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Skeleton Maps in Anatomy and Physiology: Student Perceptions

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Skeleton Maps in Anatomy and Physiology: Student Perceptions

Abstract
Heavy content, high volume courses commonly create challenges for undergraduate students. Two such courses at our university are the introductory semesters of anatomy and physiology for first-year nursing students, taught by biology instructors. Despite the vast literature indicating the efficacy of using concept maps as a tool for learning, it is still not commonly implemented in the field. An adaptation called skeleton maps, were developed and implemented to assist student learning. This qualitative SoTL study reports on student perceptions of the learning gains of utilizing these maps, under six themes that fall into behavioural, cognitive, and opinion-based categories. The results of this study indicate a strong evidence base for using concept-map based strategies within similar courses.

Les cours à fort contenu et à volume élevé posent souvent des problèmes aux étudiants et aux étudiantes de premier cycle. Dans notre université, deux de ces cours sont les semestres d'introduction à l'anatomie et à la physiologie pour les étudiants et les étudiantes en première année de soins infirmiers, enseignés par des professeurs et des professeures de biologie. Malgré les abondantes publications indiquant l'efficacité de l'utilisation des cartes conceptuelles comme outil d'apprentissage, cette méthode n'est pas encore couramment mise en œuvre sur le terrain. Une adaptation, appelée « skeleton maps » (cartes du squelette), a été développée et mise en œuvre pour faciliter l'apprentissage des étudiants et des étudiantes. Cette étude qualitative en ACEA rend compte des perceptions des étudiants et des étudiantes sur les gains d'apprentissage liés à l'utilisation de ces cartes, sous six thèmes qui se répartissent en catégories comportementales, cognitives et basées sur l'opinion. Les résultats de cette étude indiquent une base de données solide pour l'utilisation de stratégies basées sur les cartes conceptuelles dans des cours similaires.

Keywords
concept maps, skeleton maps, SoTL, anatomy and physiology, nursing; cartes conceptuelles, cartes du squelette, ACEA, anatomie et physiologie, soins infirmiers

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Heavy content, high volume courses commonly create challenges for undergraduate students, particularly first year courses intended to provide foundational knowledge. These courses survey a large quantity of material in a relatively short period of time, often not achieving the intended outcomes for student learning due to the learning conditions created and the variable levels of prior knowledge entering the course (Dukhan, 2021, p. 57). Students attempt to memorize too much material (Carr-Lopez, 2014), often without internalizing disciplinary frameworks or schema (All et al., 2003). This challenge is exacerbated by the common pedagogical practice of high-volume lecturing in some disciplines, in this case biology, and assessment strategies which favour multiple choice testing emphasizing memorization of facts.

Two such courses at our mid-sized, western Canadian university are the introductory semesters of anatomy and physiology for first-year nursing students, taught by biology instructors. Biology is by nature content-heavy, with a need for learners to make abstractions and visualize "intangible, abstract and complex processes and structures" (Dukhan, 2021, p. 57). Historically this has been a difficult course for students to succeed in, for the reasons listed above. Prior to the study, Sarah Hewitt had been teaching the course for six years and continues to teach it regularly to the present day, and thus is heavily invested in the students' success in the course. Nursing instructors who teach in the second year of the program view the biology courses as foundational for learning pathophysiology and pharmacology. Often it became apparent that many students had not retained the knowledge from the first-year biology courses which made it more challenging for them to be successful in the second year. This phenomenon may seem familiar to instructors across disciplines—it is not restricted to our university or this particular discipline.

Sarah Hewitt decided to try a different approach, creating an adapted form of concept mapping (which she calls 'skeleton maps') for students to fill in for each body system.[1] Rather than a blank page, students are given a structured outline of a map on a large, 11x17 inch paper, guiding them as to critical knowledge, and organizing it in a way that demonstrates the connections between related concepts - a complexity that is lost in the sequential presentation of slides. These maps are sometimes referred to in the literature as 'pre-prepared' maps (Daley & Torre, 2010) or 'worked-out' maps (Hilbert & Renkl, 2008) (see the Appendix for a sample blank map that students would receive). This was a radical departure for students. Previous learning strategies for students mainly involved frantic note taking, flipping through hundreds of slides, and creating flashcards to assist memorization. These strategies foster linear learning of discrete pieces of information and students fail to see the interconnectedness of the concepts. Further exacerbating the problem is that a typical lecture for one class might contain 60-80 slides. Unsurprisingly, students were not retaining information nor were they able to apply it in a flexible manner in a clinical setting. Even successful students tended to memorize atomized pieces of knowledge without connecting them in the big picture.

There is a vast educational literature on concept maps. But despite the evidence of their value (Daley et al., 2016; Schwendimann, 2015), they are still not commonly employed. Why? As Kinchin (2001) asked twenty years ago in the title of his article on biology teaching in secondary schools, "If concept mapping is so helpful to learning biology, why aren't we all doing it?" He makes some challenging suggestions as to why they are not more fully employed. He suggests that

[1] For the purposes of this paper, we use 'concept map' to refer to the pedagogy more broadly described in the literature, while 'skeleton map' refers to the specific maps created for this course which have some organizing information filled in. When the strategy was initially introduced, Sarah Hewitt called them concept maps (changing the term later on) so the reader will see some participant quotations referring to them in this way.

the constructivist assumptions of concept maps may come into conflict with teachers' underlying philosophies of teaching, and secondly, that curricula are not designed to be hospitable to constructivist approaches (in his case, the UK National Science Curriculum). While our study took place in a different context, the challenge of a "curriculum that is *designed* to be learned by rote" (p. 1265) may inadvertently have been created in an anatomy and physiology service course designed to cover broadly foundational content for the nursing program.

There are other perspectives. The reluctance to adopt a concept mapping strategy, along with other active learning techniques, might be explained by what has been termed "signature pedagogies" (Gurung et al., 2009; Shulman, 2005) - the traditional and taken-for-granted teaching approaches in each discipline. This is the way that students have 'always' been taught, and this is what is familiar and seems correct to instructors. Another potential explanation might simply be instructor unfamiliarity with the approach - there is a need for instructors to understand constructivism as a concept, and how concept maps can represent learning and thinking (Daley, 2010). However, part of the hesitancy may also be student resistance (or concern over student resistance) to the technique (Daley & Torre, 2010; Jaafarpour et al., 2016). It is this source of reluctance that we hope to address in this paper. Understanding student feelings about the strategy can help us to better see how we might implement it, and finding widespread student support from those students who have experienced it may encourage some instructors to attempt the strategy.

The implementation of the skeleton maps in this case, was an attempt to get students to think more systematically about what they were learning. It was also an effort to require regular short study sessions, as a new map needed to be completed every week and were given a small number of marks for completion. Other elements of the course were also changed into a modified flipped classroom; however, the focus of this paper is the students' perceptions of how the skeleton maps impacted their learning. We wondered, despite the enormous literature demonstrating the effectiveness of the practice, and the instructor's observations that students seemed to be learning better, what was the student experience? Did they perceive the skeleton maps to be valuable, and why or why not?

In this paper, we will demonstrate the overall positive response from students interviewed, grouped into six themes that fall into behavioural, cognitive, and opinion-based categories. The results of this study indicate a strong evidence base for using concept-map based strategies within similar courses.

Literature Review

Research on the use of concept maps stretches back decades (Daley & Torre, 2010), in a variety of disciplines and at every level from kindergarten through to graduate studies (Schwendimann, 2015). Particular interest has arisen on the efficacy of concept maps for student learning (Daley et al., 2016). Here, we will give a high-level summary of the literature on the effectiveness of concept maps although it would be impossible in the scope of this article to represent the full landscape of concept mapping literature. As well, we give a sense of the much smaller previous literature on student perceptions of this pedagogical tool.

The history of concept maps as they are currently understood, is usually traced to the work of Novak and Gowin (1984) (Daley et al., 2016). While other forms existed before this, Novak and Gowin's theorization brought concept mapping into education in a meaningful way (Schwendimann, 2015, p. 77). They based the pedagogical technique on Ausubel's significant learning theory (Aliyari et al., 2019). For the past 35 years, this work has been applied across

education, in K-12 and post-secondary settings (Schwendimann, 2015). It has gained traction in professional education, the medical field in general and particularly in nursing (Daley & Torre, 2010; Daley et al., 2016). The idea behind concept mapping is closely aligned with a constructivist framework for learning, where students add new knowledge onto their existing schema, as described by Ausubel et. al (1986) (Daley et al., 1999). Llinás et al. in 2018 argued that:

> [T]here is today almost unanimous agreement that students need to build their own knowledge structure on the basis of the effort that they themselves make. It is less well understood, however, that the structure of knowledge is built primarily through meaningful learning, and that rote learning does little to advance this process (Novak and Cañas 2004). (p. 1790-1)

Concept maps, in contrast, takes advantage of constructivist processes, "providing a visual representation of the hierarchy of the concepts that the individual possesses and the relationships between them" (Llinás et al., 2018, p. 1791). They have consistently been found to be an effective tool in "facilitating the process of knowledge creation in any discipline" (p. 1791). A number of meta-studies have demonstrated their effectiveness (see for example Daley & Torre, 2010; Nesbit & Adescope, 2006; Schwendimann, 2015).

Across a broad variety of studies (both empirical research and meta-analyses), concept maps have been shown to support the following learning goals and how we define them. We additionally provide a short list of sample studies addressing these goals in relation to concept maps. (we provide a short list of sample studies here):

1. **Metacognition:** Students' ability to think about their own thinking, demonstrating awareness of their thinking and learning processes (August-Brady, 2005; Chiou, 2008; Daley et al., 1999; Kinchin, 2005; Schwendimann, 2015).
2. **Accessing deeper learning processes:** Moving past surface memorization to processes such as pattern recognition, abstraction, and inter-connections (August-Brady, 2005; Daley & Torre, 2010; Dhindsa et al., 2011; Jaarfarpour, 2016; Lee et al., 2013; Mammen, 2016; Nicoara et al., 2020; Schwendimann, 2015)
3. **Approaching material conceptually:** big picture thinking and being able to distinguish between critical items and smaller details; creating mental schema for information (Daley & Torre, 2010; Gul & Boman, 2006; Llinás et al., 2018; Schwendimann, 2015).
4. **Developing critical thinking:** thinking for oneself, evaluating information critically, considering how information might be applied in novel situations (Chen et al., 2011; Daly, 2001; Daley et al., 1999; Garwood et al., 2018; Kaddoura et al., 2016; Lee et al., 2013; Taylor & Littleton-Kierney, 2011; Vacek, 2009; Wheeler & Collins, 2003).
5. **Assisting with problem solving:** utilizing what has been learned to solve complex questions (González et al., 2008).
6. **Assisting with long term recall:** establishing stable memory of the material learned rather than short-term memory that is quickly forgotten after the course is over (Farrand et al., 2002; Lee et al., 2013; Nicoara et al., 2020; Schwendimann, 2015).
7. **Assisting with application outside of the classroom:** in this case, application within a clinical environment (Aliyari et al., 2019; Daley, 2004; Harrison & Gibbons, 2013; Daley et al., 1999; Noon, 2013; Kaddoura et al., 2016).

A much smaller number of studies have looked at student perceptions of the approach. Carr-Lopez et al. (2014) conducted a study on the utility of the maps to facilitate higher-level learning and found that students perceived the value of the maps and used them later; they reported having better recall of the material over time and were better able to apply the concepts in practice settings. This was similar to the findings of Chiou (2008). However, students also reported not initially liking the maps, finding them time consuming, and didn't like the peer assessment component introduced in this study. Suggestions in the literature include that students should be introduced to concept mapping early in their program, and that explicit training is important as well (see Chiou, 2008; Daley et al.,1999).

Several studies demonstrate a neutral effect on student grades on traditional multiple-choice exams when compared to lecture-based instruction (Aliyari et al., 2019; Carr-Lopez et al., 2014). A possible explanation offered is that as concept mapping should work at a higher order level of thinking, the assessments should be similarly adjusted—if not, the true benefit may not be visible. Concept maps are also utilized for assessment purposes, and Schwendimann (2015) points out that one of the benefits of this is that students can demonstrate partial understanding. Instructors can then utilize this information to feed back into their teaching.

We turn now to our own study where we asked students about their perceptions of using the skeleton maps, and their value to learning.

Methodology

This is a basic qualitative study, as defined by Merriam and Tisdell (2016). We employ a constructivist theoretical framework, both in the pedagogy of the skeleton maps themselves (D'Antoni et al., 2010) and in terms of our interpretation of the data, where we take at face-value the statements of the participants. Qualitative research assumes that "individuals construct reality in interaction with their social worlds" and researchers tend to be interested in how participants "make sense of their lives and their experiences" (Merriam & Tisdell, 2016, p. 24). They suggest that "all qualitative research is interested in how meaning is constructed... The *primary* goal of a basic qualitative study is to uncover and interpret these meanings" (p. 25). In this study, we are interested in how students perceive and make sense of the concept maps as a learning tool.

We recruited participants from three consecutive academic years of the two first-year anatomy and physiology courses, and additionally invited participants to be interviewed again in the second and third years, with a high level of expected attrition. In all, we conducted 38 interviews of 26 unique participants. Twelve of these represent interviews of students we followed for 2-3 years. To add some perspective, the total possible pool of students that were taught using the skeleton map method during this time was approximately 300. In our experience, a participation rate of 5-10% for interviews is typical - in this case we achieved about 8.6%. A "representative" sample is not claimed nor expected in a basic qualitative research conducted in a constructivist paradigm, however, we did reach saturation in the data set where no new themes emerged in later interviews, therefore, after four recruitment years we determined we had sufficient data. The study had REB clearance at our institution's ethics board – for the interview protocol and to collect, analyze, and share de-identified copies of their skeleton maps, which participants provided at the time of their interviews.

This paper focuses on the results of the interviews, while analysis of the concept maps will form a future publication. These were semi-structured interviews conducted by Michelle Yeo and sometimes Sarah Hewitt, in some cases supported by the research assistant, Sarah Lang. The

interviews were approximately 25-30 minutes in length, and participants were asked about their experience learning in the course, their experience with the skeleton maps, and their thoughts and recommendations about their use. The interviewer and participant looked at the participants' maps together, and the participant described their process in filling them out and using them as study tools.

The interviews were transcribed by a professional transcriber and initially read by the PI and analyzed more deeply with assistance from the RA, with corroboration from other team members. The process followed was the PI and RA independently coded the first three interviews, and then met to discuss their evolving coding schemes. Agreement was reached on the terms that would be used for individual codes. Two more interviews were coded by the PI and RA independently; at this stage a high level of agreement was reached on the coding structure and what constituted each code. The remaining interviews were coded in NVivo by the student RA with the coding scheme agreed upon and checked back with the rest of the research team for trustworthiness. As a team, we then categorized the codes into larger thematic units - all of the codes fell into categories identified below, which were about changes to their behaviour, cognitive aspects, and expressions of their opinions regarding the maps. The broad category of "cognitive aspects" were further refined into three discrete themes as described below, giving a total of five themes. We extracted comments students made about the skeleton maps specifically in the interviews, which is the data this paper focuses on, to answer the question, What are the student perceptions of using the skeleton maps? Other interview data, such as the student response to the modified flipped classroom, are presented elsewhere. These comments are presented below within each theme, with findings and discussion combined.

Theme One: Learning Throughout the Term (Behavioural Changes)

One of the biggest challenges in these courses is to motivate students to study consistently throughout the term. For years instructors told students to spend eight hours a week studying this course material alone. Unsurprisingly, most students reported they didn’t. While instructors became frustrated at the students’ apparent lack of commitment to putting in the requisite time given the high failure rate in the course, there are many potential explanations for the students’ behaviour. Relevant to this study, the researchers suspected that students didn't study in part because of the lack of a concrete task with a deadline, and second, when they did study, they didn’t know how to focus their attention. We knew that they tended to 'cram' intensively prior to each midterm and final, which decades of research demonstrates doesn't work for long term learning (Brown et al., 2014, p. 3). The intention of the skeleton maps was to focus and capture more consistent study time each week, which according to both learning theory (Brown, p. 49) and research on concept maps (e.g. Nicoara et al., 2020) is much more effective in helping learners transfer learning from short term (activated with cramming behaviour) into long term memory (activated by repeated, short study sessions). We address the students’ perceptions of this difference in Theme 4, however, to achieve this benefit, first the repeated study time must be captured.

While the assigned grade value of the maps was just 5% of their total grade, and the instructor mainly checked for completion rather than correctness, this was enough to motivate virtually all students, and the maps became a routine task each week. A full map took hours to complete, capturing critical study time for the material. Part of what the task did was support students in consistent studying:

> ...the time it takes to do them is just dedicated study time. I am not that type of person, so I definitely put things off. The way it required me to stay more on top of things, I think was just better- it required me to budget my time better than I would have, otherwise.

Students expressed something similar to the following quote over and over, and additionally we see the idea of time management appear again: “Bio needs something to keep us motivated or we will leave three thousand pages worth of reading until one week before the final.” And again:

> The concept maps were a lot of work and they were really time consuming but I found I got that time back on the other side when I was studying for exams. I didn’t have to spend nearly as much time going back over things because everything was so condensed and already kind of laid out for me to review. So it helped me budget my time better because I don’t budget time, I am totally a person who crams so it totally forced me to review throughout the semester, but it definitely worked for me.

Within this theme appears a notion that students recognize the difference between review (which is what we think they should be doing) vs. learning material for the first time prior to an exam (which is what they were actually doing under the previous pedagogy). A student remarked:

> [W]hen it comes to studying I am not trying to learn material, I am just trying to refresh material, and I am not having to go through lecture slides – maybe if there is something I don’t understand – but I am usually just reviewing [skeleton] maps and it does not take me very long to study for an exam for this class now.

Another student, who had failed the course previously in the traditional format, remarks on how working to complete the skeleton maps is quite different than their past strategy of re-reading notes taken in class:

> It is easy to say that you put two hours into homework, like taking Bio home and studying at home, but if you are just re-reading the notes then it is not really making a difference, whereas with the [skeleton] maps I am actually required to put in work. At a certain point I remember ... the first time I took [the course], at a certain point my grade was so low that I wasn’t going home and doing any studying, whereas even if I was doing well in this class I still had to go home and I still had to do the [skeleton] map and it still mattered.

This comment also points to an important aspect of student success and failure. Failing students can start to spiral and further lose the motivation to study. Conversely, a student that was doing well might feel less urgency around studying and might allocate that time to other courses instead. Completing the skeleton map always gave the students a concrete task to work on. The consistency of study becomes key for success.

Theme Two: Making Connections (Cognitive Element)

One of the most prevalent themes in the literature is the benefit of concept mapping in helping learners make connections between concepts, to create hierarchies and structures, and to recognize patterns (e.g. Chiou, 2008; Kinchin, 2005). This claim was confirmed throughout the interviews:

> Most of the chapters that we did in the beginning, some of the concepts were the same as to what we did in the last chapters, but I could, like, see the connections between them so I could remember them.

This was something missing in the way students were learning in the past - by atomizing the information, they were missing the patterns in the body systems that are apparent to physiologists. A student commented about the skeleton maps, "I think it definitely influenced the way that I link ideas together," and another expressed, "So by being made to actually write things out in that kind of concept by grouping it all together and being able to link it, was the biggest learning curve for me." Another student described how she used colour coding on the skeleton maps to indicate relationships: "I would star or highlight different colours indicating that this is all one system kind of thing, or these are all connected." These kinds of metacognitive strategies have been shown to enhance memory and support learning (D'Antoni et al., 2010). As Dhindsa et al. (2011) assert, "The organisation of knowledge in memory, as opposed to an emphasis on only the amount, is an important factor associated with increased reasoning ability, understanding of concepts and academic achievement. The composition and organisation of prior knowledge are critically important for effective learning" (p. 186).

One student at the end of her program reported how she carried the practice forward of mapping into other courses, and even to study for her national nursing exam, to help her see the relationships between concepts:

> Like always before studying for tests I buy big sheets, like poster board basically and do the exact same thing, like I write down heart failure and then I would write down the connecting links to all of it and how heart failure related to something else. So although I didn't do that exact same thing, I still made my own kind of concept map, just in a simpler form.

The recognition of the value in understanding relationships between concepts, rather than simply remembering the information as discrete bits, was a breakthrough seen in many students' comments. We suggest that it's not only the pedagogy encouraging them to make the links, but that the practice also helps to highlight for students the importance of connections and linking. The strategy taught in this course of the skeleton maps became an adopted strategy for many students in future learning - more on that in Theme 4.

Finally, many students expressed the benefit of having the critical learning for each system on one skeleton map, rather than in dozens or even hundreds of pages of notes and slides:

> I really loved the concept map whole idea, so it completely changed how I studied because I love having everything on a single page. Before I would take pages and pages of notes and I did not like going back and having to find something, like the one little thing you are

> looking for afterwards. That is what I really liked about the concept maps, like it was right there and I didn't really feel like I needed to look anywhere else. I am a very visual person so when I have a concept map I can kind of remember where things are on like, the page, versus pages and pages of notes.

Theme Three: Knowing vs Memorizing (Cognitive Element)

Many students, in the interviews, expressed the shift in their mental access to learned material. For example, one student, who had failed the course previously, shared her excitement by interrupting the interviewer. (In this and following excerpts, 'I' is the interviewer, and 'P' designates the participant).

> **I:** So how long do you think it took you before you were…
> **P:** The first one, honestly because as soon as I finished the map, the next class I went to she would ask us questions and stuff and it was like, 'I know that! Awesome! I learned something!' So it was exciting… especially in comparison to last term when I would go to class and still be confused about what I learned, it was like, 'Oh my gosh! I know the answers!' It was exciting.

According to the literature, more effective learning is done when students make meaning of what they are learning (D'Antoni et al., 2010; Daley & Torre, 2010). This is obviously desirable in professional education, where the purpose of the learning is practice. Other students made this similar distinction between memorizing vs. knowing and understanding:

> **I:** Did you rewrite your concept maps when you were in 1221?
> **P:** No, I would just look at it. I would just look at it. I just felt that I didn't have to study too much for the Bio 1221 test, just because as I was doing the concept maps I actually learned the information and it wasn't just memorizing, like I actually understood it, so I felt it was very effective.

And this student, who commented on understanding the 'why' underneath what was being learned:

> When I was going into university, thinking that I just needed cue cards, like I can memorize values, no problem. But trying to remember why the values are that way made the difference, which is why concept maps are helpful because it wasn't about memorizing, it was about actually knowing. You had to put things down that you knew, so I think that in all, it probably kept me in nursing school.

This student, in particular, was a success story in the sense that she was at serious risk prior to this course of failing out of the program.

In this first-year course, it is easy for students to lose sight of the underlying purpose of what they are learning—to be able to access understanding of the human body in their day-to-day practice. In many of the interviews, students expressed a kind of astonishment that in learning in this novel way, they suddenly realized a new ability to carry their learning into practical situations:

> With the clinic we have to make care plans, and [for example] with care plans it talks about hypertension or things that apply with that, and then I can further go into it and be like, 'This is why hypertension happens,' and yeah, just like understanding the concepts better, I think… If I am talking with my clinic instructor and … she will ask in-depth questions like we would have learned in Bio, and being able to answer them is a confidence booster because it means I actually know what is going on.

This came up a number of times: students surprised themselves with a their ability to respond to clinical instructors based on material learned in the Anatomy and Physiology course. This agrees with previous findings (e.g. Taylor & Littleton-Kearney, 2011) on the utility of concept mapping for the complex thinking required in clinical situations.

Theme Four: Long Term Retention (Cognitive Element)

One of the most important benefits of the skeleton maps approach in this context is the students' reporting of the impact on their long-term retention of the material. Because the maps engage students in short, regular study sessions, and additionally because it activates metacognition and conceptual understanding of the material, students repeatedly commented on their surprise that they retained the knowledge beyond the exam window.

> **I:** Do you feel like your retention of this material is any different?
> **P:** Oh absolutely, yeah. I feel like I wasn't just cramming it in to remember it. Which is weird because the test was last Thursday. I could talk about it now, I think, and I could do the test again.

This student seemed surprised that a week later, they still felt they could re-write the exam. This is a remarkable comment in the sense that, as instructors, we are counting on students to be able to retain and apply this knowledge in future courses and practical contexts for years to come. Yet, the student experience is often one that once the exam is over, the knowledge slips out of reach. Research would tell us that cramming behaviour leads to short term memory, and that repeated sessions over time is required for long term memory, or what Brown et al. (2014) calls 'durable learning' through a process of consolidation: "the increased effort required to retrieve the learning after a little forgetting has the effect of retriggering consolidation, further strengthening memory" (p. 49).

Because we were able to interview some participants during their second year of the program, we were able to see the effect Brown describes and the long-term impact of using skeleton maps beyond the course itself: "Once I would read them (the maps), it's like everything snapped back. I mean, it really shows that I did truly understand it."

Students described keeping their maps from the first-year course folded at the front of their binders for pathophysiology, a course they take in their second year: "Because I still remembered stuff from Bio it made Patho much easier by a large margin. [My instructor] would mention something and I would be like, 'Oh yeah, I remember that system! I see how this works now!'"

Several students described having a visual memory of the maps that persisted into the second year of their program. They described closing their eyes and being able to 'see' their map as they had drawn it the previous year:

> Because I had such a hard time learning that material, I remember drawing it out on the map, and I remembered the process!

This brings up another important element of the skeleton maps as they are currently designed, which is to be filled in by hand. There is literature in the field of psychology demonstrating that handwriting notes, particularly incorporating drawing, is associated with better learning (Fernandes et al., 2018; Smoker et al., 2009). Some students expressed noticing this as well, with quotes such as "writing helps me learn" and:

> I know there are a lot of diagrams, like, 'Draw this,' and, 'draw that,' and that helps put the information into perspective as well because we are now able to think, 'Okay, now I know A, B and C and now I can relate it to, the diagram,' which helps a lot.

The connections made between various sections of the map, through diagrams, arrows, and an interesting phenomenon we observed where students would add layers of sticky notes onto the maps would theoretically further support the learning.

Theme Five: Students Recommending Map Use to Other Students (Student Opinion)

Most students recommended that skeleton maps be introduced as early as possible, and that all students should be given the opportunity to learn to use concept maps. In a survey (N=63), students were asked whether they would recommend the use of concept maps in the future. Out of the 46 students who had already been introduced to the maps, 74% of students recommended their use. Interestingly, of the 17 survey participants who had not used concept maps in their courses, 65% still recommended their use, pointing to a student need for more guidance in studying.

One student, who had failed the class the first time through, commented:

> In the first year, I had no idea what I was doing when I was studying and I think that's the case for a lot of students ...I mean, if it's possible, I would definitely implement them starting first year. Like I said, having the skeletons given to you would have been super helpful because I struggled with that starting point.

Another student expressed how she wished she had been introduced to them earlier:

> **P**: If I would have known about it in first year, then who knows how far I could have gone with them.
> **I**: What would you say to a first-year student about it, when they say "oh, I don't do concept maps"?
> **P**: I honestly would tell them to just give it a try. You're putting in all the work anyways, the fact that you get to use it later is really helpful. I know when I was in my [placement], we had second year students and they were so overwhelmed that they just didn't even know what to do with themselves. You know, if you're overwhelmed, just give it a try.

An interesting phenomenon occurred in our second year of interviews, where students we were re-interviewing reported that in their second-year classes, other students were picking up the practice on their own and making maps in pathophysiology. Students were purchasing large blank

sketchbooks and creating their own concept maps - both students who had been taught using the maps in first year, and other students who had not had a formal introduction picked up the strategy on their own, because they had been introduced to them by classmates who had been in Sarah Hewitt's section.

Theme Six: Students Who Did Not Find the Strategy Effective (Student Opinion)

While the response to the skeleton maps were overwhelmingly positive, there were students who did not have a positive view of the strategy. These students expressed that the maps did not fit with their learning preferences, or that they already had strategies that worked for them, and didn't need the maps.

For example, one student described how the skeleton map was laid out in a way that was not intuitive for her, and she preferred the more freeform maps introduced by Joanne Bouma in the second year:

> Some people love them for bio, but I didn't love them for bio, and I don't know why. I think it was just because it wasn't how I would have done it... Maybe if they had just one class -or even half a class- just focussed on "Here's how concept maps work" because that was so helpful for Joanne to bring out that concept map and for me to work with it and create it on my own time. So, maybe, if at the beginning, she was like "This is how I do my concept map, but you can do it however- pictures or diagrams or words, but know that the essay questions are words, so you have to be able to explain it in English." So, maybe something like that. Some people like flowcharts and things like that and I know on my patho pharm ones, I have- It's like a middle and it's like a web of all the things but I try to specific things in specific colours. So, it's like, signs and symptoms are always one colour, so it's kind of a trigger in my mind, because when I'm recalling it, I picture, like, my paper. That's how I picture it. So, it works for me with diagrams, but not when you have to describe it with words.

Another student, who was a mature student with several years of work experience, described her own note taking process which she found more effective than using the maps:

> **P:** The way I study for everything is I will make my own questions, and so on the one page is like, the questions and then on another page will be the answers, and so I find that really forces me to learn it… I would say, "Define homeostasis," and then on the next page I would have the answer for it. So for me, that is how I have always studied and I found that quite effective for me. Having the concept map was just kind of like an extra piece of work that I didn't actually use. That being said, it also is helpful to write things down as many times as you can, so perhaps it did help in the long run?

The students who reported not finding the concept maps effective were students who were highly successful in the course, reporting previously developed effective study methods. There were sometimes contradicting statements like in the quote above, where participants would sometimes backtrack and allow that it's possible the skeleton maps were beneficial, at the same time attributing their success to their own personal methods. This was not universal to the already-successful students, with others embracing the skeleton maps. One mature student, with a previous

undergraduate degree in biology described them as “the most powerful tool I have been given in school.”

Regardless, throughout the study there is no evidence that the skeleton maps hindered learning. Some students persisted in preferring their own study methods and strategies. For them, the strategy had at worst a neutral effect, some simply reverting to their own methods, while others reporting using the maps and doing as well or better than prior attempts. However, many students without a previously defined approach to studying complex, high volume material recognized the benefit of using this strategy and experienced success as we’ve demonstrated. For some, it was a pivotal point in their nursing education given that they were at risk of failing out of the program, and the strategy assisted them in progressing and ultimately graduating.

Conclusions and Implications

Overall, this study agrees with the literature in demonstrating, from a student perspective, that concept maps are an effective learning strategy, particularly for this type of material (high volume courses that students have difficulty making sense of and tend to approach in an atomized fashion). As demonstrated in our data, students confirm that the weekly use of the skeleton maps caused them to work continuously on learning the material, avoiding the ‘cram-dump’ cycle so detrimental to learning. They found it helped with their time management throughout the term. They employed more metacognitive strategies, creating connections and building schema. Students made the distinction between 'memorizing' and 'really knowing' the material - understanding rather than simply remembering. They reported long term retention of the learning, as well as an increased ability to apply their learning in practical situations, agreeing with González et al.’s findings (2008). Most students recommended this approach for other students, and suggested it be introduced as early as possible. Many students carried the strategy forward to subsequent courses on their own, similar to Daley’s (2004) finding that 65% of adult learners in their study continued to use the strategy once introduced to it. Indeed, in our study some students who had not been formally introduced to the skeleton maps learned from other students and adopted the strategy on their own in later courses. Those students who did not have a positive perception of the skeleton maps reported previously developed effective study strategies—they are students for whom the skeleton maps are perhaps unnecessary, however, we saw no evidence of a detrimental effect.

The results of this study add to the already comprehensive literature on the effectiveness of concept mapping in anatomy and physiology courses. We urge instructors to consider adapting and adopting a similar approach to support student learning where suitable. Based on the data collected in this study, it appears that the intermediate step of 'skeleton' maps, where the structure is laid out for the students to work from, is an important pedagogical scaffold in the first year of undergraduate studies, before they are ready to work from a blank page.

There are many disciplines in which the traditional approaches of lecture and exam are difficult to shift, despite decades of teaching and learning research suggesting that 'telling' is not 'teaching.' This pedagogy is a demonstrated effective alternative in supporting student learning in high volume courses, where later access to the learning is critical for student success, both in future courses and in practical applications. The results of our study demonstrate that students, despite some initial trepidation, can quickly see the benefit of such a strategy to encourage regular study, and overall are positive about the approach. Future studies should look deeply at the learning

demonstrated on the skeleton maps themselves, develop rubrics for assessment, and do parallel work on perceptions of instructors of concept mapping approaches.

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Appendix
Blank Skeleton Map