ABSTRACT  Medical school education has traditionally been driven by single discipline teaching and assessment. Newer medical school curricula often implement an organ-based approach that fosters integration of basic science and clinical disciplines. Concept maps are widely used in education. Through diagrammatic depiction of a variety of concepts and their specific connections with other ideas, concept maps provide a unique perspective into learning and performance that can complement other assessment methods commonly used in medical schools. In this innovation, we describe using concept maps as a vehicle for a modified classic Team-Based Learning (TBL) exercise. Modifications to traditional TBL in our innovation included replacing an individual assessment using multiple-choice questions with concept maps as well as combining the group assessment and application exercise whereby teams created concept maps. These modifications were made to further assess understanding of content across the Fundamentals module (the introductory module of the preclerkship curriculum). While preliminary, student performance and feedback from faculty and students support the use of concept maps in TBL. Our findings suggest concept maps can provide a unique means of determining assessment of learning and generating feedback to students. Concept maps can also demonstrate knowledge acquisition, organization of prior and new knowledge, and synthesis of that knowledge across disciplines in a unique way providing an additional means of assessment in addition to traditional multiple-choice questions.

INTRODUCTION
For many decades, medical school education has centered around single discipline teaching and assessment. Many leaders in medical education are now calling for more thorough integration of basic science and clinical aspects of medical school education. Although many medical schools have recently moved to a more integrated curriculum, such as organ-based in which multiple disciplines coordinate instruction around an organ system, assessment often remains a collection of questions from these separate disciplines gathered into one examination rather than evaluating the synthesis of a group of related ideas across disciplines. Concept maps can be used to stimulate group discussion as well as potentially facilitate the integration of basic science and clinical education. Concept maps also provide a potential means to assess how students synthesize information across disciplines and professions.

Team-based learning (TBL) exercises are widely used in education. They were introduced by Michaelsen et al and also described by Millis and Cottell, where they described structured learning teams that are developed in the classroom and sequenced assignments that allow students to apply or internalize the material being taught. In TBL exercises, a primary objective is “to go beyond simply covering content and focus on ensuring that students have the opportunity to practice using course concepts and to solve problems.” TBL is based upon a number of key ideas. First, group work is central for the students to understand and apply course content. Second, the majority of exercise time should be spent on group activities, where students are given examples to work through and apply what they have learned, and lastly group activities allow students to improve learning and develop self-managed learning teams over time such that the small group learns the strengths of each team member. Thus, the TBL format is easily applied for problem-based learning type of instruction. Next, we describe concept maps and TBL in more detail.

Concept Maps
According to Novak and Gowin’s original work, “a concept map is a schematic device for representing a set of concept meanings in a framework of propositions.” Concept maps are graphic representations to depict understanding of the meaning of a set of ideas and how the ideas are linked together (the latter through the use of specific linking words as shown in a concept map example in Fig. 1). In other words, concept maps are a potential tool for illustrating both depth (number of related ideas) as well as organization (how the ideas are interconnected) of knowledge. The latter is particularly difficult to assess with multiple-choice questions (MCQs) and a learner can summarize and analyze their ideas as well as visualize their thinking. Concept maps have been used as an assessment tool of learning in many educational areas, and have potential for increased use in medical education. A concept map published by Novak and Cañas with explanation can be viewed at http://cmap.ihmc.us.

The concept map can be used for individual study and formative assessment as summarized by Daley and Torre. Using the concept map could help faculty to evaluate student ideas and connections (breadth and organization of
knowledge) in a detailed manner, providing a visual display of a student’s conceptualization for assessment.

Concept maps are based on established learning theory and have been found to be effective in multiple disciplines outside of medicine. Concept maps can also be used to foster interdisciplinary understanding of scientific concepts, link understanding of science and clinical concepts, and inter-professional understanding of teams and their relational functions for clinical care. Without a visual tool and curriculum that supports the synthesis of ideas and relationships that the tool requires, students may not otherwise make such needed interdisciplinary connections.

Concept maps require the learner to graphically represent not only the level of detail that he/she understands about specific topics, but also how each specific topic is important and linked to and through multiple disciplines such as biochemistry, pathology, microbiology, and physical examination findings. With MCQs, students may recognize an answer or be able to reason through the question and eliminate choices. With a concept map, students can demonstrate both understanding and breadth of knowledge as well as how ideas interconnect (knowledge organization). Furthermore, this can be demonstrated between subject matter and disciplines. An example of using linking words is shown in Figure 2.

**Team-Based Learning**

In the classic TBL exercise, students are given preparation material to study ahead of the session. At the start of the TBL session, students are given an individual readiness assessment test (iRAT) to evaluate their own preparation for the exercise. This is followed by a group readiness assessment test (gRAT) where the group needs to agree on the correct answer of the same quiz that was just given. Here, the content for the gRAT and exercise is discussed in greater detail in the groups. As students discuss their interpretation of the material and come to a group agreement of what the correct response to the group quiz questions are, they deepen their learning and understanding of the material. Feedback is given by group members in the discussion of the material during the quiz or by the instructor as they move between the groups during the application exercise.

In terms of assessment, individual scores are generated for the iRAT. All the group members receive the same score for the gRAT. Typically, the iRAT and gRAT assessments are MCQs. The students then work through an exercise (application) where they typically apply the principles learned in the preparation material to examples or problems to further their understanding of the material.

In this innovation, we replaced MCQs with concept mapping; students construct concept maps as the iRAT (individual maps) and gRAT (group maps), and the gRAT and application are combined in one exercise. In this article, we describe how we designed this modified TBL exercise around the use of concept maps and present preliminary results and next steps.

**METHODS**

This innovation occurred during their first module at our medical school, the Fundamentals module (http://www.usuhs.mil-curriculum-pdf/CRNewClassof2018.pdf). In this
module, 14 individual courses are represented and present the foundations of their courses in this integrated module. The material presented has a specific science theme for each of the 7 weeks of instruction. Students were asked to review module material for their upcoming module final examination as their preparation for this modified TBL exercise, as we wanted to use this exercise as a review session, or “putting it all together” for the Fundamentals module, thus the preparation was to “study for the final examination” of the Fundamentals module.

The Modified TBL Session

The students were seated in small groups of 5 to 6 students per group, typical of a classic TBL session. A student was designated as the team leader for each group and he/she was responsible for ensuring the quizzes and group exercises were appropriately carried out and they distribute the iRAT and gRAT directions from the material in a folder on each table. The iRAT was given first to the students.

The iRAT instructions were to create an individual concept map using the topic of “inflammation.” Students were instructed to include anything they had learned in the module to the concept of “Inflammation.” Students were given approximately 20 minutes to complete the iRAT (individual concept map). The team leader collected the iRAT papers into the folder.

Following the iRAT students proceeded to the gRAT. Team leaders were instructed to distribute the combined gRAT and application activity sheets. These two items (gRAT and application activity) were the same in our exercise; however, they are separate parts of a typical TBL. In this exercise, students were instructed to create a group concept map in which they needed to use 30 concepts pulled from topics instructed in the Fundamentals module and show how they relate to one another. They could use any of the 30 topics as their starting topic for the concept map, such as inflammation, which they were just given for their individual concept map. They were given a large piece of paper, such as from a flip chart, and were told they could add more sheets of paper if needed. Students were also told they could add any additional topics from the module, but at a minimum they needed to use the 30 concepts from the Fundamentals module given to them. Students were given approximately 75 minutes to work.

Students were given feedback during this application portion of the exercise by faculty who rotated around the tables as soon as the group exercise began. Faculty specifically encouraged students to include linking words and cross-links.\textsuperscript{13} The linking words tell the reader how the student links two concepts together. For example, the concept inflammation can be divided into acute and chronic inflammation. The linking word between inflammation and acute could be “can be,” so the reader would follow that inflammation “can be” acute, and so forth. Cross-links are links that span between concepts of one arm or branch of the concept map to another arm or branch. This shows a higher level of learning from the student when they realize that concepts link across broader areas. A modified example of an individual concept map produced during this exercise using inflammation as the starting concept is given in Figure 3.

Student Grading

Grading of iRAT or individual concept map was performed by two graders independently as there is subjectivity to grading. Elements taken into account for grading included the amount of content and accuracy of content included in the concept map, whether students used linking words and cross-links. In our exercise, we wanted the students to get beyond acute and chronic inflammation and include the predominant cell types in each of these types of inflammation, and how inflammation is related to immunity, mediators of inflammation, and so forth to receive full credit for content for this individual quiz.

Grading of the group maps was done by a primary reviewer, with a second reviewer reviewing all the concept maps and providing a second opinion for the maps that were between two grades. The two reviewers then jointly discussed any concept maps where the opinion differed in grading, and came to a consensus grade. Group maps were set up a little differently than the individual concept maps as the students had the list of the 30 topics that needed to be included in the group concept map. The list was provided to provide an anchor for student discussion, structure to this new group

\textbf{FIGURE 3.} Sample Individual Concept Map. Typical concept map from a student working individually given the topic of inflammation and asked to include concepts from all disciplines studied in the Fundamentals module. Concept maps vary greatly between students as they show how each student individually links the concepts together.

\textbf{FIGURE 3.} Sample Individual Concept Map. Example of an individual concept map produced during this exercise using inflammation as the starting concept is given in Figure 3.
exercise, and to facilitate evaluation. Thus, to receive full credit for content, all of these 30 items needed to be included in the concept map. Students were encouraged to add additional concepts beyond these 30 that were given to them, and the majority of the groups did this as well. Grading of the individual and group concept maps was done on a 2-point scale (pass or fail). This description of an educational innovation does not include actual data from research participants nor does it involve patient or other sensitive data.

PRELIMINARY RESULTS
We collected preliminary data on our modified TBL activity. We will begin with discussing grading and then will present our feedback findings.

Grading
Individual and group concept maps were evaluated as above for content (knowledge of concepts), use of linking words, and the use of cross-links (knowledge organization and inter-relationships of concepts) in the assessment of the concept maps both in the iRAT and gRAT exercises. Quality of both the individual and group maps varied.

The group concept maps or gRATS were generally of high quality as students received feedback during the session from faculty as described above and were encouraged to include linking words, cross-links and additional topics if they had not already done so. Additionally, group maps involved student discussion, students had more time to complete the exercise, and for the group activity, they were given a list of 30 concepts to include in their maps.

Individual concept maps demonstrated less detail and organization than the group maps, meaning these individual concept maps included less information and did not have as many linking concepts from multiple disciplines that were taught in the Fundamentals module. For example, individual concept maps were often divided into acute and chronic inflammation, and included the basic cell types seen in acute and chronic inflammation, but did not include many other topics from the Fundamentals module. On the other hand, the group concept maps were much more complex concept maps that included more detail and organization compared to the individual concept maps as these maps needed to include the 30 concepts given in the group exercise. To link these 30 concepts, the students had to work together and think broadly about all material presented in the Fundamentals module. The 30 concepts given to the students to be used to construct the group maps were pulled from topics presented by the 11 different courses that were taught in the Fundamentals module. These courses included basic sciences (Biochemistry, Histology, Embryology, Microbiology, Pharmacology, Immunology, and Pathology) as well as the clinical sciences (Patient Interviewing, Physical Examination, Patient Safety, and Psychology). The group maps, in addition to having more concepts, were of higher quality as they all included linking words and many groups had created cross-links that spanned among the different concepts and across traditional disciplines furthering their understanding of the integration of the individual courses and the basic and clinical sciences. A modified example of a typical group concept map from this exercise is shown in Figure 4.

Faculty and Student Feedback
Faculty observed that students were very involved in the group concept map exercise and that it was hard to stop the group discussions at the end of the session. Students used the entire time, which was 75 minutes, to work on the group concept maps. Faculty commented that students were actively engaged in discussing the concepts assigned, and discussing how the various concepts best are linked together. At times, they were able to link the concepts directly, other times, they linked the concepts by adding additional concepts from the Fundamentals module that were not on the list given to them in the instructions. Faculty members who had taught in the Fundamentals module had opportunities to review some or all the student group concept maps. Faculty were surprised to see the variety of topics chosen by the students as the starting point for their group concept maps, and how the students integrated their specific course with other material in the Fundamentals module, both in the basic and clinical sciences. Faculty who taught in the Fundamentals module who reviewed these group concept maps had a unique glimpse into how the students organized the material presented to them in a unique way and provided an opportunity for these faculty members to self-reflect on how they presented their material in the context of other material in the module.

Student feedback has been largely positive. Several students provided positive feedback regarding the value of this exercise, and started to use concept maps regularly as part of their individual learning and study habits. In a few instances, students have commented that using the concept maps has refined their understanding of topics and has significantly helped them achieve higher scores on traditional MCQ examinations. Students felt that there was sufficient time in the exercise to complete the individual and group concept maps. The next steps for the faculty are to improve the precision of grading, as there is individual variation in how the knowledge is organized and the amount of detail provided in some of the topics in the concept maps.

NEXT STEPS
Based in part on the preliminary success of this innovation, concept maps are now being used in multiple additional modules during the preclerkship timeframe.

We have observed that students who create a less detailed concept map than they had constructed earlier in the curriculum often have poor study habits. As shown in Figure 5, a modification of a concept map for the Cardio–Pulmonary–Renal examination that is much more linear (i.e., less branching)
This concept map, when examined at a basic level, looks like “rain” streaming down in a linear fashion and does not show the level of branching or cross-links that we would expect to see in a learner who is continuing to acquire and organize knowledge on a topic. Further, poor performance on a concept mapping exercise appears to correlate with poor performance on future examinations relating to the topic. Thus, we believe, concept maps may be a useful indicator of students who are in academic difficulty and can be used as a starting point to discuss individual learning.
habits and help students visualize where their understanding may need to improve.

In addition, reviewing the concept map provides a unique lens in assessment by seeing the graphic display of topics of the concept maps and how the students understand these topics are related and inter-related. As faculty recognize the value of seeing this type of integrated assessment, they have been willing to add concept maps as part of the faculty-derived assessment at the midterm or end-of-module faculty-derived examinations.

Concept maps may also be a means to assess group performance as group concept maps provided a method for the students to engage each other in topics, work together in a team to discuss the concepts being used, how they interrelate, and how to best display this integration of topics in a graphic form in the group concept maps. Using concept maps as a means of TBL assessment provides a means of assessing both student knowledge and their knowledge organization, which is not evident in traditional MCQs typically used in an iRAT or gRAT.

Following student concept maps over time may alert the faculty to students who may have learning difficulties with a unique lens that may provide more insight than the limited data provided by a score on a multiple-choice examination. Concept maps created by students show the student perspective of how topics are integrated across the basic and clinical sciences and can be used to aide faculty in furthering integration of topics across multiple disciplines increasing integration in medical education.

CONCLUSIONS

Modifying a TBL exercise as a basis for practicing how to create concept maps is a novel exercise allowing faculty to assess both knowledge and its organization in students, while students can explicitly see and practice the integration of concepts across the basic and clinical sciences that may not be apparent through other types of exercises. The modified TBL format allowed the students the opportunity to first create their own individual concept map, then work together in a team to discuss the concepts being used, how they interrelate, and how to best display this integration of topics in a graphic form in the group concept maps. Using concept maps as a means of TBL assessment provides a means of assessing both student knowledge and their knowledge organization, which is not evident in traditional MCQs typically used in an iRAT or gRAT.

REFERENCES


