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A User's Guide to the Legacy Cycle

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Abstract:

Research has shown that students' mastery of content knowledge and their ability to apply that knowledge in new situations improves when certain classroom characteristics are met. The book *How People Learn* identifies these characteristics of classrooms and curricula that optimize student learning as *knowledge-centeredness*, *learner centeredness*, *assessment centeredness*, and *community centeredness*. The question then becomes how these four centerednesses can be put into practice in classroom instruction. In answer, the Legacy Cycle curriculum structure was designed as a way to embed these four centerednesses into classroom lessons. This guide is designed to facilitate an instructor's implementation of this lesson model: the curriculum structure is defined step by step, with (1) examples of each step, (2) potential advantages and possible problems associated with each step, and (3) classroom management strategies to avoid the problems proactively and thus allow students to profit from the advantages. Suggestions for introducing the Legacy Cycle to your students are also provided.

Introduction

In 1999, the National Research Council published *How People Learn: Mind, Brain, Experience, and School* [1] as the summary of what we know from research about the first three words of this title. This document proposed four "centerednesses" (explained in the following section) that, taken together, optimize learning: *knowledge-centeredness*, *student-centeredness*, *assessment-centeredness*, and *community-centeredness*. The question becomes how can these four centerednesses be put into practice in a given classroom lesson, and one answer is through the use of the S.T.A.R. Legacy Cycle (explained in a following section) as a lesson format [2]. However, after many hours of classroom teaching and observation, the authors have observed that there are a variety of management issues that affect the success of a Legacy Cycle lesson classroom implementation, and there are a variety of proactive strategies an instructor can implement to engineer the success of this type of lesson. Based on structured observations and teaching experiences, the authors have compiled a guide for implementing a Legacy Cycle lesson in a college classroom. This guide first defines in detail what each stage of the Legacy Cycle comprises and gives examples of ways one could accomplish the stage in the classroom. The guide then breaks down the Legacy Cycle stages, detailing potential advantages and possible problems, and suggesting classroom implementation techniques to provide an instructor with techniques that maximize the effectiveness of each stage.

A Summary of HPL

The National Science Foundation (NSF)-funded Vanderbilt-Northwestern-Harvard/MIT Engineering Research Center (VaNTH ERC) for Bioengineering Educational Technologies has as its primary goal improving bioengineering education. For the past seven years, bioengineers and learning scientists have worked together to improve education not only at the university level, but also at the K-12 level. Much of this work has been based on upon the text, *How People Learn* (HPL) [1].

HPL learning theory incorporates four "centerednesses" that work synergistically to optimize learning. When these four are in place, studies show that students increase both their content knowledge and their ability to apply that knowledge in new situations – i.e., their *adaptive expertise* [3-8]. First, the learning environment must be *knowledge-centered* -- appropriate information should be presented in

an appropriately sequenced and organized way. Second, the environment must be *student-centered* -- lessons should seek out students' prior conceptions and misconceptions, help students make connections with prior knowledge, and be relevant to students' own lives. Third, the learning environment must be *assessment-centered* -- it should include opportunities for formative feedback for both students and instructors: students benefit from opportunities to check their own understanding and instructors from opportunities to assess the effectiveness of their teaching. Finally, a learning environment must be *community-centered* -- students should be provided opportunities to learn collaboratively.

According to HPL theory, students learn best when (1) presented with organized information that (2) relates in some way to their own experiences, and they are given the opportunity to (3) test themselves on their own understanding and to (4) work to develop their understanding with other students. Legacy cycle incorporates these four influences on learning by providing a rich, contextually based problem, relevant in some way to students' lives, and allowing students to engage deeply with that problem in ways that include opportunities for collaboration with other students and for self-assessment.

History and Overview of Legacy Cycle

The STAR.Legacy Cycle (Figure 1 – note that the terms "Legacy Cycle" and "STAR.Legacy Cycle" are used interchangeably) was created as a means of implementing the HPL ideas in the classroom [2]. Case-based learning has been used in other fields such as medicine and law with success in learning for some time now [9]. These cases are similar to the Legacy Cycle in the use of an initial "challenge" or problem that must be solved. However, Legacy Cycle lesson design adds more specific structure to the traditional problem-based learning format, as after the stated *Challenge* and following the *Generate Ideas* activity, students examine selected thoughts from experts that relate to the problem and direct their thoughts in the desired direction(s) before engaging in "Research and Revise" activities. These steps are supported by additional research that has demonstrated improved learning when students first generate their own ideas and then hear experts' ideas prior to consulting resources or learning new material [10]. Formative assessment, or feedback, is useful to students and instructors as well in generating actual learning [11] and is incorporated in the Legacy Cycle at the *Test Your Mettle* stage. Lastly, students are motivated by creating a product or answering an authentic question [12,13] as is done in the "Go Public" stage of the Legacy Cycle.

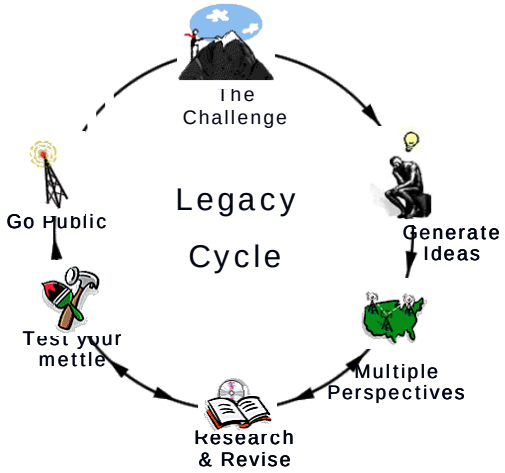


Figure 1: STAR Legacy Cycle diagram.

Legacy Cycle – A Research-Based Way of Structuring Lessons

The Legacy Cycle involves the six phases shown in the chart below:

Challenge 	A question that causes students to wonder about the topic and become engaged with it. The question frames the module and requires students to bring to bear their current knowledge and preconceptions about the topic.	Examples (science): • Your grandmother is recovering from a broken hip. In which hand should she hold a cane to help her balance? • Assume you are a living cell in a bioreactor. What things will influence/determine how long you live?

Generate Ideas 	A whole-class activity that causes students to display and compile their current knowledge/ideas/perceptions. Note that this can also be done in the form of questions: What things would you need to know to answer this question? What additional information would you like to have to help you answer this question?	Possible activities (all should include some type of written record): • Individually writing a narrative • Whole-group brainstorming • Small group brainstorming with public sharing • Think-write-pair-share • Think-write-pair-shared-squared with public sharing.
Multiple Perspectives 	Two or more outside resources that provide information related to the topic of the challenge. (These tend to "point students in the right direction" for further inquiry.)	Possible sources: • Outside expert (live, on video, or in transcribed paragraph[s]) • Web site(s) • Textbook excerpt • Magazine article, • Clip from scientific video • CD
Research & Revise 	Additional information that students receive/seek. This may be in the form of lecture, readings, websites, etc. Students revise their original ideas based on new information (often includes students' journaling regularly).	Possible venues: • In-class lectures • Textbook and other readings • All others listed in Multiple Perspectives
Test Your Mettle 	A set of activities in which students engage to help them explore their depth of knowledge. The goal is to create formative assessment situations that help them evaluate what they do not know so that they may return to the Research & Revise step again to learn more.	Possible venues: • Seek feedback from other students on product • Seek feedback from the instructor on product (poster, essay, game, practice test, role play, etc.)
Go Public 	Final conclusion(s) that students display.	Possible venues: • Test • Oral presentation • Poster/Project • Role play

Documentation of HPL Instruction

The STAR.Legacy Cycle design has been implemented with great success in the college engineering classroom [14]. Studies such as those by Roselli [15] and Pandy [16] demonstrate the efficacy of the Legacy Cycle in biomechanics education. Measures in Roselli's biomechanics class show an increase in both student ratings of the course and instructor on evaluations as well as increase in

understanding of difficult concepts. Electrical engineering concepts such as Fourier analysis and signal processing have been taught effectively [17,18] as well as physiology courses [19]. Measures in Greenberg's [18] physiology course show a statistically significant improvement in Fourier spectral analysis skills. The Legacy Cycle has also been implemented successfully at the middle and high school level as well, with multiple studies indicating a mastery of science concepts beyond that of control classrooms [7-8,20-22].

A formalized and primarily quantitative classroom observation system has been used to assess the levels of implementation of HPL and the STAR.Legacy Cycle for the past several years. This VANTH Observation System (VOS) records 1) student-teacher interactions, including measures of the four centerednesses put forth by HPL, 2) student academic engagement, 3) narrative notes of classroom events, and 4) ratings of specific indicators of effective teaching. [23] For example, VOS measures of teacher-student interaction in an extended controlled study of a biomechanics course [15] allowed instructors to identify the degree of interaction during class between instructors and students and to estimate the amount of class time spent addressing each of the four HPL centerednesses. Results from VOS classroom observations made during the study indicate that the classroom experiences in the HPL-based course had significantly more teacher-student interaction and more events per class that were learner-centered, community-centered, and assessment-centered than in a traditional classroom.

The co-authors of this user's guide bring a collective sixteen years of experience with HPL instruction and Legacy Cycle lesson format. One is the designer and primary user of VOS who has logged in hundreds of hours of classroom observation identifying what does and does not work with HPL-instruction. This knowledge contributes to this user's guide. The other is an eight year veteran of writing and implementing HPL-based instruction as both a high school teacher and university professor. Her experiences of authoring and implementing also contribute to this guide.

Maximizing Teaching Potential with the Legacy Cycle

The various types of activities involved in a Legacy Cycle each contain *potential advantages* for learning and *possible problems* in teaching. The following chart segments list several of each for each activity, followed by a more in-depth explanation of these with specific management strategy suggestions. An instructor's goal is to prevent the possible problems so that instructor and students can benefit from the potential advantages. As instructors design and implement Legacy Cycle lessons, the authors suggest that they consider the possible problems below, think of ideas they already have to address each one, and then review the suggestions after each of the five Legacy Cycle phases.

Proactive Strategies for Presenting a Challenge

	Type of Activity	Advantages & Possible Problems
Challenge 	Students think about a written question that the instructor presents.	*potential advantages* • Piques student interest, stimulates engagement, and sets the stage for the coming learning. *possible problems* • Getting students to engage deeply with the question.

The teaching advantage of a **challenge** is student motivation. A good **challenge** (1) engages your students in a topic in which they have some initial interest, thus building on pre-existing experience/knowledge; (2) causes them to realize there are some things they already know about the topic, thus fostering a sense of efficacy and anticipation of success; and (3) piques their interest to solve the problem/mystery, thus causing them to want to learn more.

As an instructor, you can do several things to maximize the motivational potential of the initial **challenge**:

1. Write a good question. Create a challenge that addresses each of the three parts of the definition of a good challenge in the paragraph above. The best challenge questions relate to real life and place the student in a hypothetical situation where their judgment or decision or solution makes a difference. (E.g., From a biomechanics course: Your grandmother is recovering from a broken right hip. The bone is mending nicely and she is about to begin using a cane. In which hand should she hold the cane and why?)

2. Begin with silent brainstorming. Preface presenting the challenge with a statement that makes visible your expectation that students will THINK about possible responses before anyone says anything. This gives everyone a better chance to contribute and avoids the first thing stated "contaminating" or limiting the direction of other responses. An introductory statement similar to the following can help communicate this expectation: "Class, in a moment we are going to consider a challenge that we will be exploring, and I'll ask you to share your initial thoughts about it. However, before anyone shares anything, I want you to jot down your initial ideas on scratch paper and see how many different ones you can come up with before we say anything out loud." Then make sure each student has pencil and paper.

3. Show and tell and check. Present the challenge both visually (on the board/ chart/screen) and verbally (read it aloud and give at least one "in other words" paraphrase of it). Consider asking two or more students to tell in their own words "just what it is we are looking for in this challenge." (This can inform you if your students do or do not have an accurate grasp of the challenge.)

4. Show interest. Present the challenge with vocal inflection, facial expression, and body language that communicate a combination of enthusiasm and mystery. Get in front of a mirror, demo to yourself how you plan to introduce the challenge, and ask yourself, "Would my presentation motivate me if I were sitting in my class?" If your answer is not a strong positive, keep practicing.

5. Allow adequate wait time. Do NOT immediately accept student call-outs once you have presented the challenge. Give students time to think. (Research reveals that the average teacher wait time in a typical question-and-answer session is less than one second (!) for a spoken response, and that allowing wait time of three to five seconds yields richer responses.) For the generate ideas section, allow at least two full minutes of thinking and independent brainstorming before accepting student ideas.

Proactive Strategies for Generating Ideas

	Type of Activity	Advantages & Possible Problems
Generate Ideas 	Students engage in brainstorming activities.	*potential advantages* • Allows the instructor to identify prior knowledge. • Allows the instructor to identify misconceptions. • Allows students to recognize one another's thoughts. *possible problems* • Some students do not participate. • Some students overparticipate.

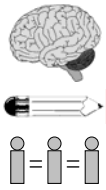
A major teaching advantage of **generate ideas** is making visible students' knowledge for formative assessment – that is, you as the instructor can determine what students know about the topic before actually beginning the study, thus identifying their accurate, inaccurate, and missing prior knowledge. Armed with this information, you are better able to design learning activities that will build on, correct, and complete their understanding. A good generate ideas session (1) involves all students – no one is left out -- and encourages mutual respect for one another's thinking, (2) causes students to make linkages with related prior knowledge, (3) causes them to recognize related areas of importance in which they currently lack knowledge, and (4) makes their related misconceptions visible.

As the instructor, you can do several things to maximize student involvement in **generate ideas**:

1. <u>Clarify the idea of brainstorming.</u> Explain that the goal is to generate as many related ideas as possible without any initial judgment of those ideas. Students are NOT to comment positively or negatively on anyone else's ideas. (Nor are you!)

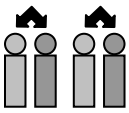
2. <u>Provide prompts for brainstorming.</u> As students read and hear the **challenge**, frame a two-part question to jump start their brainstorming by asking "What do you know that could help answer the challenge? What else can you think of that you might want to know to help solve it?" Write three prompts on the board: *What we know*, *What we know – but need a refresher on*, and *What we need to know*.

3. <u>Allow adequate wait/think time.</u> Do NOT immediately accept student call-outs once you have presented the **challenge**. (You've seen this idea before; it is worth repeating.) You may wish to use one of the following techniques:



   a. Think-Write-Share: Allot a set time (e.g., two to three minutes) for students to think and write down their ideas. Or, assign the brainstorming as homework, with the prompts and possible responses to be written in a journal. Then have students share items from their lists as you scribe them publicly (board, chart, screen). Use some system to make sure everyone has a chance to contribute (e.g., the ground rule is that after every student has contributed one idea, then any student may add a second or more).

b. Think-Write-Pair-Share: Begin as above with three to five minutes, but after the set time to think and write is past, have students pair up to combine and add to their lists, and then share items from their lists as you scribe them publicly. Again, use a method to assure that everyone contributes.



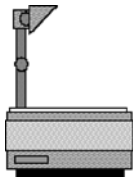
As the instructor, you can do several things to encourage students' mutual respect for one another's thought processes in **generate ideas**:

1. Give all students opportunity to contribute. Be aware of the human tendency to focus on (and call on) those students seated across the front the down the middle of the classroom and/or those students seated to your dominant-eye side. (Just as you are right-hand or left-hand dominant, so too are you right-eye dominate or left-eye dominant; hand and eye dominance may or may not be the same.) You may wish to use a system, such as equity cards, to assure that all students have opportunity to contribute their ideas.

2. Validate each student-generated idea. As a student gives an idea, accept it, repeat it, and write it on the board/chart/overhead transparency/computer screen in words as close to the student's actual words as possible.

3. Voice no judgments. Refrain from making any initial value statements about student ideas – either positive or negative. This includes maintaining a neutral voice tone as you repeat each idea.

NOTE: Remember that when you make a public list of student-generated ideas, students will refer back to that list in the next two sections of Legacy Cycle. You may choose to write student's ideas on an overhead transparency, a chart pad, or a chalk/white board. Each of the three have advantages and disadvantages for recording in the **generate ideas** section. You choose.



Overhead Advantages	Overhead Disadvantages
1. You can face students at all times – no need to turn your back. 2. Transparencies are the size of a sheet of paper and store easily in a file folder.	You can display only one transparency at a time – if you need multiple transparencies to list student ideas, then not all can be visible to students at the same time.

Chart Pad Advantages	Chart Pad Disadvantages
You can display multiple pages at the same time if student ideas fill more than one page – everyone can see all of the ideas at once.	1. You must turn your back to students to write on the pad. 2. Storing the large chart pages is a bit more difficult than storing transparencies – but they can be four-folded and fit into a folder.

Board Advantages	Board Disadvantages
It is easily available and everyone can see all ideas at once.	1. You must turn your back to students to write on the board. 2. As this text is needed for beginning the **research and revise** section, you must either not erase it and thus tie up board space or else have a student scribe make a written record for future reference.

Proactive Strategies for Multiple Perspectives

	Type of Activity	Advantages & Possible Problems
Multiple Perspectives 	Students listen to the instructor or to an outside expert speaker. Students watch a video. Students read a text, article, or scripted interview. Students peruse an instructor-selected web site.	*potential advantages* • Everyone gets the same initial information to get them started in the right direction. *possible problems* • Reading - Some students may not engage with the required material. • Listening – Some students may not attend to the speaker or media.

Your teaching advantage in **multiple perspectives** is that by completing the first two pieces of the Legacy Cycle, you have "created a time for telling." Students are – hopefully – interested, curious, and focused in the right direction. Now is your chance to get them off to a good start in their efforts to solve the challenge. The point of **multiple perspectives** is to give students some initial information and some clues to think about things they might not realize they need to explore in order to solve the challenge. Everyone will see/hear/experience the same information so that all begin with the same clues. Effective **multiple perspectives** will (1) provide a grounding of basic information on which students can build and (2) incorporate multiple modalities.

As the instructor, you can do several things to maximize effectiveness of your initial **multiple perspectives**:

1. Remember that less is more. The **multiple perspectives** segment should take no more than fifteen minutes. The key phrase here is providing students with "initial information and … clues" and the goal is to point students in the right direction(s) – not show them the destination. Keep it brief; too much information can be overwhelming.

2. Incorporate multiple modalities. Because this is a common learning experience for all students and all students learn best in different ways, it is important to involve visual, auditory, and – if possible – tactile/kinesthetic experiences. Ask



yourself three questions about providing students with initial information/clues in terms of what students might…

a. … hear (instructor-read, student-read, audio tape, etc.)?

b. … see (photo, illustration, chart, graph, video, slide, etc.)?

c. … physically do (role play interviews, manipulatives, etc.)

3. <u>Provide a focusing guide.</u> Give students some sort of guiding notes outline and/or a framing focus question to help them focus within **the multiple perspectives** segment(s) (e.g. Be ready to identify three things you learn from the video/article/paragraph/expert.) Some students may not be able to identify what things within the multiple perspectives piece are pertinent to the challenge without some teacher guidance.

4. <u>Generate more ideas afterwards.</u> Use **multiple perspectives** to enrich your students' initial list of generated ideas. At the beginning of **multiple perspectives** suggest that students listen/watch for any additional ideas that could help solve the challenge. Then after engaging students in **multiple perspectives**, revisit the **generate ideas** section by asking, "Based on what you just heard/read/saw, what else might we add to our list on we generated earlier?"

Proactive Strategies for Research and Revise

	Type of Activity	Advantages & Possible Problems
Research & Revise 	Students listen to the instructor. Students engage in planned learning activities. Students read a text or article. Students peruse a web site. Students use a CD.	*potential advantages* • Students have opportunities for multiple modalities and learning styles. *possible problems* • Reading - Some students may not read the required material or attend to a needed lecture. • Listening – Some students may not attend to the speaker or media. • Some students may not follow through on learning activities/assignments.

Your teaching advantage of **research and revise** is that you can now tailor the learning activities to fit students' needed knowledge. **Research and revise** will (1) determine in what areas students need to research, (2) provide information and/or opportunities to gather information in those areas, and (3) allow opportunities for students to revise their thinking about the challenge.

For students to focus their areas of research in ways that will help them revise their thoughts about a possible solution, they must start by organizing the ideas they have generated thus far. The first task is to guide students in organizing their thoughts on what they know and what they think they need to know into coherent categories. Consider using the concept development outline below adapted from

the work of Hilda Taba [24] (interesting fact – she was John Dewey's graduate student and he once pronounced her the most intelligent graduate student with whom he had ever worked):

	1*	2	3	4
Overt Behavioral Objectives *(What I want my students to do.)*	a. Enumerate data that are relevant to the given challenge. *Note: This first step was completed in the "Generate Ideas" section.	a. Group items by common attributes or other relationships. b. Identify commonality or relationship upon which grouping is based.	a. Suggest appropriate label for each group of items. b. State reasons for thinking each suggested label is or is not appropriate.	a. Suggest different ways of subsuming, grouping, and labeling items based on other relationships. b. State reasons for new grouping, labeling, subsuming.
Covert Thinking Objectives *(How I want my students to think.)*	a. Recall related information from prior knowledge. b. Hypothesize needed information based on prior knowledge. c. Differentiate relevant from irrelevant information.	a. Notice relationships; search for common attributes. b. Identify the commonalities or relationships.	a. Synthesize common characteristics and generalize with a word or phrase. b. Evaluate appropriateness.	a. Notice hierarchies and relationships not noted before. b. Identify hierarchies and/or relationships noted.
Focusing Questions (General) *(What I will say to my students.)*	a. "What do you know that could help us find the answer to this challenge?" b. "What else do you think you might want to know to help you answer it?"	a. "Which of these do you think could go together because they are alike in some way?" b. "Why do you think _____, _____, and _____ go together?"	a. "What do you think would be a good name for this group?" b. "Why do you think _____ would be an appropriate label?"	a. "Can you think of any other possible groupings and labels that might work? b. "Why do you those groups and labels would be appropriate?"

After you have guided students through focusing questions 2, 3, and 4 (on the bottom row of the Taba chart), cycle back momentarily to **generate ideas** and ask if students can think of anything else they know or would like to know to answer the challenge that is not already on the list – either something that would fit in an existing categories or something that might require a new category. Add their comments to the list.

Tell students that you will take the idea groups they have defined and from them develop learning activities and additional small challenge questions that can help them answer the original challenge. Present these the next day and relate them to the categories the students created in the last class. (Repeatedly, teachers report that in this step students generate ideas that lead to the very learning activities they had initially planned to use within the lesson design – but now it is student-initiated rather than teacher-imposed, and this makes a positive difference in student motivation and attitude.

Now you are ready to engage students in various academic activities, including additional small challenges that will engage them with the content. In some activities, students may work independently; in others, collaboratively with either a partner or in a group. Whether students work alone or with others, student accountability is a must.

As the instructor, you can do several things to maximize student accountability in independent work involved in **research and revise**:

- Move among all students. When students are working, walk around the room. Make sure your room allows hip-width aisles so you can easily move among all students. Give every student the benefit of your "physical presence" as you look over shoulders and listen to conversations. A teacher's roaming physical presence encourages student attention to academic activities.

- Engage students in written self-monitoring. Periodically have them reflect on their work by writing in a journal what they have been doing and how it has increased their ability to answer the challenge questions and grand challenge.

- Require students to report findings. If students have been assigned different readings or to search the web, the next day have them present key ideas they found on the board or with the overhead.

- Have students write questions. After students read or hear an initial perspective, have them write questions from what they read or heard and use these to get discussion started.

As the instructor you can do several research-based things to maximize student accountability in collaborative work:

1. Group students carefully. Consider the following research findings and classroom applications below:

    a. Smaller groups work better [25]. Keep the groups small – pairs are often optimal as it is hard to be left out of a pair: more than 5 is untenable.

    b. Students work better in groups when the teacher determines which students work together. [26] (Consider student attributes and personalities in assigning partners/groups. As few classrooms have an equal number of students by gender, race, performance, or any other criteria, you will be pairing/grouping many/most/all students across attributes. Teachers report it works best to avoid close friends combinations or boyfriend/girlfriend combinations.

2. Clearly explain what is to be accomplished. To assess the clarity of your instruction after giving directions, check students' understanding by asking each group to agree on a one-sentence statement of what it is they are supposed to do. Then see how closely their statement matches your intent. Consider the following research findings:

    a. Students work better in groups when the teacher clearly delineates the task to be accomplished. [26]

    b. In secondary classrooms, students are more engaged and have higher achievement when teachers are clearer in giving directions, in stating objectives, and in presenting information. [27]

3. Teach needed social skills for collaboration. Some students may lack the social skills needed to work collaboratively. Research shows that these skills can be taught, and this teaching requires helping students understand (1) the reason for using the skill (telling), (2) what the skill looks and sounds like in action (modeling) – and when to use the skill, and (3) what the skill feels like in action (role play). [28]

4. Avoid group grades. You may structure group work so that a team works together to achieve a group goal and team recognition, but each student must remain individually accountable for his/her work. Research reveals that students have higher academic achievement in collaborative work when there are (1) group goals and (2) individual accountability – in other words, team members work together to earn recognition, but each student is graded on his/her work. [26]

Proactive Strategies for Test Your Mettle

	Type of Activity	Advantages & Possible Problems
Test Your Mettle 	Students seek feedback from the teacher and from other students on a product designed to demonstrate understanding. Products may include a practice test, graphic organizer, academic game, infomercial, poster, essay, role play, etc.	*potential advantages* • Students receive formative feedback to self-evaluate. *possible problems* • Other students may not know how to provide appropriate feedback.

Your teaching advantage of **test your mettle** is that it can provide formative feedback to improve both instruction and learning. Formative feedback can (1) inform the student how he or she is progressing in learning concepts required to solve the initial challenge (sometimes referred to as the *grand challenge*), and (2) inform the teacher how well the learning activities are helping students learn the desired concepts. You may need simply to point out these knowledge gaps to students and they will figure out how to redirect their learning efforts to fill in the missing pieces. Or, you may need to provide additional information and/or design an additional activity to help them gain the needed knowledge and make the needed connections among available information. Note that the double-headed arrow between **research and revise** and **test your mettle** indicates that a student may cycle between these two as many times as needed to master the content.

As the instructor, you can do several things to maximize the value and effectiveness of **test your mettle**:

1. Address key concepts. Assign/develop a **test-your-mettle** activity that relates to the key concepts students must have to solve the initial challenge.

2. Maintain individual accountability. Assign/develop an individual **test-your-mettle** activity. Your goal is to evaluate each student's knowledge, rather than "group" knowledge. This enables you to identify which students need additional instruction – and which students could serve as peer coaches. Also, each student needs feedback on his or her level of understanding.

3. Make it easy to assess. Design a **test-your-mettle** activity that allows for quick grading turn-around time – fast feedback with enough time left for students to continue in **research and revise** to fill in the knowledge gaps

4. Assess and return it fast. Research indicates that timely and appropriate feedback enhances student accountability and student motivation.

5. Give feedback that identifies where the "holes" are. Provide assessment information that lets students clearly identify what they know well and what they yet need to study and master.

6. Provide additional learning activities. Follow up fast with needed information/ activities for students who need help.

Proactive Strategies for Go Public

	Type of Activity	Advantages & Possible Problems
Go Public 	Students demonstrate their knowledge and understanding in one of several ways: test, oral presentation, poster, project, role play, etc.	*potential advantages* • Students receive formative feedback to self-evaluate. *possible problems* • Providing students with appropriate guiding rubrics. • Providing timely feedback on students' work.

The teaching advantage of **go public** is three-fold: (1) it provides closure for the module, (2) it allows you to document students' learning in a variety of modalities and learning styles, and (3) it gives students the satisfaction and sense of accomplishment of answering the grand challenge. With the **go public** activity – especially if it is a project as opposed to a test, students can look back and measure their own growth of knowledge and skills. (Note that in contrast to the *formative* assessment of the **test your mettle** phase, **go public** is a *summative* assessment piece to make a final assessment of student learning – i.e., to assign a grade.)

Although **go public** options include a traditional test, students self-report that they "get more out of it" when the **go public** activity is a project in which they *apply* the knowledge they have gained along the way in answering the grand challenge. Such projects may easily be shared with the whole class, thus truly "going public" and providing a peer audience for the work as well as a teacher audience. Anecdotal evidence indicates that students remember their project-based **go public** experiences long after the close of a module.

As a teacher you can do three things to maximize students' success and your ease of grading in the **go public** experience:

1. Make the grading rubric clear. **Go public** is much easier for both you and your students if you provide a good rubric at the beginning of the task. Make your expectations clear – let students know up front which things count for how much. A good rubric makes your grading criteria visible and clear to students – which means that your students are more likely to submit an end product that is both easier to grade and more likely to merit a good grade. This does not mean that you tell them what to do – for example, a **go public** activity of creating a brochure to explain an ECG to a novice patient might have a rubric that includes 60 points for accuracy, 10 points for easy-to-understand for a novice, 10 points for neatness, and 20 points for creativity.

2. Incorporate multiple learning modalities. Allow students to demonstrate knowledge in a variety of ways beyond a traditional paper-and-pencil text. The human mind processes information in visual, auditory, and tactile/kinesthetic modalities, and your class will include students with each of these as an optimal learning style. Providing students choices and opportunities among these three (e.g., test vs. role play vs. brochure) ensures each student has a better chance to show what he or she has learned.

3. Make the time frame clear. If the go **public activity** is a project that extends over several days, provide a way for students to monitor their progress along the way (e.g., for a brochure, a first draft turned in at a prescribed time; for a role play, an outline of the proposed dialogue).

Now You've Bought In – What about your Students?

The first time that your students are asked to participate in a Legacy Cycle lesson they may be uncomfortable and unsure of this "new way of learning." After all, for years they have been "playing the academic game" (and playing it very successfully or they would not be in your college classroom!), and now with a challenge-based Legacy Cycle lesson some may perceive that you are "changing the rules in the middle of the game." No longer are they rewarded solely for repeating back what someone else has written or said or for solving a problem just like the homework set. It is important to clarify that this is a new game and to make its accompanying rules very clear -- make visible the invisible expectations of how to be successful in this type of learning. It may also increase student buy-in if you provide students with the rationale that Legacy Cycle learning has been proven to develop problem-solving expertise they must demonstrate in the real world of engineering, and remind them that engineers collaborate with others to solve problems and never have any of the answers in the back of the book. Instructors moving into Legacy Cycle lessons report that although some students may at first be reluctant to engage in this new challenge-based and active way of learning, once they experience it they tend to prefer it.

Conclusion

The National Research Council's monograph *How People Learn; Mind, Brain, Experience, and School* examined and distilled the research to inform educators *what* to do to encourage optimal learning. What was needed then was information on *how* to it. This manuscript provides a step-by-step guide to implementing effectively the Legacy Cycle method of structuring lessons and providing a proper learning environment that matches the standards set forth in the *How People Learn* framework

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