge and Indigenous science. Those Mi'kmaq Elders identified barriers to Mi'kmaq students entering science, including the teaching of science education from only one cultural perspective, and in an incomplete and non-connected manner, which were echoed in a variety of literature on Aboriginal participation in science (see also Cajete 1994, 2000). It was hoped the inclusion of Mi'kmaq traditional knowledge and other Indigenous science would attract Mi'kmaq students to pursue university studies in science, and subsequent to the implementation of Integrative Science, Mi'kmaq student enrollment in science programs at Cape Breton University increased from near zero in the early 1990's to its current level of near thirty, plus 11 graduates. The approach and ideas developed in this context will be of interest to many universities which have a similar under-representation of Aboriginal students in science, a fairly common situation both across Canada and internationally.

The curriculum of the Integrative Science program was created to bring together Indigenous and Western perspectives on science, focusing on common ground and celebrating differences. The name Integrat*ive* Science was chosen because the ending "*ive*" implies the ongoing collaborative process between Mi'kmaq communities and university faculty which is required to bring the perspectives together. The spirit of this collaboration is expressed best in a metaphor created by Mi'kmaq Elder Mr. Albert Marshall of Eskasoni First Nation, called "Two-Eyed Seeing". Mr. Marshall compares both Indigenous and Western science to eyes because they each allow us to see the world in a particular way. Instead of trying to see with one or the other, he suggests we try to see with the strengths of *both* eyes, together.

Pattern recognition is one area of common ground between Indigenous and Western science (Stevens 2000). In learning through patterns, meaning is derived from relationships, not disconnected facts. This ability to recognize relationships and connect new knowledge with previous understandings and experiences is how some researchers define meaningful learning (Novak 1993). Learners who are able to make connections and "chunk" related information into categories and relationships can retain more knowledge and for longer than learners who simply memorize and learn by rote (Novak 2002, Gobet 2005). The pattern conceptual framework described in this article was created to facilitate meaningful learning by providing a framework in which to express relationships between patterns, and in particular, share and compare perspectives on the common ground and differences between Indigenous and Western science.

CONCEPTUAL FRAMEWORKS

A conceptual framework is a cognitive tool or thinking aid. It helps clarify thinking by providing an overarching structure into which ideas and information can fit and shows relationships between abstract concepts. A variety of conceptual tools have been developed which facilitate a learner's ability to make connections and describe relationships within the content they are learning; they are expressed in a variety of forms, such as through concrete, verbal, symbolic, visual or gestural models (Gilbert 2003). A bridged analogy is an example of a conceptual framework in a verbal mode. It consists of a series of analogies designed by an instructor to facilitate students' understanding of concepts which might initially appear discordant with their preexisting mental models. The series of analogies helps students connect ideas they already accept with new ideas. A Venn diagram is a conceptual framework in a visual mode, in which circles represent sets which have some but not all in common; they are widely used in education to compare and contrast. A Concept Map is also a visual conceptual tool, in which abstract relationships are illustrated by drawing links between concepts to show hierarchies and other relationships (Novak 1993, 2002). Conceptual tools have helped science students improve their ability to learn, which suggest that more such tools be developed for science education.

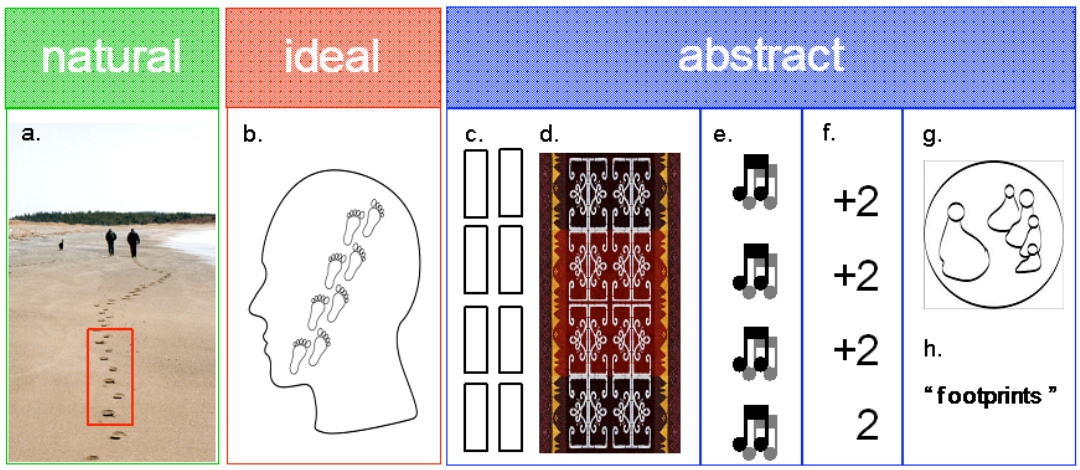
PATTERN CONCEPTUAL FRAMEWORK

Our conceptual tool, the Pattern Conceptual Framework, provides an overarching structure into which patterns can fit and shows relationships between them. The Pattern Conceptual Framework will be presented in a visual form because the abilities to interpret and manipulate images are important skills in many areas of science (Barnea 2000) and because the visual form facilitates sharing and comparing of ideas. The use of visual conceptual tools, in combination with other teaching approaches, also creates an environment which engages the human multiple intelligences (see Gardner 1983, 1993, 1999).

The main structure of the Pattern Conceptual Framework distinguishes between three types of patterns: natural, ideal, and abstract. Natural patterns are patterns that exist in nature. They may be perceived by the senses, or through instrumentation which extends the senses. Ideal patterns are cognitional models of natural patterns; they represent the way the pattern is conceptualized in the mind based on personal understanding. Abstract patterns are called abstract because they are abstracted from, or brought out of, the complex and rich inner environment of the mind. Abstract patterns are those patterns that are expressed and shared. These three types of patterns are connected via a process of engagement by the learner who perceives patterns around him or her, is aware of his/her inner conceptualization of those pattern, and can communicate those understandings to others.

A simple example can illustrate the three types of pattern in the Pattern Conceptual Framework (**Figure 1**). Imagine a person walking on a beach, which is marked behind him or her with footprints. The footprints in the sand are an example of a natural pattern (**Figure 1: a**). If that person turned his/her attention to those footprints and idealized them in his/her mind, s/he might conceive the fairly regular alternation of the right and left, and the general shape of a foot in the sand (although actually, there would be variation such as larger and smaller strides, a hop or pause, etc.) (**Figure 1: b**). And, in trying to express that pattern, s/he could do so in a variety of ways, for example by showing a series of geometric shapes each representing a right and left foot (**Figure 1: c**), weaving a tapestry (**Figure 1: d**), using mathematics (e.g. 2 + 2 + 2 + 2) (**Figure 1: f**), singing a song with each note representing a step **(Figure 1: e**), verbally naming them "footprints" or telling a story (**Figure 1: g & h**) or even dancing the pattern.

FIGURE 1: PATTERN CONCEPTUAL FRAMEWORK. The Pattern Conceptual Framework consists of three types of pattern: natural, ideal and abstract. An example of natural pattern is footprints on the beach (a.). An ideal pattern is in the mind (b.). An abstract pattern is expressed in a variety of personally and culturally relevant forms, such as visually (c. & d.); musically (e.); mathematically (f.); or verbally, as a story (g.) or label (h.).



A key point of this framework is the mindful participation of the learner in perceiving the pattern, idealizing it and expressing it, and thus moving the pattern from an outer encounter, to an inner conceptualization, to an outer form. Each form and transformation of the pattern reflects that individual's personal and cultural preferences. For example, forms of expression commonly encouraged in Western science education are primarily the verbal, visual and mathematical. In contrast, Indigenous science education may also encourage the material and gestural expression of patterns.

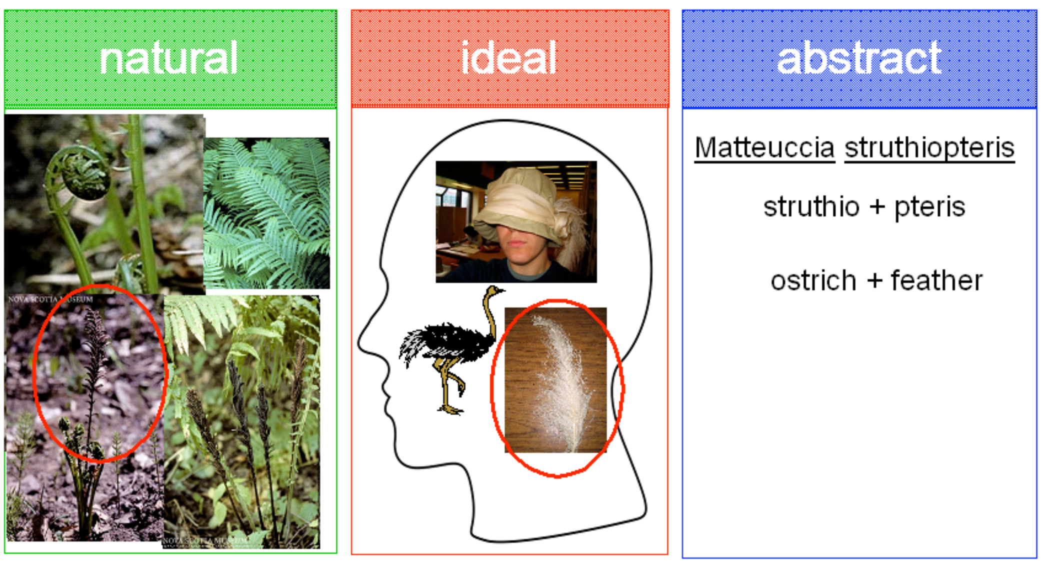
APPLICATIONS

The Pattern Conceptual Framework can be applied in a variety of natural science disciplines. This article will consider the application of the Pattern Conceptual Framework to learning fern terminology and enriching the understanding of fern names. Ferns were chosen because they are common in forests of Cape Breton and learning about their forms brings considerable pleasure to the senior author. Beyond that, they also represent a typical topic in the natural sciences in that learning about ferns involves learning a new group of terminology and linking it to observable shapes and characters of the subject.

The natural pattern of a fern, when considered over its whole life cycle, is very complex. For the species *Matteuccia struthiopteris*, it involves a variety of forms, from the tiny gametophyte which is one cell thick, to the tight coils of the immature leaf which unfurl into large green blades, to the fertile (or spore bearing) fronds that emerge from the center of the tuft of green blades and that darken from green to dark brown when ready to release the fern's spores (Cody & Britton 1989).

The name *Matteuccia struthiopteris* is the abstract pattern, which verbally expresses a model of the plant. *Matteuccia struthiopteris* is the two-word (binomial) scientific name, based on Latin words which have etymological roots that can be translated into English. '*Struthiopteris'*, the second word of this name (i.e. the specific epithet) breaks down into the Latin roots 'struthionis' for ostrich, and 'pteris' for feather. Therefore, this name verbally expresses the pattern of an ostrich feather. If we idealize this pattern in our mind, we might pay attention to a variety of aspects, such as the pattern of feathers on the ostrich, a single feather, or even a feather hat from Europe. Upon inspecting the plant's natural pattern we may observe a similarity in shape between an ostrich feather and the fertile frond of the fern. Therefore, we can connect the natural pattern of the fern (the fertile frond) with the ideal pattern (the appearance of an ostrich feather) and the abstract pattern (the name which verbally expressed an understanding of the natural pattern) (see **Figure 2**).

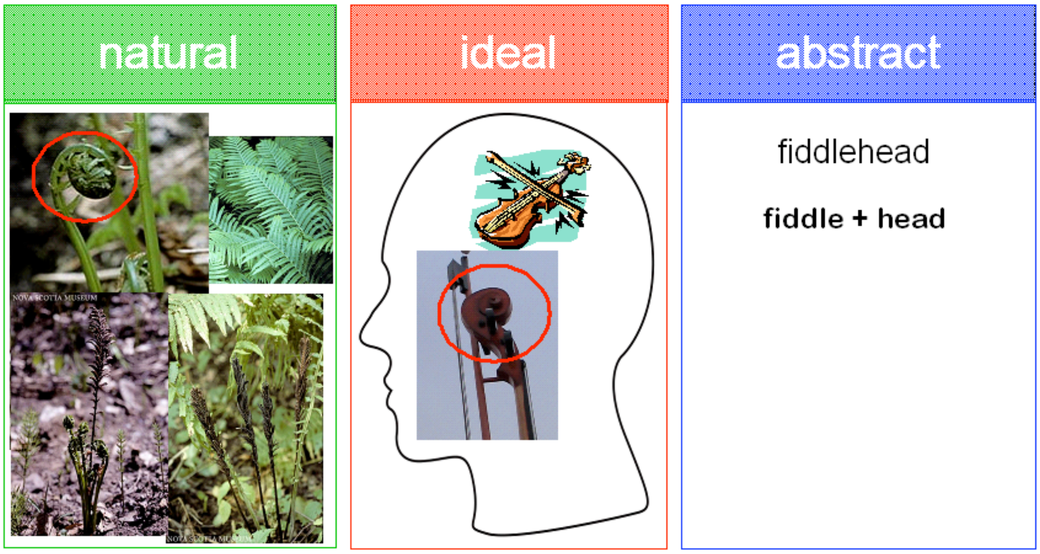
FIGURE 2: *MATTEUCCIA STRUTHIOPTERIS*. The shape of the fertile frond, the shape of an ostrich feather, and the specific epithet '*struthiopteris*' share the same pattern.



Images of *Matteucia struthiopteris* courtesy of the Nova Scotia Museum, Museum of Natural History, Halifax, NS.

This same process can enrich our understanding of other names for the plant. What is the ideal pattern that connects the natural pattern to the abstract pattern for fiddlehead? We can also break down the English name to its parts, namely "fiddle" and "head". We could idealize this in our minds as fiddle, or the coiled head of the fiddle. If we reach outwards with our imagination we find that the coiled form of the immature frond, the coiled head of the fiddle, and the name fiddlehead share the same pattern **(See Figure 3**).

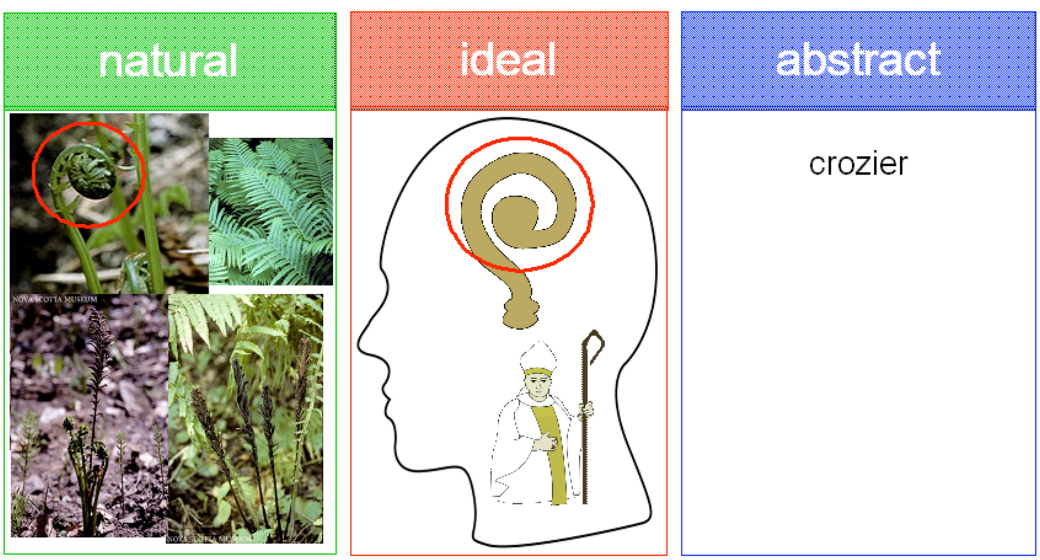
FIGURE 3: FIDDLEHEAD. The coiled shape of the young plant's frond, the coil carved in the handle of violin, and the name "fiddlehead" share the same pattern.



Images of *Matteucia struthiopteris* courtesy of the Nova Scotia Museum, Museum of Natural History, Halifax, NS.

Next, we can consider another English common name for the same fern species, in this case "crozier fern". What is the ideal pattern that connects the natural and abstract patterns? A crozier is a shepherd's hook; it can be idealized as a coiled shape or, in terms of its religious meaning, as it appears on a bishop's staff. If we reach outward with the imagination, one connection we can find is with the tightly rolled immature frond, the coil of the crozier, and the name, crozier (See **Figure 4**).

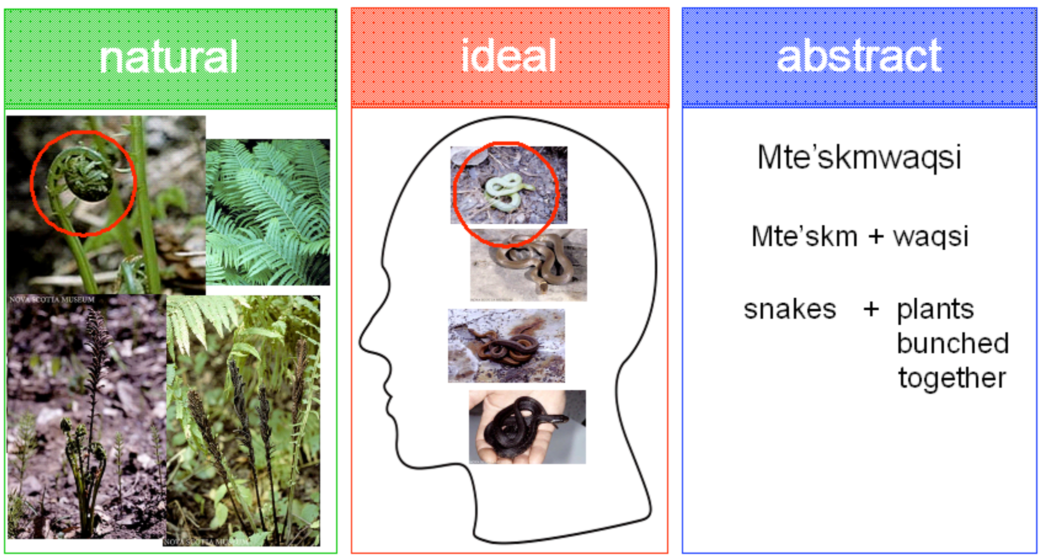
FIGURE 4: CROZIER. The shape of the young plant, the shape of the coiled staff, and the name 'crozier' show the same pattern.



Images of *Matteucia struthiopteris* courtesy of the Nova Scotia Museum, Museum of Natural History, Halifax, NS.

In the final example, we will consider the Mi'kmaq name for this fern: *Mte'skmwaqsi*. What is the ideal pattern that connects the natural and abstract pattern? *Mte'skmwaqsi* breaks down into two morphemes (or units of meaning), *Mte'skm* and *waqsi*, which translate roughly as "snakes" and "plants bunched together". We could idealize this in our minds in many ways; one way is to see the connection between the natural pattern of the tightly coiled immature frond, the coil of a snake, and the name which means snakes bunched, and even the green color shared by the common garter snake and the ferns (See **Figure 5**).

FIGURE 5: MTE 'SKMWAQSI. The coils of the young plant, the coils of a snake, and the name Mte 'skmwaqsi show the same pattern.



Images of *Matteucia struthiopteris* and snakes courtesy of the Nova Scotia Museum, Museum of Natural History, Halifax, NS.

Thus, as outlined above, the various names for just one plant species show that the natural, ideal and abstract patterns expressed in the names can reflect cultural and historical biases. Plant names provide a simple description of the plant, and yet are inherently both selective and theoretical. The plant name can privilege a certain aspect of a natural pattern, drawing attention to it, idealizing it, and abstracting that understanding of it. Worldviews (within a particular cultural context) can affect cognitional models and the way in which natural patterns are idealized. Yet, the Pattern Conceptual Framework shows that learning multiple cultural perspectives can enrich the understanding of the natural patterns and shows that instances of common ground are possible … and, furthermore and significantly, shows that we can indeed work together to share our scientific world views.

DISCUSSION

Normally, natural science education focuses on only two types of the pattern which we have described in the Pattern Conceptual Framework. Natural and abstract patterns are presented to students and they are encouraged to connect them. For example, a botanical key encourages students to connect the natural pattern of the fern with abstract patterns of terminology, or in other words, "most botanical keys are based on matching a verbal picture to the ones made by the eye" (Cobb 1963). Cobb includes the natural pattern with what he refers to as the pictures in the eye, and the abstract pattern, with what he refers to as "visual pictures". However, what is the role of the "mind's eye" in this approach to natural sciences education? There is no reference to the ideal, although the ideal connects the abstract with the natural. Indeed, natural and abstract patterns are often conflated. The omission of the ideal omits the conceptual roots of our abstract expression making it difficult for science students to recognize the limited nature of those conceptual and/or philosophical roots and their own role in coming to understand a topic.

CONCLUSIONS

The pattern conceptual framework developed for the Integrative Science program at Cape Breton University is one example of a simple conceptual tool which fosters meaningful learning for science students. Natural, ideal and abstract pattern are three categories of pattern which are used in the framework to show the relationship between outer encountered patterns and inner conceptual patterns which reflect personal and cultural contexts. The conceptual framework encourages meaningful learning by fostering pattern recognition, transformation and expression, and metacognition in the learner, who must become aware of his/her own thinking and connect an inner cognitional model to external encountered patterns. This pattern thinking encourages the learner to take an active engaged role and to use imagination and creativity to visualize, transform and express patterns, and as necessary reiterate and enrich the process. Normally in the context of natural science education, there is a focus on natural and abstract patterns, while ideal patterns are neglected. However, the inner, ideal pattern is very important because it can strengthen the learner's understanding of the connection between the natural and ideal pattern and illustrate the historical and cultural context of that connection. As a result, the pattern conceptual framework is a conceptual tool that can assist in teaching science in any context, and particularly when it is important to incorporate diverse cultural perspectives.

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