Map-Activate-Check: A Systems Thinking-based Approach to Curriculum and Program Design

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Abstract: Map-Activate-Check (MAC) is a systems thinking based curriculum and program design strategy that integrates cognition, learning, and evaluation. MAC has been applied to diverse situations including formal and non-formal youth education, adult learning, program development and evaluation, and community programming, and in varying scales from a single lesson or presentation to an entire unit or program.

The fields of cognition, learning, and evaluation are all highly researched and developed fields. MAC builds relationships among these distinct and often isolated fields to provide a tool that helps practitioners develop effective learning experiences and programs. MAC offers a structured approach to curriculum and program design that integrates systems thinking into education and enhances learning experiences.

Literature Review

Cognition is the process of structuring information to create knowledge [1]. By definition, cognition is part of the learning process, in which learning is the process of developing new knowledge, skills, and/or values. Learning is inherently an individual experience of change that results from a process of experience, reflection, abstraction, and new application [2–4]. Metacognition is a particularly important aspect of cognition and learning. Metacognition is “the process of reflecting on and directing one’s own thinking” ([5], p.4) (see also [6] for a full review of the definition of metacognition). Magno [7], Plate [8], Akturk and Sahin [6] and Pellegrino, Chudowsky and Glaser [9] all found that metacognitive skills were essential to thinking, knowledge development and problem solving.

Effective education is a structured endeavor in “which educators purposefully engage with learners in direct experience and focused reflection in order to increase knowledge, develop skills, clarify values, and develop people's capacity to contribute to their communities” [10]. Metacognition is an important part of learning; therefore, teaching metacognitive strategies are an important part of education [7,9]. Effective education includes a deliberate process in which abstract ideas or information are presented, that content is activated through an experience relevant to the learner, and then the experience is reflected on to build knowledge [9,10]. This knowledge can then be applied to new situations. Therefore, education is an iterative process of abstraction and concretization of concepts.

Evaluation is a process of assessing the effectiveness of an activity. Program evaluation is a “tool to both inform strategy development and track the progress and impact of strategy implementation" [11]. Evaluation generates information (data) from which to learn about the effectiveness relative to program goals that can then be used to make program improvements [12].

Evaluation, or assessment, of learning is focused specifically at measuring or determining knowledge acquisition and learning. The knowledge is assessed relative to identified knowledge to be gained (learned) [13]. Assessment "can be used as a means to reinforce learning, to drive learning and to support learning" ([14], p. 85). Given the importance of metacognition in learning, assessment should examine the metacognitive skills of the learner [9]. Mental maps which show both the structure of thinking and concepts are therefore an effective way to assess learning [8,13].

Overview of MAC

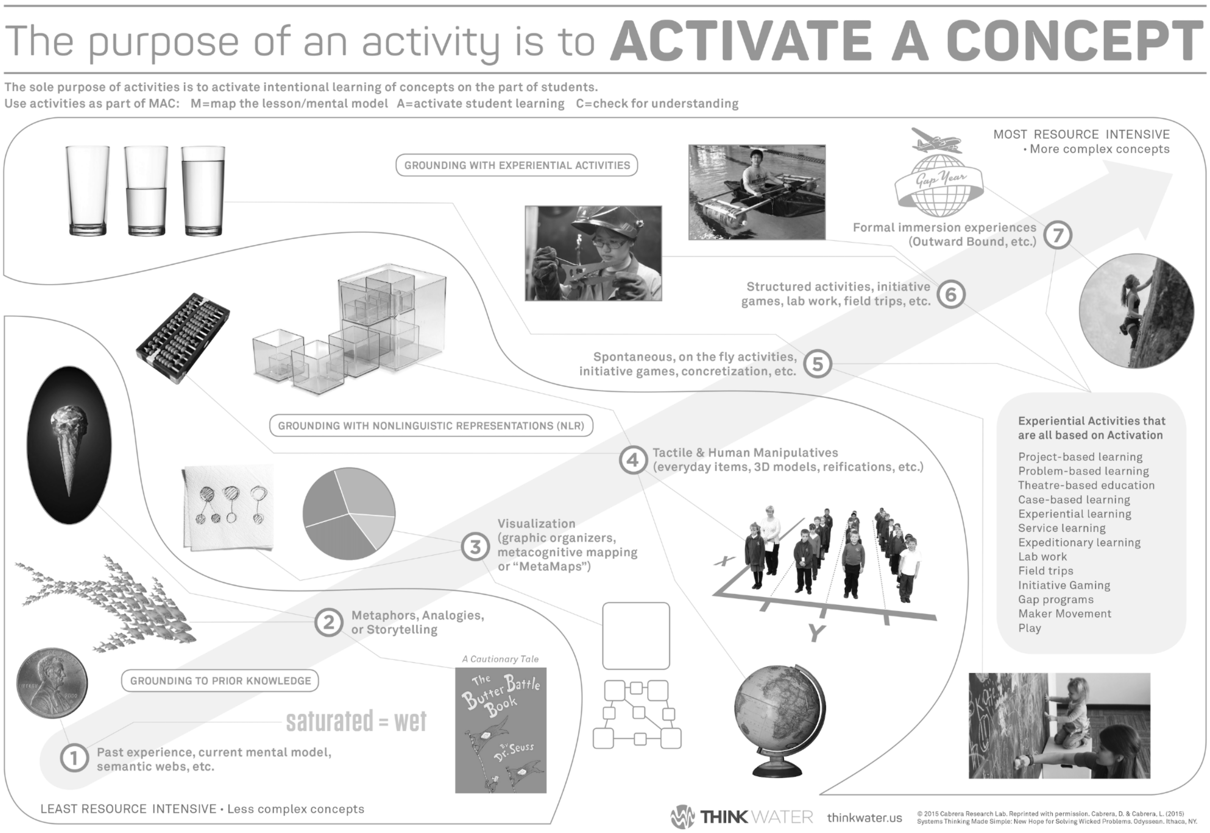
Map

Mapping is about framing or structuring the substantive content (core concepts or ideas) and emphasizing the thinking students need to use to learn it. Mapping can be done in a variety of ways, including through a visual map that identifies relevant distinctions, systems, relationships, and perspectives (DSRP) on the content to be taught. This is an essential step that ensures educators are clear about the learning outcome(s) they wish to achieve. This step also enables thoughtful choices about how to best teach that content and then clarify what to focus on when checking for understanding.

While educators choose the content to frame, ideally the frame is created in a transparent way involving students. Active, co-construction of the frame can signal to students that they should build knowledge through thinking, rather than passively receiving information [1].

Activate

Once the content to be constructed and the *thinking required to build knowledge* are identified, an activity that grounds this content and thinking to students' experiences and existing knowledge can be developed [15]. The purpose of an activity is to activate, or bring to life, the content for the learners. Activation strategies/activities can take various shapes and forms, such as experiential learning (see Figure 1). When designing experiential activations for the purposes of activating knowledge, it is essential that educators ensure the activity is directly tied back to the content and thinking framed at the beginning of the lesson. This prevents activity for activity's sake and instead harnesses activation for learning. Activation creates the space for learners to deepen their understanding about a concept, while considering how this knowledge applies to other issues.



Check (for Understanding)

Since learning is an active process and occurs differently depending upon learning styles and many other variables, another vital step in this teaching method is checking for understanding. Once the material taught is activated, checks for understanding enable the educator to gauge what understanding is being built, and if those will lead to desired outcomes. Checks help the educator *and the learner* assess where they are in the learning journey. Teachers are often surprised and consternated by what individual students take away from experiential learning. Rubrics can guide the assessment of understanding but are generally insufficient to gauge students' comprehension. Checking for understanding should be viewed as an ongoing process, with checks embedded throughout lessons. Educators should also teach students how to check their own understanding throughout the learning process by way of self-assessments and reflections [1,15].

The process of framing, activating and checking is most successful when educators ensure there is a clear relationship between the content framed, the method(s) chosen to activate the lesson, and the mechanisms designed to check understanding. This methodology can promote a deeper, more comprehensive way to learn new knowledge and ways of thinking. When applied with DSRP, it can develop students' metacognition skills to promote a more systemic way of thinking, which can then be transferred across topics and subjects. The DSRP cognitive rules are embedded within MAC, which are applicable across all content and compatible with a variety of teaching methods and styles.

MAC is not linear in design and practice. MAC is best practiced when the components are integrated. That is, a check could be part of an activation strategy which feeds back into the identification of the concept to learn. MAC can also be started at any of the components. For example, if a program already exists, MAC could be used to identify check strategies that inform new activation strategies or even different concepts (mental models) to be developed within a given lesson or unit plan.

Case Examples

The case examples provided below come from the work of ThinkWater. ThinkWater is a national systems thinking-based water education and research initiative supported by the United States Department of Agriculture to engage, educate and empower a nation of water thinkers. It aims to change how people of all backgrounds and ages think about water. ThinkWater partners with scientists, extension professionals, educators and citizens, to apply a new form of systems thinking built around four cognitive building blocks; distinctions, systems, relationships, and perspectives (DSRP) to deepen both the understanding of - and engagement with - water [1]. ThinkWater works to integrate systems thinking into water education through the design and implementation of widely available resources and training. The program helps water educators enhance water lessons with systems thinking (DSRP) to increase participants' understanding and retention of the information offered about. In addition to systems thinking-boosted curriculum materials, ThinkWater provides professional development, support, and resources to the broad range of formal and non-formal water educators and researchers.

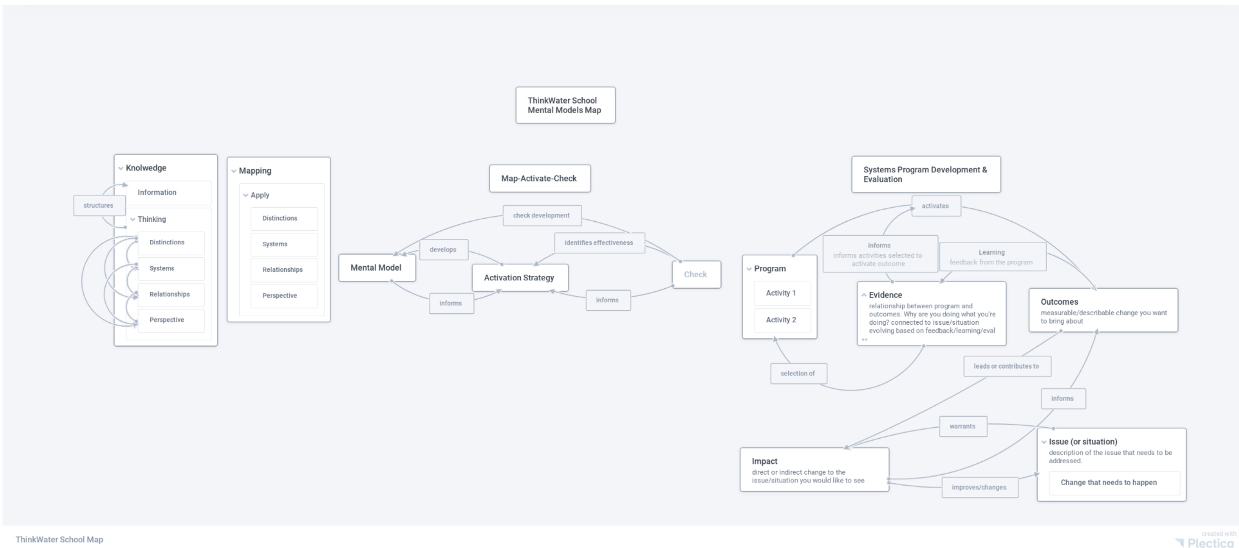
Case Example 1: Wisconsin ThinkWater School

The Wisconsin ThinkWater School was a cohort and team-based professional development program focused on developing systems thinking skills and capacity within water professionals in Wisconsin. The program provided multiple in-person and on-line training components so that participants could apply systems thinking to their water-related public education and engagement programs. MAC was used in the design of the overall program and within specific program components. Described below are the ways in which MAC was used at the programmatic level, that is, at a level broader than just an individual lesson or activity. The application of MAC was used to design a long term, multi-faceted program to build participants' knowledge, skills and access to resources.

Map: The map of Wisconsin ThinkWater School identified four distinct and inter-related learning outcomes:

- an understanding of how knowledge is constructed,
- the ability to map using systems thinking (applied to water issues and program design),
- developing programs using a systems thinking-based program development and evaluation framework, and
- using MAC in education program design.

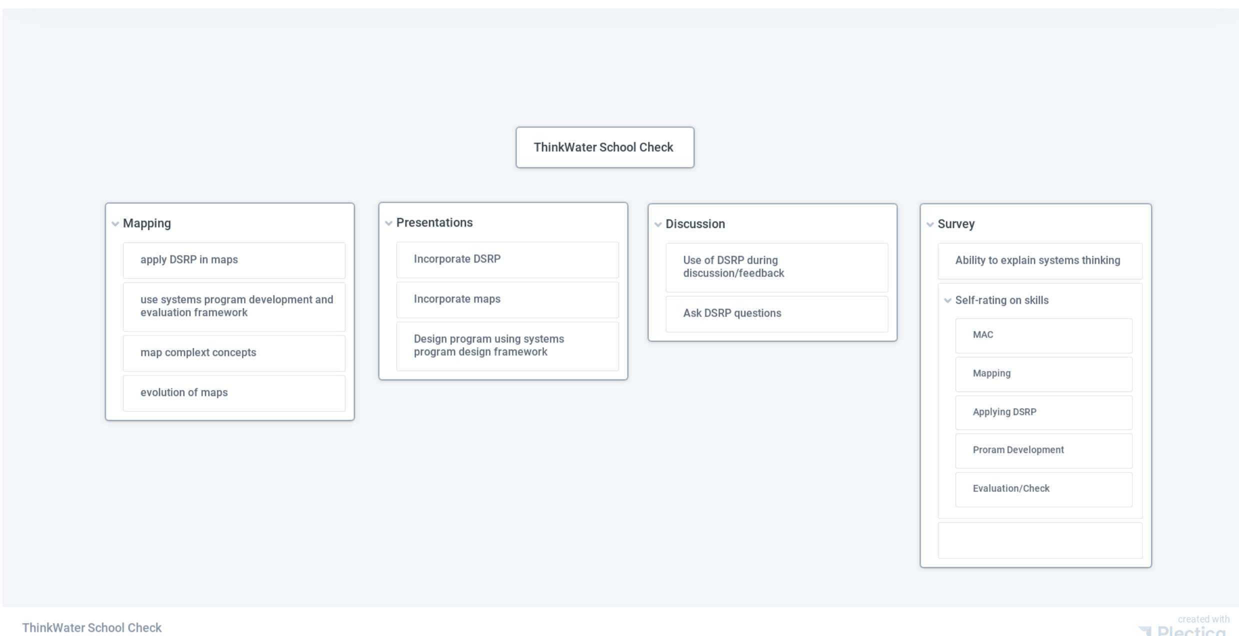
Each of these primary learning outcomes were mapped using a systems thinking software (initially MetaMap and then Plectica). These were refined via feedback from the ThinkWater team and other professionals to focus on the most essential concepts to better understand systems of interest. See Figure 2 for the map of Wisconsin ThinkWater School.



The example provided here focuses on understanding how knowledge is constructed. Knowledge (K) can be described as the process of structuring information (I) using thinking (T). In other words, K = I x T. Therefore, understanding the development of knowledge includes making a distinction (and building a relationship) between knowledge and information. Thinking can be further understood by the four rules or patterns of thinking which are; making distinctions among ideas, breaking ideas down into parts and forming wholes, building relationships between ideas, and identifying and employing perspectives to better understand ideas(DSRP). The Wisconsin ThinkWater School program emphasized understanding, reflecting on, and intentionally applying Systems Thinking/DSRP in other situations. Similarly, each of the primary learning outcomes was mapped out to fully and distinctly identify the concepts to be learned during the program.

Activate: Activation strategies help participants build those concepts and apply them to different situations. Multiple activities were developed to introduce and reinforce the concepts. The activities were selected to be as experiential as possible (be further toward experiential on the activation continuum - as shown in Figure 1) given the situation. Specifically for the concept of knowledge, the activities included an introductory discussion using images, large group concept mapping, an online video presentation and activities including mapping, a personal story from the facilitator relating thinking to seeing (i.e., telling someone to look harder for something is akin to asking people to think about information without providing strategies or tools to do so), and individual and team mapping of water issues. Through the course of instruction and application, multiple points of reflection and discussion, and application into different areas were included. With this specific example, participants were presented with the abstract concept of knowledge and then mapped their knowledge of a peanut butter and jelly sandwich. That mapping included both information (parts of a peanut butter and jelly sandwich) and the thinking (applying DSRP) to that information. Following the presentation and mapping, a discussion was held in which participants reflected on the meaning of "knowledge." This was later reiterated through online presentation and mapping. Later in the program, participants applied their concept of knowledge in team mapping of water issues and identified the knowledge they wanted to develop among the people participating in their programs. This iteration of abstract (initial concept) to concrete (through application) to abstract (via reflection) to concrete (application in a novel situation) is the essential process of teaching and learning. And, the activation component of MAC is designed to bring about that process.

Check: The purposes of check were to help educators (leaders of Wisconsin ThinkWater School) determine to what extent the desired concepts/mental models were constructed among the learners and to support learners' self assessment of where they are in the learning process relative to the concepts identified for learning. Feedback/evaluation was used to adjust activities to further develop the concepts. In this case, multiple checks were integrated into the activation strategies, including mapping and discussion. In addition, checks were used following program sessions. Figure 3 shows the check strategies used during ThinkWater School. These check strategies were tied to specific concepts and activation strategies, although for space considerations, those are not shown in Figure 3.

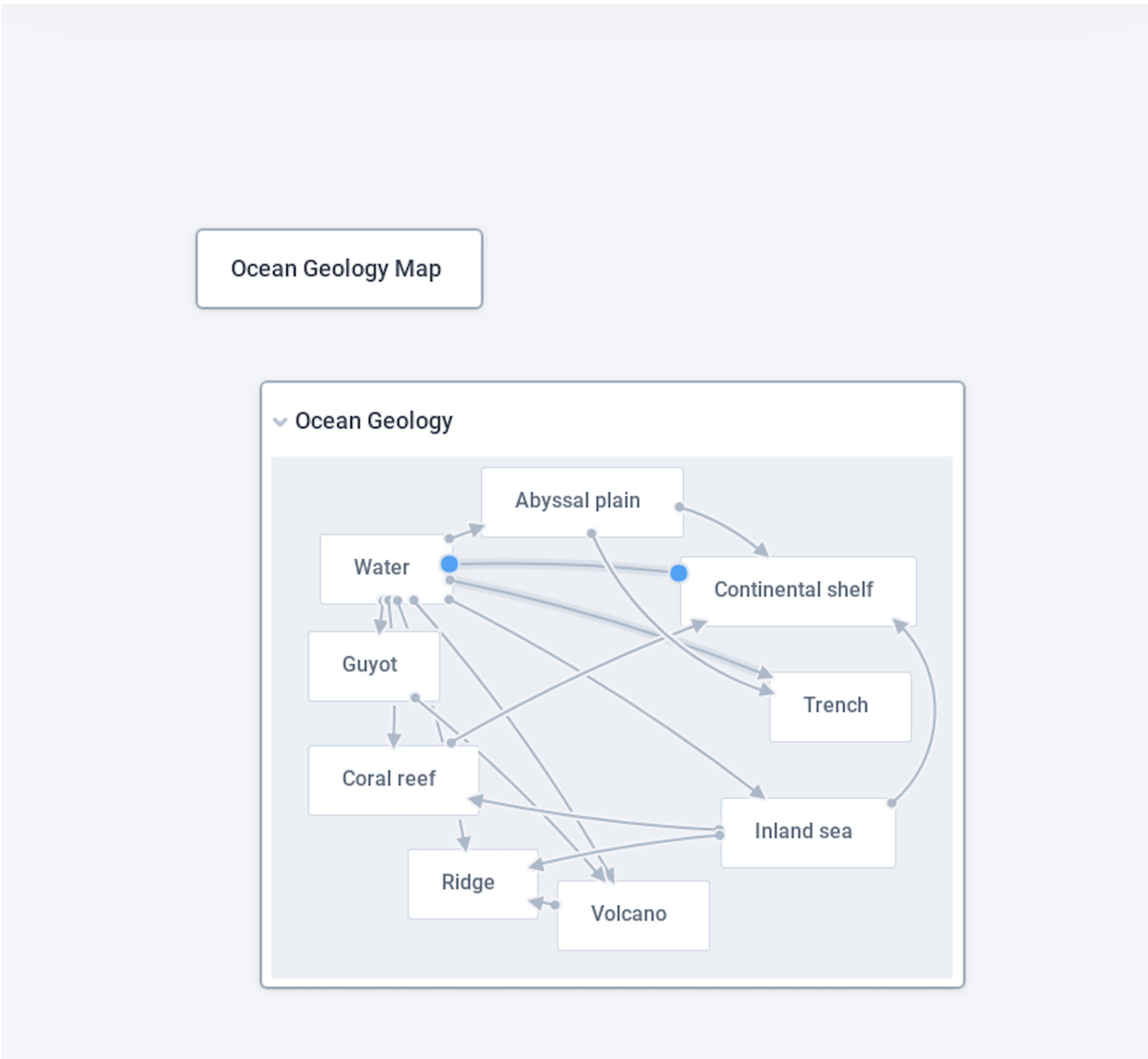


The feedback from the check process was used to modify activities either during the course of a lesson or in follow up sessions. Mapping and discussion were both activation strategies and checks during the course of the program. By observing the discussion of both the individual and team mapping, the instructor determined if participants were constructing the desired understanding of knowledge (information x thinking) presented. A survey was sent out after each session that asked participants to rank their comfort with applying this understanding of knowledge and to describe knowledge and thinking. Through the course of ThinkWater School, additional examples or activities deepened understanding based on the check activities. One specific example of how an integrated check was used to shift activities within the program, was the addition of a group mapping activity building relationships between knowledge and behavior. This arose due to questions that were brought up during an activity of mapping knowledge of water issues. The additional activity was used to address a specific gap in understanding among many of the participants.

Case Example 2: Ocean Geology Lesson

An ocean geology lesson was developed for a middle school science class as part of their standard school curriculum. The lesson was delivered in two different classrooms. In one room (the control) the teacher delivered it in the typical manner. The teacher in the other classroom was provided training and guidance in using systems thinking and MAC by ThinkWater team members. In the example provided here, the teacher used MAC in the development and delivery of the lesson.

Map: The content of the lesson included the geological features of the ocean. Importantly, in the map for this lesson, in addition to the parts of the ocean being distinguished, the relationships between these parts were identified and described. This strategy helped to highlight not only the information to be presented, but the thinking needed to construct knowledge of ocean geology. See Figure 4 for the map of this lesson.



Ocean Geology Lesson Map

Activate: The lesson was presented in two phases. The first phase, the presentation of the abstract concepts, was an introduction to the geologic features and a discussion about relationships among the features. The map was presented as the mental model to be constructed through the lesson. The second phase was a project in which students constructed physical models of the ocean that included the geologic features. Given the content and the school's location, it was not possible to have a full experiential activity for this lesson, that is, they could not travel to the ocean and interact with the geologic features. The construction of the model was determined to be the furthest along the activation spectrum (see Figure 1) that could be achieved given the circumstances and resources available. During this phase of the lesson, students were able to observe each other's models and were provided guidance by the teacher, but each student was responsible for the model construction based on information presented.

Check: The checks for this lesson were integrated into the lesson itself. During the first phase of the lesson, the discussion provided an opportunity to check for initial understanding of the concepts being presented. The construction of the models, the final project, provided the ultimate check for the lesson in ways in which the teacher and students were able to visually observe the understanding of the concepts which included creating the ocean features and being able to develop a model that related those features to accurately represent the geologic structures of the ocean. In other words, the check verified acquisition of the lesson content (I) and the student's understanding of the thinking (T) to build their knowledge (K) of ocean geology.

Discussion

MAC provides a structured, systems thinking-based framework that integrates cognition, learning and evaluation, which are fields or strategies that are not often deeply integrated and mutually reinforcing in both theory and practice. As a result, MAC is a more effective way to design, deliver and assess programs and learning experiences. MAC should be applied at various phases in the life of a program/lesson. MAC was used to both design evaluation/assessment and to review learning activities in an already existing program to make improvements throughout program delivery. MAC was used in an iterative improvement process. MAC also facilitated alignment among concepts, an appropriate activation strategy, and assessment of I and T, to build learner engagement in their own learning process through self-assessment and reflection on how they were building their own understanding of concepts.

In the cases provided, MAC was used to design education programs and to improve learning through the feedback provided by the check developed. In Wisconsin ThinkWater School, having the mental models to be learned, activation strategies and evaluation tools all mapped out, identified where additional activation strategies were needed to ensure all participants developed relevant mental models at both the team and individual levels. In line with the recommendations of Pellegrino, Chudowsky and Glaser [9] and Plate [8], the selected checks, particularly online and on-paper mapping, allowed *both content and thinking structure* to be assessed. thereby incorporating both cognition and metacognition. Mapping also became part of the participants' learning through reflection on their current mental models and incorporation of what they learned in one setting into another application. The ability to transfer these metacognitive skills is easily facilitated by the MAC model -- and is an important educational outcome. The process of iteratively working through an abstract concept to concrete thinking, that is, from concept (Map) to application (Activate) and back to concept (Check), is a particularly salient part of the participants' learning.

In the case of the ocean geology lesson, the class that was presented the mental model of the interrelated geologic features developed models that were better representations of reality (see Figure 5). In the class that was presented with the interrelated mental model, the physical models included geologic features that were integrated together to represent ocean structures. In the class in which the geologic features were simply presented as independent items, the physical models represented those features, but they were not integrated to create a model that realistically represented the ocean. When students are encouraged to see how concepts are related through an activity (activation) they master both content (I) and thinking (T) - facilitated by the MAC Model.

The cases provided are short-term snapshots that highlight the need for additional application, resources and research with MAC.. Research that follows programs for extended periods that examine improvements made to activation strategies, and even changes to identified mental models, through feedback from checks would be beneficial to better understanding wider applications and power of this model. Although previous research shows that learners who can identify their thought structure (be metacognitive) are effective in problem solving and critical thinking through time [6,9], additional research should examine the long-term impacts of learning in MAC-designed approaches. Tools to further enhance educators' use of MAC are also needed to identify effective activities higher on the activation spectrum connected to particular mental models. This could be accomplished through artificial intelligence connected with online mapping by analyzing evolving online maps and data sets on learning. A tool that could identify effective activation strategies for particular mental models based on data from past lessons would be an important asset for educators across grades and topics. In the interim, having an accessible database of MAC online maps would be a useful resource.

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