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The Power of a Doodling Brain: Concept Maps as Pathways to Learning

Milagros I. Rivera Cora[1], Soledad Gonzales[1], Matilde Sarmiento[2], Alejandra Esparza Young[3], Edith Esparza[1], Nikolina Madjer[1], Pinaikini Shankar[1], Yadmarie Rivera[1], Isaac Abulatan[1]

[1] University of Medicine and Health Sciences – St. Kitts
[2] Oyster Adams Bilingual School Washington, D.C.
[3] Department of Chemistry, Stanford University, Stanford, CA

Correspondence: Edith Esparza, University of Medicine and Health Sciences, Camps, Basseterre, St. Kitts.
E-mail: eesparza@uhms-sk.net

Abstract
Children begin to emulate writing and what they see around them at a very early age (Byington & Kim, 2017). The simple scribbles they begin to produce are representations of complex cognitive processes occurring. The constant cognitive scaffolding which medical students experience can be compared to the cognitive process children participate in when they doodle, this could be aiding them to visualize and to efficiently create concept maps as adults to learn key concepts and to quickly make connections. The ability to visualize and to understand the relationship of critically important medical concepts remains an invaluable skill which can be reflected through diagramming, concept mapping and doodling.

Keywords: Concept Mapping, Teaching/Learning, Critical Thinking

1. Introduction

Children begin to emulate writing and what they see around them at a very early age (Byington & Kim, 2017). The simple scribbles or doodles are representations of complex cognitive processes occurring. Over time, when some of those children become medical students they find themselves tapping into those early childhood experiences and reflect the learning which is taking place in their brain. Medical students develop their scribbling in order to cement concretely specific key concepts in medical school courses including: Pathology, Neuroscience, Microbiology and others. The ability to visualize the relationship among critically important medical concepts is represented through diagramming, concept mapping and doodling.

When asked about the benefits of drawing and using color to understand concepts and to make connections between topics before a test, recent Stanford graduate, Alejandra Esparza Young, who will be entering medical school in the Fall of 2021, stated the following, "In my Organic Chemistry classes, instead of writing down sentences and bulleted lists, I represented chemical reactions with drawings made up of dots, lines, and arrows." Alejandra grew up bilingual along the U.S. and Mexico border in the small town of Brownsville, Texas. She recalls that the act of drawing and coloring brought forth an element of elegance when it came to learning Chemistry at Stanford. She adds:

> In class, I genuinely enjoyed watching my organic chemistry lecturers draw out simple hexagons and sticks in blue, green, red, or black to represent much more complicated concepts. There were often almost no words or numbers to be seen on the white board, and it was pleasantly surprising and refreshing!

This description is in line with the much-needed brain break which can occur through the process of doodling (Pillay, 2016). Medical students seem to experience a sense of relief by illustrating and drawing out their ideas and the organization of those ideas simply because the learning process becomes more fun. A blank sheet of paper can quickly become geometric shapes and arrows which fit together like a mosaic, and which can fill almost any empty space on a note page with another new piece of information.

The lasting effect and benefit of creating these drawings means that during an exam some images may call for an understanding of key information which can be found in lab reports. For instance, a concept map on a complex topic like treatment of cardiac arrhythmias requires a student to start with basic fundamentals that gradually build upon mechanisms of ionic movement in cardiac action potentials and electrophysiology of cardiac myocytes, which is a complex physiological concept, until ultimately students find themselves comfortable interpreting the interrelationships that exist between antiarrhythmic drugs and the effect they cause on patients EKG or to clinically relevant abnormal lab reports seen in patients who are overdosed with these medications. The understanding of medical concepts requires deep thinking and serious synthesis of volumes of information. Alejandra confirms the need to master this critical skill by further adding that as she moved forward in her course work, she found great value in reducing complicated processes to simple drawings. She shares that feels confident this strategy will help her in medical school. The process of using concept maps, doodling and drawing made studying other subjects a more creative and engaging process. Reviewing the critical skills and tools utilized by Alejandra, we can identify that visual representations that are student-centered and student-created emerge as invaluable tools to manage large amounts of new knowledge.

2. What is a Concept Map vs. a Graphic Organizer?

Concept maps are visual representations of information and can take the form of charts, graphic organizers, tables, flowcharts, Venn Diagrams, timelines, or T-charts. They are a framework for visualizing the relationships between big, cross-functional ideas (Simmons et al., 1988). Concept maps can be a powerful study tool and strategy because they help you see the big picture. They allow the learner to start with higher-level concepts and proceed to chunk information based on meaningful connections and therefore making the details more significant and easier to remember (Robinson et al., 2006). More importantly, the use of concept maps allow students to visualize and remember concepts when it matters, during an exam and on a long-term basis , such as remembering protocol during specific situations. Yadmarie Rivera, who is originally from Puerto Rico and a second year medical student at the University of Medicine and Health Sciences in St. Kitts (UMHS-SK), finds that when she closes her eyes she can still see the image of a concept map and can remember even the location of a concept on the actual concept map and where the color can be found and what that color represents. Medical students are consistently scaffolding their learning and using prior knowledge to make further connections in a meaningful and permanent way. For Yadmarie, as a bilingual medical student, the practice of accessing prior knowledge of words remains a frequently used skill. She has found her bilingual skills to be a plus especially in medical school where so much of the vocabulary is Latin based. Yadmarie states:

> The benefits of a concept map are endless, but the most important is that you really get to extract the information that you need to really understand a topic. The concept map gives you the substance to ace your classes by providing a meaningful relationship among the concepts.

It would make sense that concept maps work very well for medical school content since these courses have visual elements as they pertain to the nervous system, skeletal structure, circulation system, and other similar concepts in which it is important to see and understand relationships between different elements. Creating boxes and connecting lines, drawing concept maps connect ideas and show their relationship to each other. In a concept map, each idea in a box is called a ***node.*** The branches that connect two nodes are called ***cross-links***. The cross-links often have words that help explain the relationships between the connection (Ermis, 2008).

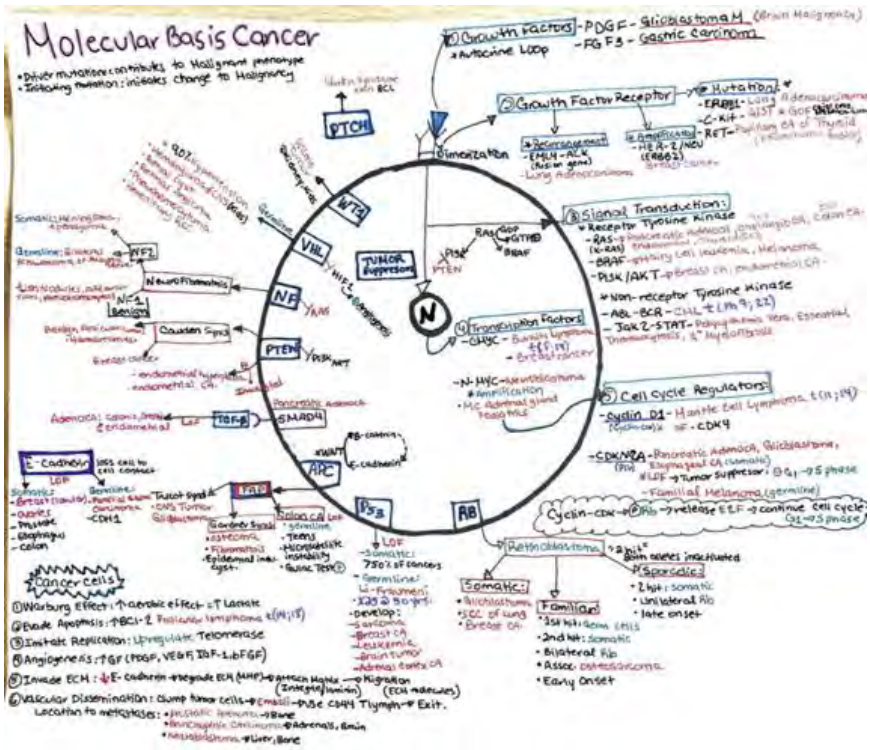

Figure 1: Yadmarie Rivera, Maine student, UMHS SK, Pathology 1 Concept Map. Reprinted with Permission.

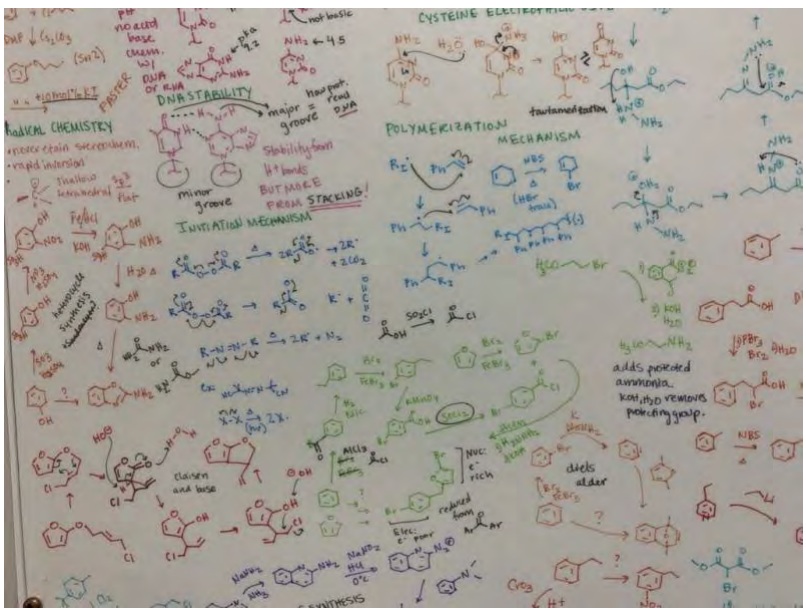

Figure 2: Alejandra Esparza Young, Stanford University, Organic Chemistry Concept Map. Reprinted with Permission.

Figure 3: Milagros Rivera, EBS 5 UMHS SK, Microbiology Concept Map Using MIRO Application. Reprinted with Permission.

3. Graphic Organizers are useful in Science Learning

A graphic organizer can be defined as a "visual representation of knowledge" regarding a certain concept (Bromley et al., 1999). Graphic organizers facilitate learning in content areas by providing clear visualizations of ideas and fostering student reflection. Students can also use the open-endedness of graphic organizers to gain a more thorough understanding of concepts since they allow for information to be arranged in a way that best shows the interrelatedness of pieces of information presented (Horton et al., 1990). Additionally, the structure of graphic organizers remains more suited for comprehension as compared with traditional linear note-taking of information; graphic organizers are able to show the relationship among concepts (Ermis, 2008; Fisher, 2001; Robinson et al., 2006). Graphic organizers have been sorted into four categories according to the interrelatedness of information to be presented in a particular graphic organizer (Ermis, 2008; Struble, 2007).

CONCEPTUAL is suitable for presenting a central idea with supporting information. examples: concept maps, Venn diagrams, and KWL	**SEQUENTIAL** show events that happen in sequence examples: cause/effect, problem/solution, and storyboards
HIERARCHICAL rank information according to such qualities as importance and have sublevels to show such examples: classifying charts, branching diagrams, and topic/subtopic webs	**CYCLICAL** designed to show the natural cycle of various concepts examples: an organism life cycle chart

Figure 4: The four categories of graphic organizers include conceptual, hierarchical, cyclical, and sequential (Struble, 2007).

4. The Process of Visualization as a Means to Organization

When medical students go about the business of reading in medical school, they try to go about it in a systematic fashion. The first approach considers factors such as the amount of time a medical student has to review the number of slides in a presentation. Based on this initial assessment, a decision is made in order to determine how much time should be spent on each slide. Medical students have to maintain a pace even when taking a first glance at important content. Even after an initial review, the first step of recollection and understanding begins. Repetition is key here. After a second look, the process of visualization continues and depending on what is not recalled, further concrete actions may need to ensue. One of these behaviors includes concept mapping.

To be able to make connections between key concepts from different courses in a meaningful way, the visualization process is invaluable. Concept maps can illustrate these links and relationships during the process of learning. A visual representation of these relationships can provide opportunities to see how multiple topics are synthesized. The experience of intentionally seeking ways to interweave the content from lectures leads to moving from abstract ideas to more concrete representations of multiple topics. Medical students begin to make logical correlations between Pharmacology and Physiology, for example. The two subjects are related and creating a concept map can support picturing these relationships.

A concept map basically represents the knowledge structure of the information medical students have stored and organized in their minds about a certain course topic. Medical students find it helpful to learn new topics by grouping facts and ideas in a different and creative way (Daley et al., 2016). Visualization continues to be an effective way to foster self-directed and life-long learning by using the act of moving from visualizing to drawing which literally creates and keeps a free space to park knowledge and information in a logical manner. Even when a diagram is not complete, the diagram can still serve as a parking lot of ideas which can be revisited later and repeatedly (Alias & Tukiran, 2006).

5. Collaborative Learning and the Brain

An overview of how collaborative decision-making through visualization can be supported through node-link diagrams where nodes are either arguments or statements and links between the nodes represent inferences between those visualizing different points of view to comprehend the topic at hand (Ahn & Brusilovsky, 2009; Wang et al., 2006). Such visualization not only helps the decision-making process, but it also provokes understanding of various opinions and provides insights as to how other learners construct their learning (Sumner et al., 2005). Overall visualization is aimed at fostering awareness and reflection about learning processes or changes in them. It enables medical students to compare and contrast their understanding with peers (Braak et al., 2006).

Interaction with fellow interns, during clinical rotations, is a core aspect of how learning is organized in medical school. The organization of this learning and the critical thinking skills utilized are particularly relevant to medicine where learning is not only a matter of accepting fixed facts, but it is the dynamic, ongoing, and evolving result of complex interaction taking place. Visualization, therefore, as mentioned before, is extremely useful to make people aware of the context in which they are functioning and enables them to explore this context (Adnan et al., 2008).

Visualization can support learners in coordinating their actions. One advantage is that this can help to overcome the over-scripting problems that often occur- a collaboration script is a set of instructions that describe how students should work together, form groups, and how they should collaborate to reach a common goal such as determine a course of action for a set of symptoms. problem. Visualization helps with overcoming scripting that may interfere with the learning process by forcing students to interact.

6. Learning Effect on the Brain When We Write

One of the hardest things to learn while in medical school is to first learn how to learn in order to be a successful learner. Certainly, a concept map is an easy way to acquire the golden skill of learning medical school content. Acquiring and learning medical concepts efficiently takes time, but once this skill is learned, then this same skill can be applied to visualizing ideas in the future and for, perhaps, a larger and more comprehensive, complex concept. The process remains dynamic because concept maps bring an open space to create and organize thoughts in a fun way much like the doodling that kids do in school. Besides being more fun than just reading linear text, this intentional and organized doodling gives license and the freedom to be creative while at the same time thinking critically and in a substantive and meaningful way. In many ways, literally connecting the dots as well being able to think outside the box

Reading and writing have undergone an evolution over a long period of time. Its history begins 50,000 to 100,000 years ago when our early ancestors created drawings on cave walls. Which will pave the way for quill pens, pencils, ink pens, ball point pens, and felt tip markers, and later typewriters and computer keyboards. We see how this evolution has impacted the education landscape, and how digital devices and technology dominate the classroom, but we still see the importance of children learning to write on paper and pencil. The act of putting pencil to paper is a complex cognitive process that is essential and important for the development of thought, since the act of writing involves multiple senses in our brain and these senses are part of the learning experience. When writing by hand, our brain receives feedback from our motor actions, together with the sensation of touching a pencil and paper. This kind of feedback is significantly different from those we receive when touching and typing on a keyboard.

The very act of handwriting appears to have important cognitive benefits. For example, a study of 15 children in Indiana (James & Engelhardt, 2012) who were asked to write, trace, or type letters while having their brains scanned found that *writing* letters activated more regions of the brain than typing letters—in particular, visual processing centers at the heart of perceiving letters (Alamargot, & Morin, 2015). Note taking is an effective memory and learning aid because it prompts students to *think about* their learning; it's more effective when done by hand (Mueller & Oppenheimer, 2014; Stevenson & Just, 2014) and more words were recalled after writing on paper than typing (Mangen et al., 2015; Kiefer et al., 2015; Hatano et al., 2015). Additionally, handwriting seems to be more effective for conceptual comprehension than typing. In fact, comprehension assessment of listening to technology/entertainment/design talks was superior among college students who made notes in a notebook using a pen as compared to those who typed notes on a laptop computer (Mueller & Oppenheimer, 2014). The advantage of handwriting over typing has also been indicated in neuroscientific approaches using electroencephalography (van der Meer & van der Weel, 2017).

What may start as a doodle and can also quickly materialize into an organized concept map. The many creations include: flow charts or tables with arrows and sticky notes which can actually serve as a narrative for an entire lecture in medical school. The ability to see the disease or mechanism of action in your head and to see this during an exam is key. Visualizing these concepts in your head will be retained in memory and cognitive processes go through the processes of consolidation, active recall, and storing information as part of long-term memory.

Concept mapping comes in handy when the vast amount of information and facts begin to overwhelm the process of thinking and the concepts and ideas begin to become random and disconnected. There is great value in being able to make connections between important topics even though, as to be expected, the ability to effectively understand critical material remains challenging when a medical student is receiving information at a speed they have never experienced before. Oftentimes, medical students may be in a state of cognitive paralysis and find themselves unable to analyze at a very quick pace and on a consistent basis. Therefore, concept mapping, from the very start, remains among the most effective options to aid with the classification of critical ideas.

The ability to use and create concept maps is a skill many students develop throughout their years enrolled in medical school; this particular skill in medical school is extremely important, and for many reasons. Learning the art of concept mapping takes a fair amount of work. Upon entering medical school there is a common

misconception that memorizing everything is the key to success. The consistent delivery of new information can be overwhelming and that feeling can be furthered by the knowledge that all of that material has to be processed, understood and applied. How can a medical student organize all of these ideas efficiently and quickly?

Note-taking during lectures by using symbols, arrows and hand-written notes help to connect the dots from one concept to another. Without realizing it, these digital or hand-written notes help to develop the skill of creating concept maps. By connecting different subjects and creating a map-like structure not only helps to organize the material faster, but research suggests that there is higher retention of the material when using concept maps (D'Antoni, 2009). Retention remains vital for medical students who must keep this information in the near future for board and STEP exams and of course, for the real-world.

7. Using Drawings, Diagrams, Doodles or Concept Mapping in Clinical Rotations

Although some may think that the volume of medical information a medical student must learn decreases as they approach the end of their four years of medical school, this actually could not be farther from the truth. As medical students enter their clinical years, the quantity of information stays the same or increases, but it is the content that changes. In order to keep up with the ever-changing content, concept maps and organized studying is what ultimately keeps medical students afloat and up-to-date with the information they are expected to learn. For example, content is often taught by chunking the content by the organ system, then further broken down by specific organ, pathological conditions of that organ, diagnostic management of that disease process, and ultimately treatment of that condition. Much like students learn, while in elementary school, that the human body is organized by organ systems that can be broken all the way down to a single cell, medical students use this logic to help organize this medical content at a much higher cognitive level. Eventually, when the time comes to review all of the material medical students are responsible for - studying and reviewing all the content can be done more efficiently with the visual support that concept maps provided by assisting the student to recall the connections previously made while working on the wards.

There are multiple ways concept mapping can be used; the visual representations can be tailored to the student's learning and also be content specific allowing for the learning to be individualized. For example, highlighting or selecting a particular color to use for one student can be important in the learning process and a different color may represent classifications or prioritization of concepts. For medical students, the use of symbols, arrows or lines can represent pathways and routes of specific diseases and reflect an understanding as to how those diseases progress. This can help medical students to work on improving their organizational skills. Over time and certainly over a period of two years in the Basic Sciences, medical students can gain tremendous proficiency when working with concept maps, since they tend to yield desirable outcomes, such as better retention of information and good exam results (Alias & Tukiran, 2006).

In addition, concept maps help support active learning through the many decisions that need to be made in order to be able to construct the diagram or map. This process also requires the use of multiple higher order thinking skills such as analyzing, interpreting, summarizing and evaluating (Ausubel, 2000). The practice of decision making keeps the brain actively engaged with what is being read and processed cognitively instead of just having the behavioral experience of transcribing content**.**

This way of learning includes a higher level of thinking; it is not just memorizing facts. The byproduct of this creative process can be the ability to produce a highly organized review for an exam or a highly detailed and effective outline to study. The diagrams or concept maps make the connections and relationships between concepts more visible in a concrete manner. Research suggests this method leads to better retention of material and to retaining information in a way which fosters long-term memories (Eppler, 2006). Without a doubt, long-term memory is essential in medical school.

8. Using Color

Although on the surface, doodles, drawings, arrows, notes, bubbles, circles and other geometric figures may seem simple and whimsical, the truth is that these illustrations demonstrate, in a concrete manner, the learning process as it is occurring. The use of colors can represent levels of knowledge and hierarchy of prioritization of concepts.

The process of classifying and categorizing appears to be simple; however, it is actually complex. A medical student might ask how putting in so much effort would help a medical student to actually do well in medical school given that time is the commodity in demand. Well, that is precisely the key is to using time more wisely and concept mapping is one way to do so, According to Milagros Rivera, a bilingual medical student from Puerto Rico, who is now in her second year at UMHS SK. She excitedly shares, "I started trying out this method of learning by doing handwritten diagrams. The moment I sat down and began, I found myself with the following questions: Where does this topic belong? Is this important? How could I further divide the concept? What should be grouped together?"

It may take multiple attempts at drawing in order to understand how to connect concepts. Milagros adds further, "I even found myself finding relationships that were perhaps not mentioned during class time. Creating these diagrams also helped me to prioritize between topics." The value of creating pictorial illustrations of important divisions is that although one topic may appear in multiple sections, the relationship of that topic to other topics may differ. For example, when a medical student is learning about treatment of congestive heart failure, a clear understanding of compensatory pathophysiological responses in a failing heart is very important. This idea could correlate to the clinical signs and symptoms of heart failure. Basically, having to decide on the order of what should appear earlier on in the concept map, calls for making sense of key concepts and the logic of it all. Even though the process can be harrowing, it can also be fun and appear to be whimsical even.

For an exhausted medical student, doodling can actually provide the brain with a much-needed break, aid with recalling details and with paying attention. Additionally, specifically with medical students, "a simple 30-minute doodle helps them remember information, fills in gaps in their thinking, and provides a much-needed reprieve from the loads of information they must wade through (Pillay, 2016). Using color can readily complement the use of concept maps because the use of color can help classification of topics and ideas easily.

The need to look for ways to group topics and compare them promotes the practice of analyzing more deeply in order to be able to answer a medical school question. This graphical tool also can be complemented with color coding which makes it easier to classify things. Color coding facilitates thinking when separating thoughts or big ideas. For example, the use of the color red versus the use of the color green could indicate similarities or differences between key ideas. The use of the color blue could indicate or represent a related disease which is associated with these specific topics.

The logical question after creating a diagram is to consider the most effective way to use them. How can the diagrams be used to review in order to prepare for an exam? In Microbiology, for instance, a medical student can create quite a large concept map on the topic of bacteria. Color-coding, which consists of marking things with different colors as a method of identification, helped to classify some of the following subtopics: Treatments, Clinical Manifestations, Method of Action, Complications, etc. Being able to go over whatever a student feels deserves the most attention in the moment, allows a student to reinforce those areas that a student may still not be comfortable with while at the same time not losing time reviewing topics which have already been mastered or understood. Furthermore, color coding facilitates the comparing and contrasting of high volumes of material. The use of color and the concept maps allows for the making of further connections between Microbiology and Epidemiology.

Through the use of concept mapping and color-coding, a student can decide what to focus on, without forgetting about the bigger picture. A student can effortlessly zoom in and zoom out of the network of information and concepts which have been created. One application can be used to create concept maps is *Miro*. *Miro* is an online platform that already offers different templates for to be used and to edit as the user prefers. Tables, posters,

diagrams and so much more can be created. When using *Miro* to create diagrams, the user selects the *Mind Map Template* and then names the Parent Concept which is the "trunk of the tree". From that big subject (or trunk) branches are developed by clicking the main subject and then clicking the *+ sign* that appears right after that. This process is repeated over and over again until the user is satisfied with the structure of the diagram. Finally, everything can be classified by changing the colors of the branches, highlighting and bolding.

Technology has become invaluable to the art of studying in medical school. It is an art because of the intricate detail required to draw images, create diagrams, color-code pertinent information, and other components. Technology has developed so much in recent years, that it has nearly replaced the need for paper notes and review materials. Specifically, one area of note-taking that technology supersedes paper notes is being able to convert PowerPoint lectures to pdf documents where students can insert their own hand-written notes over them. This allows students to also visualize real pathological and histological images without ever taking their focus away from the one-stop notes document. However, like anything else, there are some downfalls of solely technologically generated notes. For example, it eliminates at least one round of repeated review required to retain material. Prior to iPads and tablets, students had to copy down lecture notes by hand-writing all of the material from class or from lecture slides. This provided yet another read over the lecture material in addition to hearing it once in class. When the lecture slides are already on a student's tablet, they are no longer forced to write down the information as they are hearing it from the lecturer. Technology certainly has its place in medical learning, but the degree to which it is incorporated is likely dependent on each individual student and how they learn and retain information best.

9. Conclusion

Learning can be defined as the cognitive change that results from experience (Hay, 2007). To learn meaningfully and purposefully, students must choose to relate new concepts to concepts they already know (Merriam & Bierema, 2013). In medical education, concept mapping is worth researching and understanding how to make this useful technique work for the benefit of students as they process large quantities of information/knowledge and be able to relate the concept to the application of therapeutics with other disciplines like pathophysiology, microbiology, histopathology etc. When students join concepts they have learned in various disciplines with correct and valid cross-links, long term learning and memory is enhanced.

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