Creating Modules for Team-Based Learning (TBL)

By John W. Pelley, PhD
Texas Tech University HSC School of Medicine

The Importance Of A Well Designed TBL Exercise

 The Team-Based Learning process is aimed at teaching students to apply knowledge. To accomplish this they are first tested with Readiness Assurance Tests (RATs) to assure that they understand the concepts they are applying. This is followed by vignette test questions (application exercises) that require the utilization of these concepts in team problem solving. Thus, testing in teams using the TBL method combines the motivation of formative evaluation provided by the dialogue during the group activities with the learning of analytical thinking skills as students defend their rationales for ruling out incorrect answer choices. Thus, students are more likely to be better prepared for the summative evaluation milestones that mark their progress through a course of study.

Efficiency: Getting The Most Out Of Your Time

The most efficient way to develop a Team-Based Learning activity is to start with the application. This is based on a highly relevant principle first proposed by Covey in his best-selling book, *The 7 Habits of Highly Effective People (1989, Free Press).* The principle—*begin with the end in mind*—is explained by Covey:

> To begin with the end in mind means to start with a clear understanding of your destination. It means to know where you're going so that you better understand where you are now and so that *the steps you take are always in the right direction* [emphasis added].

The Right Direction Is Tightly Coupled

The "right direction," when applied to the development of a TBL exercise, creates objectives that are directly relevant to the RATs and RATs that are directly relevant to the application exercise. Thus, one fundamental aspect of TBL is that each phase of the process must be coupled together logically. From the student perspective each successive phase of the TBL exercise will be seen as meaningful work, i.e. the students will view this as something for them and not just for the teacher. As such, the students will quickly acquire a respect for the entire process, from individual preparation to group problem solving. If, on the other hand, the application exercise is not appropriate to both the stage of the student's development and to real world application of course content, the remainder of the TBL exercise, i.e. RATs and learning objectives, will seem like busy work and have no obvious purpose.

Expectations: Comprehensive vs. Selective

Before undertaking the steps outlined below for constructing an application exercise, it is worth considering the issue of "coverage." When a teacher organizes a lecture, the primary concern is whether the content has been covered satisfactorily. A classroom teacher has an instinct for the

essential concepts and examples that provide the student with a basic fund of knowledge without regard to how it is to be used later. By comparison, when a teacher organizes a TBL exercise the primary concern is teaching students to use selected aspects of that content to solve a problem. To be specific, coverage is no longer the primary concern during a TBL exercise. This is initially uncomfortable for both faculty and students and it surfaces as one of the major criticisms early in the introduction of the TBL process.

The secret to adopting a positive attitude for both faculty and students is to clearly announce:
1. the team problem solving goal of the TBL exercise and
2. that there is no intention to comprehensively review course content.

Problem solving thinking emphasizes "prefrontal" decision making and is different from the more high entropy search-and-select fact recall thinking that is mediated primarily by the temporal lobes. Thus, problem solving must be learned differently from comprehensive organization of memorized concepts and facts. One way to explain this is that TBL exercises "teach thinking" and they only use the subset of facts and concepts needed to accomplish that goal. Another highly motivational (for the students) way to explain it is that a TBL exercise is an efficient method of preparation for USMLE Step 1 examinations because it teaches thinking with Step 1 questions.

Working Backwards

The most efficient way to create coupled TBL exercises is to create the application exercise first, then to create RATs that match the application exercise, and finally to create objectives that match the RATs. This eliminates objectives that are not relevant to the RATs and thus ensuring that they will be accomplished before the group TBL exercise begins. This also eliminates questions on the RATs that are not relevant to the application exercises, thus eliminating the feeling that they are simply just another course exam. After several TBL sessions have been conducted, the students will acquire a sense of purpose in each step of the process and improve the quality of their participation. Thus a coupled TBL exercise will ensure a meaningful, high quality involvement of the students in the process… and we haven't even mentioned how much easier it will be to conduct the exercise itself.

Steps in Developing A TBL Exercise

The steps involved in developing a TBL exercise can be represented by a list of questions aimed at what needs to be accomplished. The first question concerns the creation of one or more vignettes (the application) that represent current course material with opportunities for integration with other disciplines. This is followed by a question that concerns the best way to assess the student's readiness to think about the application (the RAT). The final question relates to the clearest description of individual study that will prepare each student to get the most out of the TBL session (the objectives).

An example case titled, "Metformin induced lactic acidemia" is included as an Appendix here. This topic integrates biochemistry, physiology, and pharmacology. A discussion accompanies the case to: 1) describe the rationale in selecting the case and 2) describe the type of thinking that

each answer choice (rational alternatives) is intended to elicit from the student. Keep in mind that, because each answer choice is a rational alternative, the students must develop a rationale to rule out the incorrect answers.

First Step – What is the application that I want to develop?

For many basic science faculty, this is the most intimidating question to answer. It asks about an unfamiliar aspect of a subject for many teachers, namely, how is the information meaningfully applied to problem solving. This dilemma is not unique to clinical applications since faculty involved in bench research often teach subject content and overlook how that content is applied in laboratory investigation. The least efficient approach is to attempt to derive a vignette question directly from lecture content. Fortunately, there are resources available that can speed up this process: NBME templates, GRIPE Learning Objectives and Webpath, other faculty – both clinical and basic science, experimental vignettes, and commercially available case setups.

NBME templates as a resource

Once an idea has been identified, it can be quickly developed into a case vignette by following the item writing templates provided by the National Board of Medical Examiners. These templates are shared freely at the NBME website (NBME Item Writing Manual, "Constructing Written Test Questions For The Basic Sciences, 3rd Ed., www.nbme.org) and are a part of the NBME Item Writing workshops that are held at most medical education conferences. The NBME Item Writing Manual provides thorough guidance on the construction of high quality vignette questions. The NBME Item Writing Manual refers to a good question as one that can be answered by masking the answers. Also, a good question should require that all of the patient data be relevant to either eliminating wrong answers or selecting the correct answer. It is possible to use different lead-in questions with the same patient case information.

NBME Question Templates
(refer to NBME Item Writing Manual for additional examples from the various disciplines)

1. Anatomy
   - A (*patient description*) has a (*type of injury and location*). Which of the following structures is most likely to be affected?
   - What symptoms would be produced if (*process*, *structure*, *etc.*) were defective?

2. Biochemistry
   - A (*patient description*) has (*symptoms and signs*). These observations suggest that the disease is a result of the (*absence or presence*) of which of the following (*enzymes, mechanisms*)?

3. Physiology

   - *Insert a patient vignette describing a patient with a problem.* Which of the following humoral substances is most likely involved?

4. Microbiology
   - (*time period*) after a (*event such as trip or meal with certain foods*), a (*patient or group description*) became ill with (*symptoms and signs*). Which of the following (*organisms, agents*) is most likely to be found on analysis of (*food*)?

5. Pharmacology
   - A (*patient description*) has (*history findings*) and is taking (*medications*). Which of the following medications is the most likely cause of his (*one history, PE or lab finding*)?
   - A (*patient description*) has (*symptoms and signs*). Exposure to which of the (*toxic agents*) is the most likely cause?

6. Pathology
   - A (*patient description*) has (*abnormal findings*). Which [*additional*] finding would suggest/suggests a diagnosis of (*disease1)* rather than (*disease 2*)?
   - A (*patient description*) has (*abnormal findings*). Which of the following (*positive laboratory results*) would be expected?

7. Template for Mechanisms

   - Item Stem (Patient Vignette): (Describe a patient with a problem)
     - Lead-In: Which of the following mechanisms is the most likely cause of the patient's findings?
     - Options: (List of mechanisms)

8. Other template examples

   - A (*patient description*) has a (*type of injury and location*). Which of the following structures is most likely to be affected?
   - A (*patient description*) has (*history findings*) and is taking (*medications*). Which of the following medications is the most likely cause of his (*one history, PE or lab finding*)?
   - A (*patient description*) has (*abnormal findings*). Which [*additional*] finding would suggest/suggests a diagnosis of (*disease1)* rather than (*disease 2*)?
   - A (*patient description*) has (*symptoms and signs*). These observations suggest that the disease is a result of the (*absence or presence*) of which of the following (*enzymes, mechanisms*)?
   - A (*patient description*) follows a (*specific dietary regime*). Which of the following conditions is most likely to occur?
   - A (*patient description*) has (*symptoms, signs, or specific disease*) and is being treated with (*drug or drug class*). The drug acts by inhibiting which of the following (*functions, processes*)?
   - A (*patient description*) has (*abnormal findings*). Which of the following (*positive laboratory results*) would be expected?
   - (*time period*) after a (*event such as trip or meal with certain foods*), a (*patient or group description*) became ill with (*symptoms and signs*). Which of the following (*organisms, agents*) is most likely to be found on analysis of (*food*)?

- Following (*procedure*), a (*patient description*) develops (*symptoms and signs*). Laboratory findings show (*findings*). Which of the following is the most likely cause?
- A (*patient description*) dies of (*disease*). Which of the following is the most likely finding on autopsy?
- A patient has (*symptoms and signs*). Which of the following is the most likely explanation for the (findings)?
- A (*patient description*) has (*symptoms and signs*). Exposure to which of the (*toxic agents*) is the most likely cause?
- Which of the following is the most likely mechanism of the therapeutic effect of this (*drug class*) in patients with (*disease*)?
- A patient has (*abnormal findings*), but (*normal findings*). Which of the following is the most likely diagnosis?

GRIPE Learning Objectives and Webpath as resources

The Group for Research in Pathology Education has an outstanding set of learning objectives at their website (http://peir.path.uab.edu/griper/). These learning objectives are very well written and can serve as source material for linking any basic science area to the patient data that can be included in a vignette question. Pathology is considered by many as the "ultimate integrator" for the basic sciences because all disease states present with abnormalities in the normal function that is taught in the other basic science courses.

Webpath is an internet website that was created at the University of Utah School of Medicine, and is still maintained, by Edward Klatt, MD, who is now at the Mercer school of Medicine in Savannah, Georgia. It contains a rich selection of USMLE quality pathology questions that could be adapted to other subject areas. Remember that a given clinical setup can be paired with different lead-in questions and answer sets, thus saving composition time.

Other faculty – both clinical and basic science as resources

If a basic science teacher and clinical science teacher collaborate, they can compensate for each other's blind spots. This is because they bring different types of expert thinking to the topic under consideration. The basic science focus on organization of content balances the clinical science focus on application of content. It is unlikely that clinical faculty will have an easier time composing vignette questions on their own because their expert-level thinking becomes unconscious with respect to many basic science fundamentals. Taken together, each perspective can rapidly compose a clinical vignette. In this way, basic scientists can help clinical faculty develop TBL exercises for use in clinical training. Good sources for collaboration might be clerkship directors, either directly or by referral, clinical colleagues on service committees, or even other basic science faculty members with vignette writing experience.

Experimental vignettes as a resource

Legitimate applications can be set up with experimental, or laboratory, vignettes. These can involve tissue culture situations, whole animal experiments, or well patient scenarios. Experimental vignettes are described in the NBME Item Writing Manual.

Commercially available case setups as a resource

Other resources that can be used by basic science faculty are clinical case books that are written to illustrate the clinical applications of the various disciplines. A number of study aids aimed at Step 1 review offer a surprising number of high quality case vignettes and case vignette questions. The "Underground Clinical Vignette" series by Blackwell Science is an example of such a resource. Review articles in major clinical journals can also stimulate ideas for case vignettes.

How many case vignette questions?

The discussion of an application will usually take considerably more time per question than a RAT question because there are more aspects to discuss. Many answer choices will have partial validity and the students need to be encouraged to discover the greatest validity through dialogue, and that will take extra time. By comparison, a RAT question is seeking understanding and, while there will be dialogue aimed at achieving understanding, the assumptions about the topic in the RAT question will usually be fewer. Thus, a two hour total time period (including the RATs), should not exceed three question sets and it would be better to start with two. It is not necessary to have a different case vignette for each answer set. Since cases are integrative in nature, both application questions can have different answer sets and lead-ins, but the same clinical scenario.

Second Step – What is the core knowledge needed to solve the case vignette(s)?

After the development of the application exercise the steps become much more manageable for both basic and clinical science teachers because the task is more familiar. Now it is necessary to construct a Readiness Assurance Test (RAT) to determine the students' fundamental grasp of knowledge that pertains to the application exercise. For a two hour TBL session, there will be enough time for a RAT of approximately 5 questions. Experience will guide you if more are needed, but it is less stressful to have too few initially, allowing plenty of time for discussion. The RAT questions are ordinary test questions. To be sure they are selected to elicit discussion and, likewise, they are selected to be relevant to the case. However, they probably already exist in your test item bank.

Good RATs and Bad RATs

There are several important considerations when choosing RAT questions that concern: 1) sampling of knowledge and 2) relevance to the application case vignette answer choices and trigger words.
- Sampling of knowledge: It is worth remembering that the RAT can be relevant without being a comprehensive sampling of knowledge. You will likely find that if you target the RAT questions to correlate with the case vignette answer choices and the trigger words in the vignette, then you will automatically have a good sampling of the content for that topic from your lectures.

- Relevance to answer choices and trigger words: The rationale is that, if the students are going to be deciding on a single best answer for your case vignette questions, they need to understand each of the answer choices presented to them and not just the correct answer choice. Knowledge that is restricted only to the correct answer choice is not enough to assure the thinking needed to rule out incorrect answers. "Ruling out" thinking is the essence of critical, or analytic, thinking.

Third Step – How do I help the students prepare for the TBL activity?

Ideally, your students should already be prepared for the TBL activity since you are testing on what you have been teaching. But, education is rarely ideal. Students are not homogeneous in their understanding of new concepts and in their management of limited study time. Thus, they will benefit from some guidance in preparing for a TBL exercise. Specific behavioral learning objectives will help them to focus on the knowledge that pertains directly to the team learning activity.

- If the objectives are not specific they more likely represent broad goals which are also important in education, but don't help students use their time effectively.

Putting the Fun Back In Writing Learning Objectives

The prospect of writing learning objectives is often discouraging and intimidating to teachers. It is a task that seems unduly contrived and tedious in its demands, but this does not have to be the case. Learning objectives only have to follow a simple rule.

"A good learning objective is a good essay question."

We are all experienced in framing essay questions; basic scientists ask them to their graduate students, clinicians ask them to their clerks and interns. These questions can be Socratic in nature or more aimed at recall, but in every case they are behaviorally specific. No one would ever ask a question on a test that begins with "understand," "appreciate," or "know."

- Goal – Understand type 2 diabetes.
- Objective – Compare the pathologic outcomes of type 1 and type 2 diabetes.

Thus, the essay question model is a natural and self-correcting guide to effective learning objectives.

Identifying The Learning Objectives Needed For The TBL Exercise

The reference point for composing your list of learning objectives is the list of RAT questions that you have just composed.
- First look in the question stems and write objectives that assure the students will give the proper attention to the concepts present.
- Proceed to look at each answer choice and continue adding objectives if these concepts are not already covered in the objectives you have just written.

- You should expect to either consolidate some objectives or to divide others as you consider the list as a whole.

HOTS or not?

Another consideration when deciding how to phrase a learning objective is the specification of the level of learning. For our purposes, we are focused on either recall level learning, i.e. memorization, or higher order thinking skills (HOTS). Both types of learning are important since the development of HOTS is critically dependent on the fund of memorized information in the students' vocabulary. Thus, a proper mix of learning objectives will assure not only the information needed, but also the understanding of that information that is needed. Table 6.1 provides sample trigger words that can be used in either learning objectives or in RAT questions. These are organized for the level of thinking needed in the TBL exercise.

Supplementary reading

There will be some occasions where the course content needs to be supplemented with additional reading before a given case vignette is feasible as an application exercise. This additional reading can be supplied along with the learning objectives and can be accompanied by additional learning objectives that guide the study of this additional material. Supplementary material can be as brief as a bulleted list of facts as illustrated in Appendix D or can include articles or other assigned reading. Ideally, no supplementary reading should be necessary so that the student sees TBL as an extension of what they are already learning for course exams. Extensive supplementary reading with unclear or uncertain expectations for the course or the exercise, e.g. technical papers, *will be met with low morale and resistance from the students*.

Table 6.1 Trigger words and sample phrases for objectives or questions

Recall	Higher Order Thinking Skills
List	Classify _____ according to _____ .
Name	What is the function of _____ ?
Define	What is the relationship between ___ and ___ ?
What (is, are)	Compare _____ to _____ .
When (does)	How is _____ like _____ ?
	How are _____ and _____ different?
	Compare _____ before and after _____ .
	Distinguish between _____ and _____ .

(Note: Any question becomes a recall question if the answer has already been explicitly provided to the student in class or in the text.)

HOTS objectives generally require the student to make comparisons and to describe cause-and-effect. The following list of objectives templates should help you get started.

Generic Learning Objectives Templates

- How is _____ like _____ ?
- How are _____ and _____ different?
- Compare _____ before and after _____ .
- What causes _____ ?
- What is another possible cause of _____ ?
- In what sequence did _____ happen?
- Break _____ down into its component parts.
- Give an example of _____ .
- What is the relationship between _____ and _____ ?
- Make a simple paraphrased definition of [terms].
- What concepts are related to [terms]?
- List causes and/or effects of [terms].
- Compare or contrast [terms] with one or more [terms].
- Describe the relationship between [terms] and [terms].
- Explain the function of each step in (a sequence or a process).
- What do [terms] have in common and how are they different?

Appendix: Example of case application question

Appendix A – Case Vignette Question

A 74 year old female has come to your office suffering from hyperventilation, malaise, dizziness, and muscle pains. She was diagnosed with Type 2 diabetes at the age of 50 and has managed her disease successfully with diet, exercise, and hypoglycemic agents. She was initially put on a hypoglycemic agent called an oral sulfonylurea (chlorpropamide), but recently was switched to metformin which is better tolerated in the elderly. Her blood pH is 7.2 and her serum lactate is 10X normal levels. Her creatinine clearance and serum creatinine concentrations indicate diminished renal function. This patient has a blood pH of 7.2 because:

    A. ketones from excess fat mobilization are making her blood acidic.
    B. increased glycolysis and reduced TCA cycle activity leading to excess lactate formation.
    C. hypoxia resulting from inhibition of electron transport is creating excess carbon dioxide.
    D. increased blood sugar increases glycolysis and lactate production in red blood cells.

Discussion: The correct answer choice is B since her acidosis is primarily due to lactate that is being overproduced. The supplementary information on metformin action has the information on a lactic acidosis side effect needed to deduce this answer and the learning objectives direct the student to review exactly that information. Both the elevated lactate concentration and the data on kidney function help to confirm this as the correct answer. Keep in mind that the purpose of the each exercise is to generate discussion of alternatives and a rationale for the one best alternative based on the information given. Also, note that answer choices that would not be considered proper by NBME standards are often excellent discussion generators for TBL exercises.

The students will consider answer choice A as possibly correct when they refer to their lectures on ketoacidosis in diabetes. Students who learned all of their facts will note the absence of ketoacidosis in type 2 diabetics because even minimal insulin action prevents ketone body formation. When answer choice C is considered, the information on metformin action on inhibiting the electron transport chain through respiratory control will give this choice credibility but the conclusion that hypoxia and excess carbon dioxide are created is incorrect and will not be defensible. This will bring out cause and effect reasoning during the problem solving dialogue. The final answer choice D will have credibility since red blood cells do produce lactate from blood sugar, but the group will have to deduce that the rate of glycolysis and, thus, the rate of lactate formation is under tight regulation and would not respond to increased blood sugar concentrations.

Appendix B – Example of a RAT Question

Which of the following would NOT produce lactic acidosis?

    A. Carbon monoxide poisoning
    B. Impaired gluconeogenesis
    C. Impaired pentose phosphate shunt
    D. Impaired pyruvate oxidation
    E. Cyanide poisoning

Discussion: The correct answer choice is C, impaired pentose phosphate shunt, since this would lead to hemolytic anemia but would not be associated with lactic acidosis. Note that this question relates directly to the correct answer choice in the case vignette question (Appendix A). The answer choices have been deliberately written out of conformity with the style recommended by the NBME to illustrate that, ironically, less than perfect test questions can be good RAT questions. The reason for this is that RAT questions are designed to create discussion and a little ambiguity helps with that. However, a regular non-TBL test question should be designed to avoid the technical item flaws that are related to testwiseness and irrelevant difficulty (see Case and Swanson, Chapter 3, NBME Item Writers Guide, 2002 – available online at www.nbme.org).

Note that since each answer choice concerns a different metabolic pathway, most of intermediary metabolism is addressed and is likely to be discussed. However, if the RAT discussion does not address all of the answer choices, then you can address your thinking about them when you close out the question.

Appendix C – Example of Learning Objectives

Learning Objectives
1. *Give a definition for lactic acidosis. At what pH does a patient become acidotic?
2. *Describe the steps leading to increased lactate production resulting from hypoxia.
3. *List the various causes of hypoxia.
4. *Describe the action of rotenone, amytal, antimycin A, oligomycin, and pentachlorophenol in the mitochondrion.
5. Describe the action of fluoride on glycolysis.
6. *Describe the metabolism of lactate by the liver in the normal patient.
7. *Describe the steps involved in the nonenzymatic glycosylation of proteins. What is the effect of this process in renal glomeruli?
8. Describe the activity of the polyol pathway in type 2 diabetics.
9. Compare the effect of insulin on gluconeogenesis in a normal patient and a patient with Type 2 diabetes.
10. Give the two causes of hyperglycemia in diabetes mellitus.
11. *Compare fat mobilization in type 1 and type 2 diabetes.
12. *Describe the actions of metformin that would lead to lactic acidosis.

Discussion: The full scope of learning objectives for the original TBL exercise is included here to illustrate that coverage of any given topic can be fairly comprehensive. An asterisk identifies the objectives that relate directly to the application exercise and the RAT question in this Appendix. The remaining objectives relate directly to information that was covered in other RAT questions in the original exercise.

Remember that the objectives prepare the students to rule out wrong answers in addition to identifying the correct ones.

Appendix D – Example of Reading Sources and Supplementary Information

Reading Sources: pp 653-657 in Textbook

Discussion: Note that the heading is "Reading Sources" and not a reading "assignment." Students who have been sensitized by test questions containing esoteric detail will attempt to learn 100% of the material in an assignment. By comparison, the semantic of "sources" implies that the objectives can be completed from material contained in the suggested pages. This saves the student time in preparation and improves their quality of preparation.

Supplementary Information (a source for the information can be given here on omitted)

A. Diabetes supplementary information:
  - Type 2 diabetes occurs in nearly 19% of those between 65 and 74.
  - Nearly half of those with type 2 diabetes are over 60 and half of those are undiagnosed.
  - Risk factors for type 2 diabetes are visceral adiposity, increasing age, and lack of physical activity.
  - Type 2 patients develop impaired renal function.
  - Type 2 diabetes is characterized by insulin resistance:
    o Insulin is present in the blood, but is required at higher concentrations than normal.
    o The intracellular signal that is produced when insulin binds to its cell surface receptor is diminished.
  - Some type 2 diabetics progress to insulin dependence.
  - Elevated blood sugar is largely due to *inability to suppress gluconeogenesis* in the liver.

B. Metformin therapy – supplementary information:
  - The specific action of metformin is not known with certainty, but it seems to work generally by increasing insulin sensitivity, i.e. increasing the intracellular signal response to insulin
  - Metformin inhibits gluconeogenesis (from whence it gets its common name, "glucophage"). Thus, it prevents lactate conversion to glucose in the liver; lactic acidosis is a side effect.
  - Metformin is also thought to inhibit oxidative phosphorylation. This would reduce ATP production and cause an increase in NADH concentrations.
  - Metformin and reduced renal function occur together with most cases of lactic acidosis.
  - Reduced renal function causes circulating metformin concentrations to increase causing a functional overdose of this drug.

Discussion: The bulleted list permits rapid review and also rapid reference when working on the application exercise. (Remember that the RAT is taken with no reference material, but that the application exercise allows access to any reference material.)