Concept Mapping: Renewing Learning and Thinking
Proc. of the Eighth Int. Conference on Concept Mapping
Medellín, Colombia 2018

LEARNING OBJECTIVES FOR CONCEPT MAPPING BASED ON THE COMPLETE BLOOM'S TAXONOMY TO PROMOTE MEANINGFUL LEARNING

James Gorman
Nipmuc Regional High School, Upton, Massachusetts, United States
Email: jgorman@mursd.org

Abstract. Bloom's Taxonomy is important to instructional design. Bloom's cognitive domain is relied upon by educators to craft learning objectives that drive content and activity selection for the classroom. Educators strive to engage their students in higher-order thinking skills and concept mapping has been demonstrated to be a good tool to engage a student in higher-order thinking skills as well as promoting meaningful learning. However, all too frequently, educators have students complete "fill in the blank" concept maps that can be graded as correct or incorrect. This task encourages rote learning rather than promoting critical thinking skill and meaningful learning. This paper will review the complete Bloom's Taxonomy and suggest learning objectives for concept mapping that would significantly increase the likelihood of students being more fully engaged while creating an environment where meaningful learning can occur. The author concludes by examining how two common concept mapping activities engage different levels of learning and predicts their effectiveness toward creating a meaningful learning experience.

Keywords. concept map, meaningful learning, learning objective, instructional design, Bloom's Taxonomy, cognitive domain, interpersonal domain, psychomotor domain, perceptual domain, affective domain

1 Introduction

Classroom teachers are expected to be cognizant of Bloom's Taxonomy when they are creating or revising curriculum and assessments (instructional design). Few recognize Bloom's Taxonomy is more than the cognitive domain so this paper will seek to apply all the learning domains to concept mapping. It is all an attempt to make education measurable and meaningful. David Ausubel (1978) defines the process of "meaningful learning" as actively linking new learning to their prior knowledge. Meaningful learning contrasts with rote learning, in which learners memorize arbitrary concepts, do not link them to prior understanding, and consequently, do not store them in long-term memory nor have access to them for future problem-solving and decision-making. Joseph Novak (1998) stipulates that meaningful learning requires:

1) the learner to possess relevant prior knowledge in order to successfully acquire new knowledge
2) concepts to be presented in a manner that the learner finds them meaningful
3) the learner to choose to learn.

Meaningful learning tends to organize concepts in a hierarchical fashion which enables long-term retention and application of those concepts. Two key characteristics of meaningful learning that will be focused on in this paper are *progressive differentiation* and *integrative reconciliation*. Progressive differentiation occurs when the learner adds subordinate (more specific) concepts to a superordinate (more general) concept. However, integrative reconciliation occurs when a learner restructures their conceptual understanding under a new overarching concept.

Conceptual maps are visual representations of knowledge that clarify relationships among multiple concepts and are commonly employed in classrooms. A concept map (cmap) is a special type of conceptual organizer originally designed for science education research about learner's thinking process and is a visual representation of meaningful learning.

This paper seeks to provide specific and measurable learning objectives for concept mapping based on the complete Bloom's Taxonomy (cognitive, interpersonal, affective, psychomotor, and perceptual domains). It will be shown that concept mapping can reach the entire cognitive domain and all the other domains.

2 Bloom's Taxonomy of Learning Domains

In the 1950s, Benjamin Bloom and his colleagues developed a framework for understanding and communicating about learning objectives and it has come to be known as Bloom's Taxonomy (Bloom, et. al., 1956). Their taxonomy is composed of two dimensions: domain and level. A domain is a realm of human experience in which learning can occur. These include the cognitive, psychomotor, affective, interpersonal, and perceptual domains.

This paper will elaborate on how concept mapping can touch upon each of these domains to achieve meaningful learning. Each of these domains is composed of levels which detail the level of learning. The levels are arranged in a hierarchical order where the learner is meant to progress from the most simple to complex with prerequisite skills/knowledge at the base of the hierarchy. Therefore, Bloom's Taxonomy is well suited to aid in meaningful learning. This paper will now briefly describe each domain and attempt to demonstrate how concept mapping can be employed to satisfy many of Bloom's Taxonomy.

2.1 Cognitive Domain

Bloom's Taxonomy has provided a common language for educators which has aided in collaboration to develop and select learning content, activities, discussion questions, assignments, and assessments. However, in 2001, Anderson and Krathwohl published an updated version of Bloom's Taxonomy which focused on the cognitive domain. Their aim was to change the original focus from static learning objectives to a dynamic classification system which employs action words to describe the cognitive processes utilized by the learner. This updated classification system is known as the Revised Bloom's Taxonomy and will be the taxonomy this paper will utilize. The cognitive domain is focused on intellectual abilities from concrete operations like recognition of facts to abstract skills like producing new or original work. Another one of Anderson and Krathwohl's innovations was to break the cognitive domain into two dimensions: process and knowledge. The cognitive process dimension consists of the following levels listed from lowest to highest: remember, understand, apply, analyze, evaluate, and create. Each of these will be considered below. The second dimension of the cognitive domain is knowledge which is concerned with the types of knowledge or "ways of knowing." These include the following which are listed from the most concrete to abstract:

- Factual: Factual knowledge is declarative knowledge which is generally accepted as fact that can be learned by rote like terminology and specific details. These make up the basic elements of a topic.
- Conceptual: Conceptual knowledge is explanatory and summarizes major ideas and their parts. It can include knowledge of classifications and categories, principles and generalizations, as well as knowledge of theories, models, and structures.
- Procedural: Procedural knowledge is concerned how to do a task including knowledge of subject-specific skills and algorithms, of subject-specific techniques and methods, and knowledge of criteria for determining when to use appropriate procedures.
- Metacognitive: Metacognitive knowledge is concerned with the awareness of one's thought processes. This includes strategic knowledge, knowledge about cognitive tasks, and self-knowledge.

Each of these levels of the cognitive knowledge dimension will be incorporated into the discussion on the cognitive processes levels below which are summarized in table 1.

2.1.1 Remember

Remembering is the most fundamental cognitive process skill because it involves using recognition or recall to retrieve knowledge from long-term memory. Concept maps are a graphical display of a person's knowledge. Therefore, concept mapping inherently must involve the whole spectrum of the knowledge dimension.

- Factual: On the factual level (the most concrete level), concept mappers are asked to define a concept and list concepts that are related to the focus question. A practice often employed when using concept mapping is called a parking lot, a list of concepts that are to be developed into a concept map. An appropriate concept mapping learning objective would be "Students will be able to list relevant concepts related to a focus question." Another learning objective would be "Students will be able to define a particular concept."
- Conceptual: Moving up to the conceptual level of knowledge dimension, the concept mapper now uses their explanatory or summarizing ability. The learner needs to review a cmap to recognize the knowledge already present and reflect upon what still needs to be added so that the cmap is a complete expression of their understanding. A concept mapping learning objective would be "Students will be able to recognize what is already represented in the cmap and what might be useful to more fully address the focus question.
- Procedural: It is not enough to have learners to just observe cmaps. The true value of a concept is only unlocked when the learner actively constructs his own. During the process of constructing a cmap, the concept mapper must recall how to construct a cmap to graphically display their knowledge. Therefore,

students need to know the steps involved in building a cmap. An appropriate concept mapping learning objective would be "Students will be able to recall how to construct a cmap."

- Metacognitive: For a concept map to be valuable to the learner, he/she has to value cmaps as a way to retain information. An appropriate concept mapping learning objective would be "Students will be able to identify cmaps as a way to retain knowledge and express their understanding to others."

2.1.2 Understand

For a learner to demonstrate an understanding of a concept he/she must make sense out of knowledge or explain a particular. Some action words that carry a connotation of understanding are restating, interpreting, summarizing, paraphrasing, or translating knowledge. Examples of a learner demonstrating understanding are having them find the main idea of a text, summarize a text, or explaining the trends and their significance.

- Factual: On the factual knowledge level, understanding can be applied to be seen in concept mapping when a learner generalizes from a perceived reality or labels a concept. An appropriate concept mapping learning objective would be "Students will be able to generalize from a perceived regularity to label a concept."
- Conceptual: On the conceptual level, a typical concept mapping task that would apply is to arrange concepts in classes or categories according to shared qualities or characteristics. A concept mapping learning objective would be "Students will be able to classify concepts into appropriate groupings."
- Procedural: Understanding requires the learner to not just recall or state the steps to build a cmap as they did on the knowledge level, but it requires him/her to paraphrase or summarize the steps. A concept mapping learning objective would be "Students will be able to summarize the steps to construct a cmap."
- Metacognitive: Understanding, as applied to concept mapping, could involve the reader of a cmap to make a prediction. A concept mapping learning objective would be "Students will be able to make a prediction based on cmap."

2.1.3 Apply

Apply is the highest level of the lower-order thinking skills which are characterized as having correct or incorrect answers. This cognitive processing skill level requires a learner to carry out or use a procedure in a given situation. For example, a learner can select, transfer, and use data and principles to complete a problem or task with a minimum of direction.

- Factual: Educators who provide their students with cmaps as graphic organizers could use these cmaps as a means for the student to answer simple questions about the topic at hand. An appropriate learning objective would be "Students will be able to respond to questions relying on a concept map."
- Conceptual: In the classroom, it is common for concept mappers to work together on a cmap or review each other's cmaps. A concept mapping learning objective would be "Students will be able to provide advice to another concept mapper."
- Procedural: As a learner constructs a cmap there are certain rules he/she needs to follow which include all 1) concepts go in circles and 2) linking phrases go on lines. Some concept mapping tasks provide students with a list of concepts and linking phrases for them to use. Other times the concept mapper could have generated a list of propositional phrases which they need to circle the concepts and underline the linking words. A concept mapping learning objective would be "Students will be able to apply the appropriate rules to a set of propositional phrases."
- Metacognitive: On the metacognitive level of the apply level, the learner could choose concepts from a text and choose explicit linking phrase to express the relationship between two concepts. Additionally, the learner could be asked to decide whether a particular cmap appropriately addresses the focus question. Some concept mapping learning objectives would be "Students will be able to choose concepts from a text and linking phrases" and "Students will be able to decide whether the cmap is helpful."

2.1.4 Analyze

The analyze level of Bloom's Taxonomy is the lowest level of the higher-order thinking skills. These higher-order thinking skills require the learner to self-generated reasoning, critical thinking, problem solving, and creative thinking (Barak & Dori, 2009; Brookhart, 2010). Mizraie *et al*. (2008) employed concept mapping with their students and determined these higher-order thinking skills are characteristic of meaningful learning.

- Factual: Analyzing involves the breaking down of information into parts and finding the evidence to support any generalizations they are making. A key skill for concept mappers to do is break a text up into propositional phrases which are short statements that composed of two concepts and linking words to relate them. These propositional phrases are the backbone to any concept map. A concept mapping learning objective would be "Students will be able to outline a text into a series of propositional phrases". Another learning objective could be "Students will be able to break down a concept into propositional phrases."
- Conceptual: One of the key characteristics of Ausubel's meaningful learning is progressive differentiation, adding more specific concepts beneath a more general concept. Since this involves defining or elaborating on the relationship between concepts it clearly fits the conceptual level of the knowledge dimension. An appropriate concept mapping learning objective would be "Students will be able to progressively differentiate between concepts."
- Procedural: Another key skill for concept mappers is to be able to take a draft of a cmap and organize it into a visually pleasing and clear graphical display of the learner's knowledge. Therefore, an appropriate learning objective would be "Students will be able to organize a cmap to be aesthetically pleasing."
- Metacognitive: Cmaps will clearly display certain structural features like spokes, chains, networks, and cycles (Kinchin *et al*., 2000) which are indicative of the learner's understanding. The learner can also determine their depth of learning by comparing their present cmap to their first version. Gorman & Heinze-Fry (2015) provide a qualitative rubric for this which combines the work of Kinchin *et al*. (2000) and Hay (2007). A concept mapping learning objective would be "Students will be able to analyze a cmap for evidence of meaningful learning."

2.1.5 Evaluate

Evaluate was moved from the top of Bloom's original taxonomy and placed on the second highest level in the revised version (Andrerson & Krathwohl, 2001). This cognitive process is concerned with making judgments based on criteria or standards. For a learner to effectively evaluate, he/she must make decisions based on in-depth reflection, criticism, and assessment.

- Factual: Once concept mappers have brainstormed relevant concepts they are often faced with the challenge of having too many concepts. Typically, a cmap should be limited to 15-25 concepts to remain intelligible. An appropriate learning objective would be "Student will be able to select the most appropriate 15-25 concepts that address the focus question." Once the learner has narrowed the list to the most relevant concepts, the need to rank the concepts from the most general concept to the most specific concept for this particular situation. Therefore, another learning objective could be "Students will be able to rank order concepts from the most general to the most specific concept within the context of the focus question."
- Conceptual: A key skill when evaluating a concept map is to assess the validity of the propositional phrases. These propositional phrases can be made by an individual (Analyze + Factual learning objective) or by a software program like CmapTools. In either case, these propositional phrases allow the evaluator to assess the validity of the statement on its own merits and modify them as needed. A learning objective would be "Students will be able to assess the validity of propositional phrases."
- Procedural: There is a myriad of different types of graphic organizers that help classify ideas, communicate effectively, and facilitating the learners' comprehension of newly acquired information. Each type has its own advantages and appropriateness for a particular task. A learning objective would be "Students will be able to evaluate the appropriateness of using concept mapping."
- Metacognitive: Once a cmap has been constructed, the next step is to reflect on how well the cmap addresses the focus question it is seeking to answer. There might be missing concepts or links not obvious before but now they have become apparent and can be fixed. A learning objective would be "Students will be able to reflect on how well the cmap concisely addresses the focus question."

Cognitive Domain			**Knowledge Dimension**			
			concrete ----------> *abstract*			
			Factual	**Conceptual**	**Procedural**	**Metacognitive**
Cognitive Process Dimension	*abstract* ^ | | | *concrete*	**Create**	Add resources (e.g., web links, videos, pictures, etc.) to a cmap in support of the concepts it details	Restructure conceptual understanding through **integrative reconciliation**	Compose a cmap/ knowledge model.	**Negotiate meaning** with other learners
		Evaluate	Select the most appropriate 15-25 concepts to answer focus question & Rank order concepts	Assess the validity of propositional phrases relative to the focus question.	Evaluate the appropriateness of using concept mapping.	Reflect on how well the cmap concisely addresses the focus question
		Analyze	Outline a text into a series of propositional phrases	**Progressively differentiate** between concepts	Organize a cmap to be aesthetically pleasing	Analyze a cmap for evidence of meaningful learning
		Apply	Respond to questions relying on a concept map	Provide advice to another concept mapper.	Apply rules (e.g., concepts in circles, linking phrase on line, etc.) to a set of propositional phrases.	Choose concepts from a text and linking phrases & Decide whether the cmap is helpful
		Understand	Generalize from a perceived regularity to label a concept	Classify concepts into appropriate groupings.	Summarize the steps to construct a cmap	Make a prediction based on cmap
		Remember	List relevant concepts & Define a concept	Recognize what is already represented in the cmap and what might be useful to more fully address the focus question.	Recall how to construct a cmap	Identify cmaps as a way to retain knowledge and express their understanding to others.

Table 1: This is a table of learning objectives which should be preceded by "Students will be able to...." Each objective was constructed with a verb associated with the Revised Bloom's Taxonomy (Anderson and Krathwohl, 2001) cognitive dimension. The gray section highlights the cognitive dimensions that Mizraie *et al.* (2008) determined were characteristic of meaningful learning.

2.1.6 Create

The pinnacle of critical thinking within the Revised Bloom's Taxonomy is the ability to create which involves putting elements together to form a coherent whole as well as to reorganize into a new pattern or structure. As part of this cognitive process, the learner originates, integrates, and combines ideas into a product, plan, or proposal new to him/her.

- Factual: CmapTools (Cañas *et al.*, 2004) software by Institute for Human and Machine Learning (https://cmap.ihmc.us/) allows students to link any digital resources to any concept or linking phrase. For example, if a learner pulls an important concept from a website, video, or paper they can attach it to the concept for reference later on. Pictures can also be added to lend to an illustrated cmap which emphasizes certain concepts. A learning objective related to this would be "Students will be able to add resources (e.g., web links, videos, pictures) to a cmap in support of the concepts.
- Conceptual: A key feature of meaningful learning according to Ausubel is integrative reconciliation which concerns the restructuring of conceptual understanding. This can be viewed in a cmap as cross-linking between two concepts which are in different parts of the cmap. Kinchin *et al.* (2000) note these cross-

links form a network indicative that the learner understands the topic and therefore demonstrating meaningful learning. Another type of integrative reconciliation is when the learner identifies a more general concept not already present in the cmap and he/she makes it superordinate to concepts already present. A appropriate learning objective for this would be "Students will be able to restructure conceptual understanding through integrative reconciliation."

- Procedural: The ability to draft a cmap is an important skill and requires procedural knowledge. Cmaps can be sketched on paper, on surfaces with sticky notes or with software. You can even link concept maps together into what is called a knowledge model, a collection of two or more linked cmaps. For instance, you could have a concept like "frog" as a subordinate concept in one cmap but link it to another concept map which has "frog" as the superordinate concept. This second cmap contains all concepts related to what a "frog" is. A learning objective for this procedural knowledge would be "Students will be able to compose a cmap/knowledge model."
- Metacognitive: Creating a cmap by following a procedure is one thing and it is another to negotiate the meaning of the relationship between two concepts. Learners often do not have much trouble coming up with concepts to add to a cmap. However, what they do find difficult is finding the precise words to use as the linking phrase. It often takes much thought and adjustment of those words as the learner actively ponders the true relationship between the concepts. When creating a cmap with others or some else is reviewing a cmap it often results in a conversation about a particular set of linking words. The two then enter a negotiation as to what the relationship is between the two concepts. Thus, an appropriate learning objective would be "Students will be able to negotiate meaning with others."

2.2 Interpersonal Domain

Next, we will consider the interpersonal domain of Bloom's Taxonomy which seeks to elaborate on the interaction between people. Fournier *et al*. (2008) stipulated the interpersonal domain is context specific and characterized by patterns of behavior and attitudinal dispositions toward others. Some examples of interpersonal skills are listening, speaking, writing, non-verbal communication, assertiveness, managing interpersonal stress, group decision making and problem solving, and understanding the causes of communication failures. There are six levels of the interpersonal domain which are listed below from lower to higher-order:

- Seeking and Giving: This skill involves asking and offering facts, opinions, or clarifications from others. When constructing a cmap, seeking and giving is a fundamental skill from finding the information about the concepts to negotiating meaning. A concept mapping learning objective would be "Students will be able to ask and offer concepts and clarification from others while constructing a cmap."
- Proposing: A person who proposes a new concept or suggestion needs to do so in a manner so it will be considered and accepted. A concept mapping learning objective would be "Students will be able to present their concept map to others and not impose it but use the cmap as the start of a conversation."
- Supporting: Supporting involves assisting another toward their goal. Cmaps are a work in progress and a start for a conversation. There will be good and bad parts on the cmap but the reviewers are to build up the other person by providing constructive feedback. A learning objective would be "Students will be able to provide support to others during the concept mapping process."
- Including: This skill is concerned with making sure that others are involved in the discussion of ideas. A concept mapping learning objective would be "Students will be able to ask for opinions from others and welcome their feedback."
- Disagreeing: Disagreeing occurs when a person offers a contradictory opinion with discretion and consideration. Learning is forged through challenges. Cmaps get better because others take time to review them and offer their constructive feedback. A learning objective would be "Students will be able to offer a contradictory opinion considerately."
- Summarizing: To summarize is the ability to restate something in an abbreviated form. It is an important skill for a listener to summarize what he/she just heard as to confirm understanding. Being an active listener is a crucial part of negotiated meaning. A concept mapping learning objective would be "Students will be able to be an active listener during the concept mapping process."

2.3 Affective Domain

The affective domain was described by Kratwohl *et al*. (1964) as the way people react emotionally and their empathy focusing on the awareness and growth in attitude, emotion, and feelings. Meaningful learning theory states that the person be willing to learn so the affective domain needs to be tapped into for meaningful learning to occur. The affective domain has five levels which are listed below from lower to higher-order:

- Receiving: A person who is receiving is one who pays attention, considers, and attends to information. Some examples of receiving include the ability to listen for, read, view, respond to, meditate, ponder, reflect, contemplate, and differentiate. It is important to note the receiving does not imply that the learner has made any decision about the new information, but has agreed to take the information in.
- Responding: Responding involves actively participating in or interacting with a new concept. Having a discussion about a topic would be an example of responding. A person who responds would volunteer, comply with, follow, commend, spend leisure time in, or acclaim. A learning objective would be "Students will be able to willingly participate in the concept mapping process."
- Valuing: A person values something when he/she perceives it to be worthwhile, useful, helpful, meaningful, or justifiable. Valuing would be indicated by a person showing increased measured proficiency in, relinquishing, subsidizing, supporting, or debating. We can clearly see this as part of the concept mapping process of negotiated meaning because part of the process is a debate. The learner has to place value on a topic to meaningfully learn which can be measured as discussed above.
- Organization: Organization involves fitting new concepts into your existing understanding and deciding how it makes sense to you. One who organizes would discuss, theorize, formulate, balance, or examine. Organization is most certainly a valued skill as one concept maps. A concept mapping learning objective would be "Students will be able to organize the concepts and linking lines a cmap so it is visually pleasing."
- Characterization: Characterization by value set means the learner has incorporated the new value into his/her thinking and way of being. Some examples of this would include revising, requiring, avoiding, resisting, managing, and resolving. A concept mapping learning objective would be "Students will be able to incorporate concept mapping into their learning process."

2.4 Psychomotor Domain

In the ideal classroom, students would be engaged in activities that require them to leave their seat and move around. It is an important way to engage the learner and help them make long-term memories. Kilber *et al*., (1970) and Simpson (1971) were one of the first to elaborate the psychomotor domain is associated with physical skills like speed, dexterity, grace, use of instruments, expressive movement, dance, and athletics. There five levels which are listed below from lower to higher-order:

- Movement: Movement is the most fundamental level and includes basic actions of the limbs like lifting, reaching, pointing, swinging, walking, and turning. If one is constructing a cmap they are actively writing, sketching, typing, or just moving in general.
- Coordination: Coordination involves the synchronized movement of the limbs and head including typing, lifting, carrying, dancing, positioning, connecting, and aligning.
- Performance: Performance involves the ability to execute a complex pattern of coordinated movements including to carry out, complete, portray, demonstrate, present, construct, assemble.
- Adaptation: Adaptation involves the ability to alter performances in response to new circumstances including to modify, update, syncopate, convert, and adapt.
- Origination: Origination involves the ability to create new forms of performances including to compose, choreograph, orchestrate, produce, and coach.

2.5 Perceptual Domain

The last of the commonly accepted learning domains is the perceptual domain which involves extraction of information from stimuli. The perceptual domain is key to developing expertise as experts efficiently filter out important information and recognize patterns in that information. Perceptual learning is task specific and occurs mostly non-verbally. Moore (1967) elaborated on five levels of perceptual learning which are listed below from lower to higher-order:

- Sensation: Sensation is the awareness of some stimuli through the five senses (sight, smell, hearing, taste, and touch).
- Figure Perception: Figure perception is the awareness of basic components in a formation of a concept (magnitude, form, location, position, etc.) and their relationships to each other and the whole. It also expands to an awareness of relationships between the parts and the background, or between the stimulus and its context. An example of figure perception is who you identify an object apart from its surroundings. A learning objective related to concept mapping would be "Students will be able to recognize key structural components of a concept map (e.g., spoke, chain, network, and cycle)."
- Symbol Perception: Symbol perception is the awareness things that have an attached meaning and form including the ability to name and assign them to appropriate classes as well as to define the similarities and differences between them. An example of this would be to recognize the difference between the letters I and J. A concept mapping learning objective for symbolic perception would be "Students will be able to name and classify concepts."
- Perception of Meaning: Perception of meaning is the awareness of the significance or value of a behavior, object or symbol including the discovery of new relationships, cause-effect relationships, generalizations, and implications enabling decision making and problem solving. The ability to generalize, understand implications, and make decisions all fall in the realm of perception of meaning. An example of perception of meaning is the ability observe the face and body language of another person and know their emotional state. This skill is closely related to integrative reconciliation. A concept mapping learning objective would be "Students will be able to evaluate a concept map and establish new relationships between previously unconnected concepts" and "Students will be able to provide advice based on a concept map."
- Perceptive Action: Perceptive action is sensitive differentiation and accurate observation enabling diagnostic, explanatory, and predictive ability to guide performance. People who display this skill demonstrate a successful analytical or global approach to problem solving. An example of this is a car mechanic running test on a vehicle and being able to diagnose the problem. A learning objective would be "Students will be able to review a cmap and help guide the concept mapper."

3 Discussion

Educators do not realize or reflect on how many domains and levels of the complete Bloom's Taxonomy concept mapping can engage. Science textbooks will sometimes have a "fill in the blank" concept map in their chapter review but these tend to have the structure of the cmap already established and the students are plugging in the concepts. The linking words are already present and part of the structure of the cmap. This is the lowest level of concept mapping task and table 2 demonstrates there is little critical thinking or meaningful learning occurring in this activity. Additionally, this activity is usually done individually by the learner. It is clear after reviewing the levels of learning that are touched upon in this concept mapping activity that they mostly stick to the lower-order thinking skills. Unfortunately, all too often educators will have their learners engaging in this lowest level of concept mapping and think they are encouraging their student to think. However, the evidence is clear from complete Bloom's Taxonomy that meaningful learning is not occurring. Therefore, this is a rote learning exercise.

On the other end of the concept mapping spectrum, learners have to generate their own concepts and linking phrases based on a focus question. The learner is not provided with a structure for the cmap. Novak and Cañas provide a concept map flow chart of the steps involved in constructing a concept map like this (http://cmapskm.ihmc.us/). Once the learner is assigned the focus question, he/she would follow these steps:

1. Suggest relevant concepts
2. Narrow that list to 15-25 relevant concepts
3. Rank order those concepts from most general to most specific.
4. Start constructing a cmap with the top four concepts.
5. Choose explicit linking words to define the relationship between concepts
6. Continue to build the hierarchy by progressively differentiating concepts
7. Search for possible cross-links between concepts in different branches
8. Reposition and refine the cmap structure.

If the learners are allowed to work together on their cmaps either for the whole or part of the process, much of the complete Bloom's Taxonomy can be touched upon to give learners increased odds of learning meaningfully. It is important to emphasize that concept mapping is a process that involves feedback and revision to effectively practice those higher-order thinking skills. Table 3 graphically shows which levels and to what depth they are touched upon in this process. The educator can add other learning objectives from table 1 which were not covered in this simple construction of a concept map to cover more levels. Table 3 does account for the possibility that the learner will restructure their knowledge (create + conceptual knowledge levels) which would only be evident to the observer if they had at an initial cmap to compare to. An educator could require students attach resources to their concept and this would then add another level of higher-order thinking to the activity (create + factual knowledge levels). Having learners evaluate other cmaps is a valuable activity and this can be done by simply reviewing a list of propositional phrases generated from the cmap (evaluate + conceptual knowledge).

Cognitive Domain							
Knowledge Dimension	**Process Dimension**	Remember	Understand	Apply	Analyze	Evaluate	Create
Factual Knowledge		✓					
Conceptual Knowledge		✓	✓			✓	
Procedural Knowledge		✓					
Metacognitive Knowledge							
Interpersonal Domain		Seeking/Giving	Proposing	Supporting	Including	Disagreeing	Summarizing
Affective Domain		Receiving ✓	Responding ✓	Valuing	Organization	Characterizing	
Psychomotor Domain		Movement	Coordination ✓	Performance	Adaptation	Origination	
Perceptual Domain		Sensation	Figure/Ground	Symbol ✓	Meaning ✓	Action	

Table 2: A table of the complete Bloom's Taxonomy with check marks for all learning skills that would be touched upon during construction of a "fill in the blank" concept map where the structure, concepts, and linking phrases are provided.

Cognitive Domain							
Knowledge Dimension	**Process Dimension**	Remember	Understand	Apply	Analyze	Evaluate	Create
Factual Knowledge		✓	✓			✓	
Conceptual Knowledge		✓	✓	✓	✓		
Procedural Knowledge		✓		✓	✓		✓
Metacognitive Knowledge				✓	✓	✓	✓
Interpersonal Domain		Seeking/Giving ✓	Proposing ✓	Supporting ✓	Including ✓	Disagreeing ✓	Summarizing ✓
Affective Domain		Receiving ✓	Responding ✓	Valuing ✓	Organization ✓	Characterizing	
Psychomotor Domain		Movement	Coordination ✓	Performance	Adaptation	Origination	
Perceptual Domain		Sensation	Figure/Ground	Symbol ✓	Meaning ✓	Action ✓	

Table 3: A table of the complete Bloom's Taxonomy with check marks for all the skills that would be touched upon when one creates a concept map where the learners generate the concepts, linking phrases, and structure.

In conclusion, it is hoped the learning objective for concept mapping proposed in this paper will aid educators in understanding the learning skills they can tap into and provide them with the learning objectives to promote meaningful learning in the classroom. Bixler *et al.* (2015) points out that learners find concept mapping easy but if concept mapping is not frequently practiced and the skill honed critical thinking is not improved. Educators need to see concept mapping as part of the learning process and not just an assessment tool and should know how to cmap well (Cañas *et al.*, 2017). Learners need to be taught "how to think" rather than "what to think." If educators truly desire to increase higher-order thinking skills they will target the appropriate learning objectives and develop activities so that students can meet those objectives.

4 Acknowledgments

The author would like to thank his wife, Andrea, for her unwavering support and encouragement as well as Jane Heinze-Fry for providing feedback in the initial stage of developing this topic.

References

Anderson, L. W., Krathwohl, D. R., Airasian, P. W., Cruikshank, K. A., Mayer, R. E., Pintrich, P. R., ... & Wittrock, M. C. (2001). A Taxonomy for Learning, Teaching, and Assessing: A Revision of Bloom's Taxonomy of Educational Objectives, Abridged Edition. *White Plains, NY: Longman.*

Ausubel, D. P., Novak, J. D., & Hanesian, H. (1978) *Educational Psychology: A Cognitive View, Second Edition.* Holt, Rinehart, and Winston, Inc.: New York, New York.

Barak, M., & Dori, Y. J. (2009). Enhancing Higher-Order Thinking Skills Among in Service Science Teachers Via Embedded Assessment. *Journal of Science Teacher Education*, 20(5), 459-474.

Bixler, G. M., Brown, A., Way, D., Ledford, C., & Mahan, J. D. (2015). Collaborative Concept Mapping and Critical Thinking in Fourth-Year Medical Students. *Clinical Pediatrics*, 54(9), 833-839.

Bloom, B.; Engelhart, M. Furst, E. Hill, W. Krathwohl, D. (1956). *Taxonomy of Educational Objectives: The Classification of Educational Goals. Handbook I: Cognitive Domain.* New York: David McKay Company.

Brookhart, S. M. (2010). *How to Assess Higher-Order Thinking Skills in your Classroom.* ASCD.

Cañas, A. J., Hill, G., Carff, R., Suri, N., Lott, J., Eskridge, T., Lott, J, Carvajal, R. (2004). CmapTools: A Knowledge Modeling and Sharing Environment. In A. J. Cañas, J. D. Novak & F. M. González (Eds.), *Concept Maps: Theory, Methodology, Technology*. Proc. of the First Int. Conference on Concept Mapping (Vol. I, pp. 125-133). Pamplona, Spain: Universidad Pública de Navarra.

Cañas, A. J., Reiska, P., & Möllits, A. (2017). Developing Higher-Order Thinking Skills with Concept Mapping: A Case of Pedagogic Frailty. *Knowledge Management & E-Learning: An International Journal*, 9(3), 348-365.

Fournier, M. A., Moskowitz, D. S., & Zuroff, D. C. (2008). Integrating Dispositions, Signatures, and the Interpersonal Domain. *Journal of Personality and Social Psychology*, 94(3), 531.

Gorman, J., & Heinze-Fry, J. (2015). Conceptual Mapping Facilitates Coherence and Critical Thinking in the Science Education System. In *STEM Education: Concepts, Methodologies, Tools, and Applications* (pp. 1227-1258). IGI Global.

Hay, D. B. (2007). Using Concept Maps to Measure Deep, Surface and Non-Learning Outcomes. *Studies in Higher Education*, 32(1), 39-57.

Kibler, R. J., Barker, L. L. and Miles, D. T. (1970). *Behavioural Objectives and Instruction.* Rockleigh, NJ: Allyn and Bacon.

Kinchin, I., Hay, D. and Adams, A. (2000) How a Qualitative Approach to Concept Map Analysis can be used to Aid Learning by Illustrating Patterns of conceptual Development. *Educational Research*, 42(1): 43 – 57.

Kratwohl, D. R., Bloom, B. S., & Masia, B. B. (1964). Taxonomy of Educational Objectives, the Classification of Educational Goals–Handbook II: Affective Domain. *New York: McKay.*

Mirzaie, R. A., Abbas, J., & Hatami, J. (2008). Study of Concept Maps Usage Effect on Meaningful Learning Frontier in Bloom's Taxonomy for Atomic Structure Mental Concepts. In A. J. Cañas, P. Reiska, M. Åhlberg

& J. D. Novak (Eds.), *Concept Maps: Connecting Educators*. Proc. of the Third Int. Conference on Concept Mapping. (Vol 3, pp. 226-229-). Tallinn, Estonia: Tallinn University.

Moore, Maxine R. & Educational Testing Service, Princeton, NJ. (1967). *A Proposed Taxonomy of the Perceptual Domain and some Suggested Applications.* [Washington, D.C.]

Simpson, E. (1971). Educational Objectives in the Psychomotor Domain. *Behavioral Objectives in Curriculum Development: Selected Readings and Bibliography*, 60(2).