A Conversational Guide for the PBL Teacher: "Tragedy of the Commons"
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1. Problem Discussion and Identification

Welcome to this problem of Tragedy of the Commons, one that takes so many forms all around us! We have lots of helpful material for you to read and think about before you start this PBL journey. It is arranged in a web-based layered format for your ease of use. Here, our purpose is not to duplicate those materials, but rather to offer a top-level conversational informal guide as to how you may engage with the students, starting on Day 1 of the PBL project, all the way to the last day. We realize that this may be your first PBL project with students. Or, perhaps you are an old hand, and all of this comes very naturally to you! Either way, let's start.

1.1. Starting the Conversation with the Class

If I were teaching this PBL lesson to a class, beginning the next class after the one experiencing the BLOSSOMS video -- with lots of cows and grass --, I'd start by asking the students their reactions to it. Open ended, no agenda at first. See if they "get" the metaphor. See if they suggest examples of the metaphor in your own community or region.

My hunch is that "metaphor" will be a new word to most students. If you sense that, pause and have them reflect and gain some understanding of the term. Dictionary definitions tend to be somewhat circular and not all that clear. To me, a metaphor is a fictional story or narrative that can serve as a "model" for something real. A more dictionary-like definition is "An object, activity, or idea that is used as a symbol of something else." Some equate it to a "figure of speech," like, "Your family is so Simpsons!" The act of cows grazing (and then over-grazing) on the Commons is a clear metaphor for overuse of freely available public resources. Ask the students for other examples of metaphors, not even necessarily related to Tragedy of the Commons. If you're stuck, you can find examples of 100 metaphors here: http://bit.ly/2WmcD9Y .

1.2. How to Pick a Problem

Next you get to a class discussion related to Problem Identification – how might Tragedy of the Commons apply to our community? What might that mean. You might ask the students first to list, as many as they can, freely available public resources in your community. These can be very concrete, like sidewalks (pun intended ☺), to more abstract – like the air we breathe or even sounds we hear. (Here, silence is a freely available community resource that can be abused by noise.) My hunch is that a good 5-to-10–minute discussion, with you or a student putting suggestions on the blackboard, could give rise to at least 20 examples. Then you could ask the students,

> "Do any of these pose problems of overuse and abuse?"

At this stage, if you are lucky, the best problem(s) to work on would come from this list. But then, maybe not. If the students are stuck, and find no serious issues with any items on their list, then you could shift the discussion along the following lines:

> "OK, we do not see any major overuse issues associated with items on our 10-minute list. But remember, this list is a quick first pass, and most likely not complete! Separate from Tragedy of the Commons, what do you see as some of the major problems in our community?"

Here they start a new list. My hunch is that least one of these will fit the Tragedy of the Commons metaphor. Example: Smelly and unhealthy air pollution from local facility; maybe air was included in the first list, maybe not, but clearly is it a freely available public resource that can be abused, overused, and then – ultimately – collapse as a useful resource. There are industrial areas in China where air pollution reduces life expectancies of residents by over 5 years!

My hunch is that many student lists would contain items such as the following: public parks, public sidewalks, public roadways, public libraries, 911 emergency number, air we breathe, municipal water, …

On our website for Tragedy of the Commons, we have references that offer lots of different local problems to work on. You may have to "suggest" one or more of these to your students, if they come up dry. Most Tragedy-of-the-Commons problems align themselves naturally with mathematics (for resource depletion modeling) and one or more of the sciences (i.e., chemistry, biology, physics, earth sciences). This allows the students to see and build the linkages between what they have learned in class and what they see in the real world around them.

This process we have just discussed should conclude with agreement among the students and yourself on the one or more community problems that will be the focus (foci) of the student's PBL activities. As you wrap up this class discussion, you may want to ask the students about their conjectures about resource growth of use, peaking, and then collapse – as happened with cows and grass. Do they think there may be an analogous behavior for the problems they have identified to work on?

2. Student Teams

Now, suppose we have at least one and preferably more problems identified as Tragedy-of-the-Commons problems in our community. Then we have the issue of dividing the class into teams, each team to work on one problem for say, 3 to 5 weeks, the exact duration being your call.

Suppose, for example, the class has 28 students and each team will have four students. This implies 7 teams. If the class has identified 7 different Tragedy-of-the-Commons problems, then it's easy – a different problem for each team. But such luck is rare! If they have only identified one problem, then we have a real issue – each team is working on the same problem – not as good. More likely, you will find the class somewhere in between, say 3 identified problems for the 7 teams. So, it is likely that two or more teams will be working on the same problem.

How to handle that? Well, there is the laissez faire approach – let them work independently and compete! I think that is ok as long as the students do not need to speak with and "interview" local stakeholders associated with the issues being addressed. That is, for a purely library and/or Internet-based data acquisition process with no live interviews and observations, letting the student teams operate independently would seem to be fine. But, we actually would prefer community involvement, with workers in the facility and their customers (if this description applies) becoming involved and ultimately invited to the students' final presentation. In that case, we would suggest dividing the problem into parts or compartments, and have each team associated with that problem look only at their assigned compartments. It may take a "learning week" or so to sort this all out. Once formed and operating, the teams would then collaborate and meet together at least once a week, to share each other's progress and to chart out next steps.

On our website for Tragedy of the Commons, we have additional information about students and their working in teams – problems that may arise, independent of the specific PBL topic they are addressing. Examples: How do you make sure each student in a team is doing his/her fair share? How do you respond to discouraged students who find troubling working on an open-ended problem with no "right or wrong" answer? How do you respond to discouraged students who have gone down a dead-end and think they have wasted a lot of time?

3. Problem Formulation

Now the hard work begins! We have identified the problem, now we need to formulate our approach to attacking it. You will need to provide guidance to the student teams as they try to formulate the problem and then later come up with a plan to collect information (data) about it. With Problem Formulation, you have lots of flexibility on how to guide them. One approach I've found successful has several sequential parts:

(a) Describe "the problem." What is it about the system we are looking at that makes it problematic? A system with too much use and possible abuse, and threatening to get worse, perhaps much worse – leading towards system collapse? You may try to start this with an open class discussion, and then have each student team more formally state their problem and hand it in for your reading and constructive feedback.

(b) Who are the stakeholders and what are their interests?? If the problem is caused by a service or industry, with customers, then the immediate stakeholders are the employees at the service or industry and their customers. But if others in the community experience the system's negative effects (e.g., air pollution, sound pollution, water pollution), then all in the community may be stakeholders.

(c) What are the "system objectives" to be maximized or minimized? Examples: minimize pollution, maximize accessibility, maximize safety, minimize roadway congestion, …

(d) What are policies that can be changed or manipulated to improve things? Examples: Installing filtering systems to reduce pollution, change speed limits, time-of-day pricing of services, etc.

Expect that these four steps are iterative in nature and grow more sophisticated over the course of the PBL experience. You should ask for updates on these steps on each written weekly project review. **Also, a lot of these ideas will be new to the students, the ideas of stakeholders, system objectives and operational policies.** One way to bring them down to earth is to relate each of these ideas to the cows grazing on the green, as depicted in the BLOSSOMS video lesson.

On our website for Tragedy of the Commons, we discuss how over-fishing in part of the ocean or in a lake can lead to a Tragedy-of-the-Commons situation. The key is that fishermen need to leave enough fish in their fishing areas so that the fish can

reproduce and maintain a steady population. Else they die out, like the grass in the Commons case, and the system crashes. The example is brought to life in the BLOSSOMS video lesson, 'Ecological Tipping Points: When Is Late Too Late?'
https://blossoms.mit.edu/videos/lessons/ecological_tipping_points_when_late_too_late

4. Information gathering

Now the students become applied researchers, gathering data from multiple sources: library, Internet, local library, observation, stakeholder interviews, contributed data sets, etc. Some of this information will be descriptive, sufficient in detail to describe the system being studied in conceptual terms, perhaps using flow charts to show inter-relationships. Some will be statistical, that can be placed in spreadsheets. And some will be attitudinal, as garnered from interviews.

Since it is highly likely that the students, to be successful and thorough in their work, will need to interact with stakeholders, you may need to write a letter introducing them to relevant stakeholder communities. In some cases, you may have to seek their permission by direct phone or face-to-face contact before the students interact with them. One way to get stakeholders on board is to say that the students are seeking to help and not criticize. And invite them to the final student presentations.

There is no right or wrong answer as to what types of information and how much to obtain. The students will be highly constrained by the several-week time schedule of the project. We do not expect research-publishable results! But we do expect sufficient information and data from multiple sources to allow the students to come up with and defend their problem formulation and suggestions for system improvement(s). They can conclude their analysis, both oral and written, with a set of suggested Next Steps, if sufficient additional time were to be devoted to the problem.

5.   Mathematical modeling

The Project will likely draw on students' knowledge of at least one science, on mathematics and perhaps even engineering. The science will likely be imbedded in the steps described above. But the math stands out as being somewhat distinct. The idea is to approximate the "system output" as a function of system level of use (and abuse).   This is an exercise in mathematical modeling, an important general skill to develop over time. We do not expect a lot of sophistication in this step, but we do expect good thinking and several steps in a defendable direction for math modeling.

In the "cows-on-the-commons" situation of the BLOSSOMS video lesson, the math showed three distinct phases: (i) Initial linear growth in system milk output as more cows are added to the Commons; (ii) Diminishing returns and eventual leveling off, as adding more cows does not yield more milk from the system; (iii) system gradual crashing to zero output as too many cows results in grass not replenishing itself fast enough for what healthy milk-giving cows need, eventual weight loss of cows, death of the grass, and perhaps even death of the cows. The mathematical model is embedded into the BLOSSOMS web site here:

https://blossoms.mit.edu/legacy/tragedy/index.htm

In fact, there are four alternative mathematical models that can be studied via these animated simulations. **The students should become familiar with these and then think about the possible applicability of one or more of these models to the problem they are examining.** We expect that in most cases none of the four models on the "Cows-on-Commons" website will be perfect for the students' problems. In a few short weeks, we do not expect the students to then create their own animated simulations! But at the least, we expect them to describe in words the property of a function that approximates the situation they are studying, the x-axis representing level of use and the y-axis the system output (or perhaps system pollution or similar noxious output). In the straight system output case, they may find that one of the four functions on the BLOSSOMS web site follows their logic sufficiently closely to be a reasonable initial approximation. Again, this is not to be a refereed journal article, but it is the students' first attempt to model in an approximate aggregate way a complex system within their own community, with the idea of offering suggestions for improvement.

6. Meaningful analysis to present to audience for action consequence

At the conclusion of the PBL exercise, the students on each team should present their results, both orally and in writing. Our preference is 10-minute oral presentations, aided by PowerPoint slides – and when appropriate - short student-made videos. Also, when appropriate, our preference is to invite stakeholders who assisted the students in their work to come to the presentations. They should be invited to make brief comments after the students' presentations.

The students' analysis should be organized into a logical, coherent structure. They could start by reviewing their work under the organization of Section 3 [(a), (b), (c), (d)], and then proceed to present their activities, findings and recommendations. As they will only have about ten minutes, they will have to be very organized and pithy. Their accompanying written report (about ten pages) can provide somewhat more detail. They should emphasize that their work is not meant to be critical but rather helpful, with potentially useful suggestions for change. Also, they need to be humble, as their work represents only a few weeks of work and it is likely that

any suggested change needs to be more heavily vetted in a follow-on effort, prior to actually implementing any change.

If the report and accompanying materials are of high quality, the students may wish to add the report to their **personal high school portfolios of accomplishments and artifacts.** In that case, you will need to e-sign them to verify authenticity, especially important if the materials are to be used later in college applications.

7. Brainteaser extension – Reverse Tragedy of the Commons

[On our website for Tragedy of the Commons](#), we offer material for advanced students who may want to look at an inverse problem: "The Reverse Tragedy of the Commons." The usual metaphor has selfish players overusing the shared free public resource for their own narrow benefit, but having negative consequences for the community as a whole. The Reverse Tragedy of the Commons has individuals taking a particular action that benefits not only them, but also others in the community that they likely do not even know!

The classic example is acquiring immunity from a contagious disease, usually by vaccine injection. Getting the vaccine not only prevents you from acquiring the disease but also the unnamed unvaccinated others who you likely would have passed the disease on to, if you had not been vaccinated and were to become infected. This twist is probably too complicated to use for a PBL multi-week exercise, but it certainly could be a topic for an advanced in-class discussion in a final wrap-up class, once the entire multi-week exercise is completed.

8. Getting There

Finally, what we have omitted until now is all the logistics of scheduling during the multi-week PBL process. You will need to design the process so that the students understand what is expected of them, and when. Best to have required Friday (end-of-week) team progress reports submitted to you, for weekend review, and given back the following Monday. The initial published schedule, prepared by you, should list the milestones expected each week, to be covered in the weekly progress reports. This is a bit tricky, because we do not want to over prescribe. Too much handholding takes away from the students' own new learning related to project design and management.

[On our website for Tragedy of the Commons](#), we provide an example of a plausible schedule, for a 5-week PBL exercise. But we expect your details to be different, as each class PBL situation is different.

Also, the students will need your plan or rubric for evaluating and assessing the quality of their work. This need not be formulaic as your "grades" for the efforts will of necessity be subjective. There is no standardized test that the students will take related to PBL. And subjective evaluations, done routinely in the arts and humanities, can be more nuanced than numerically scored test evaluations. The students need to design their work to be responsive to your plan or rubric.

On our website for Tragedy of the Commons, we offer one possible rubric for your consideration.

Thank you for trying this PBL exercise. Have fun and Good Luck!