TIEE

Teaching Issues and Experiments in Ecology - Volume 12, March 2017

PRACTICE

Understanding Causes of Reservoir water quality deterioration using Socio-environmental Synthesis approach

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ABSTRACT

In this seven-week module, students explore the focal question: what are the major socio-environmental and biophysical factors causing deterioration of water quality in the Liberty Reservoir (primary source of drinking water for Baltimore). Students first generate a list of what they would need to know to answer the focal question and then produce pre-systems map in their assigned 'expert' groups (land use, climate change, policy/politics and social). Students from each 'expert' group mix to form 'synthesis' groups and then produce post-systems map and final report. This two-level Jigsaw method entails distilling and integrating data and ideas

KEYWORD DESCRIPTORS

- **Ecological Topic Keywords:** watershed, reservoir, abiotic factors, ecosystems, human impacts, land use, water, water quality, drinking water
- **Science Methodological Skills Keywords:** data analysis, library research, oral presentation, data acquisition, quantitative data analysis, use of primary literature, report writing
- **Pedagogical Methods Keywords:** assessment, background knowledge, brainstorming, cognitive skill levels, concept mapping, formal group work, jigsaw, problem-based learning (pbl), role playing

CLASS TIME

The module takes place over 7 weeks, using lab hours (3 hours per week) and part of the lecture for group work and in-class presentation.

OUTSIDE OF CLASS TIME

Estimated at 10-15 hours, depending on level of engagement.

STUDENT PRODUCTS

Students generate:

1. the What Do You Need To Know (WDYNTK) list for addressing the focal questions
2. expert group pre-systems map
3. narrative (expert group) report and oral presentation
4. revised systems maps
5. final synthesis report and final oral presentation

SETTING

In order to provide access to data and information, a computer lab is used for the implementation of this module.

COURSE CONTEXT

The module is designed for upper level science students majoring in one or more of the following areas (Biology, Chemistry or Geography).

INSTITUTION

Public, comprehensive university.

TRANSFERABILITY

The module was developed at Coppin University, an urban Historically Black College. The SES method used in the module can be used in any other science course as it involves distilling and integrating data, ideas, and theories in understanding of a real world issue. It is suitable for meeting the Student Learning Objectives in many science classes. Use of the module in places that are distant from the Liberty Reservoir could necessitate substitution of a similar drinking water source nearer (and therefore more locally relevant) to the site of implementation. See section 4 below for more discussion about this and other challenges for implementation (e.g., time management).

ACKNOWLEDGEMENTS

This project was part of a multi-institutional study supported by the NSF Socio-Environmental Synthesis Center to assess the effectiveness of teaching socio-environmental synthesis (SES) using different pedagogical approaches in a variety of undergraduate institutional settings. I thank all of our colleagues from the participating institutions (Washington State University (Vancouver), University of Maryland College Park, Gallaudet University, Widener University) and Alan Berkowitz of the Cary Institute of Ecosystem Studies. This work benefited from support from the National Socio-Environmental Synthesis Center (SESYNC) - NSF award DBI-1052875.

SYNOPSIS OF THE MODULE

Principal Ecological Question Addressed

The Liberty Reservoir is the primary source for the drinking water supply of Baltimore city and much of the surrounding County. The reservoir's water quality has been deteriorating over the last decades. The focal question is what are the major socio-environmental and biophysical factors that cause water quality deterioration?

What Happens

This module was tested in an Earth and Space Science class which consisted of 20 students majoring in Biology, Chemistry, Geography and political science. Students investigate the underlying causes of water quality deterioration in the Liberty Reservoir watershed. Based on the focal question, students are asked to come up with a list of direct and indirect factors that affect water quality deterioration. The whole class reviews the lists together and categorizes them into four components: Land Use, Climatic, Social and Policy/Politics. Using the jigsaw approach, five students are assigned in each "expert group" that does detailed qualitative and quantitative research on how their 'category' causes water quality deterioration in the liberty reservoir. Each group produces pre-systems maps (socio-ecological systems map), writes a narrative report and gives an oral presentation to the whole class. In step two of the Jigsaw, students are assigned to 'synthesis' groups with one member from each 'expert' group. Each synthesis group revises the pre-systems maps, writes a narrative report and gives an oral presentation. At the conclusion of the two jigsaw exercises, students (as a class) review the pre and post systems maps and discuss the "evolution" of their thought process.

Module Objectives

- Students will define scientific problems using systems approach.
- Student will interpret the components, processes, and dynamics of watershed systems and reservoirs
- Students will research, analyze and interpret existing publicly-available data specific to liberty reservoir
- Students will understand the biophysical and social dimensions of the reservoir water quality deterioration
- Students will synthesize (from various perspectives) and communicate research priorities to a general non-expert-audience

Equipment/ Logistics Required

Students need access to socio-environmental datasets. They will analyze data to write narrative reports.

Summary of What is Due

- A list containing “What Do You Need to know” (WDYNTK),
- Expert group pre-systems map (group report),
- Narrative report explaining the interconnectedness between factors on the pre-systems maps (group report),
- PowerPoint slides for oral presentation by the ‘expert’ group (group report),
- Revised concept maps by ‘synthesis’ group (group report),
- Final narrative report (group report)
- Final oral presentation (group report)

DETAILED DESCRIPTION OF THE MODULE

Introduction

Liberty Reservoir is one of three reservoirs (along with Loch Raven and Prettyboy) that supply drinking water to all of Baltimore City and much of surrounding Baltimore County. This system is partially designed and fully maintained through the city's Department of Public Works. The Liberty Reservoir and Dam are located on the North Branch of the Patapsco River on the boundary between Baltimore and Carroll Counties. From this source, raw water is supplied

by gravity for treatment to the Ashburton Water Filtration Plant through a 20 km long and 3 meters diameter tunnel.

In June 2003, the National Resources Defense Council (NRDC) conducted a study titled “What's on Tap? Grading Drinking Water in U.S. Cities” and subtitled “The NRDC reports on the drinking water systems of 19 cities and finds that pollution, old pipes and outdated treatment threaten tap water quality.” Baltimore City was one of the 19 cities in the study during 2000-2001. Three key contaminants were found: Lead (from the corrosion of pipes or faucets), Haloacetic Acids (HAAs, by-products of chlorine disinfection), and Trihalomethanes (TTHMs, results when chlorine is used to treat drinking water and then interacts with organic matter in the water). Overall, Baltimore earned a Water Quality and Compliance grade of failing for the year 2000 (Koterba and Kraus, 2011).

Maryland Department of Environment (MDE, 2012) also identified Liberty Reservoir as one of the watersheds that failed to meet water quality requirements. Liberty Reservoir was categorized as category 5 – impaired by chromium, lead, nutrients, suspended sediments, methyl mercury and fecal coliform. Agricultural development occupies 40% of the watershed and releases excessive amounts of total N, P, NO_3, and Ammonia. Urban development constitutes 23% of the watershed. Excessive chloride is released from sewer/septic sources. The concentration of disinfection by-products (DBP) has been increasing. An emerging issue is the impact of climate change on water quality deterioration. Extended droughts followed by intense precipitation, one of the results of climate change already taking place in the region, is believed to cause water quality deterioration (MDE, 2012).

In this module you are expected to research the underlying socio-environmental and bio-physical causes of water quality deterioration in the Liberty Reservoir using the socio-environmental synthesis (SES) approach. SES integrates existing knowledge and data from natural and social sciences to advance understanding of complex socio-environmental systems. Based on the given focal question of this module, you need to develop a list of factors that affect water quality and in your assigned ’expert’ group (Jigsaw one), produce a pre-systems map. In order to explain the relationship you indicated on the systems map, you need to use both qualitative and quantitative data. At the end of the first jigsaw exercise, you are expected to write a narrative report and give an oral presentation. Jigsaw two begins with forming ‘synthesis’ groups by taking a member from each ‘expert’ group. Each group revisits the pre-systems maps and

produces a revised map (post-systems map). The group writes a synthesis report and gives an oral presentation on how their component (land use, climate, policy/politics and social) contribute to water quality deterioration. Table 1 below presents a detailed list of activities and expected products.

Materials and Methods

This module focuses on water quality in the Liberty reservoir. You are expected to find and analyze appropriate datasets from local and national sources. Possible data sources are provided under "Links for data acquisition" section below.

Overview of Activities and Assignments: This module takes place over 7 weeks. The table below shows the overall schedule of activities. Please address the focal question following the detailed activity schedule given below.

Table 1. A detailed list of activities and expected products

Instructional Schedule	Activities	Product
Week 1	• Pre-assessment • Sharing ideas in small groups • Creating socio-ecological systems maps • Form Expert Groups for Jigsaw one	• Submit WDYNTK list for the focal question (Challenge question.docx)
Week 2	• Each expert group gather to review literature and collect data to produce systems map using the research prompts (Research Prompts.docx)	• Literature review on the focal question, produce graphs on systems components
Week 3	• Expert group produce systems map, writes report and gives oral presentations	• Expert group submits pre-systems map and report • PowerPoint presentation by expert group
Week 4	• Synthesis groups formed • Each group reviews the synthesis assignment and starts to gather information	• Gather data and additional resources

Instructional Schedule	Activities	Product
Week 5	• Groups continue to gather and analyze data	Produce graphs & establish relationship between water quality and system components
Week 6	• Groups revise systems maps and writes report • Prepare PowerPoint presentation	• Produce draft systems map and synthesis report
Week 7	• Synthesis Product submitted and oral presentations given	• Post-systems map produced • Written report submitted • PowerPoint presentation by synthesis group

Week 1:

Pre-Assessment: Prior to class, think about the focal questions below:

What are the major socio-environmental and biophysical factors causing deterioration of water quality in the Liberty Reservoir (primary source of drinking water for Baltimore city)?

Generate a typed list – What do You Need to Know (WDYNTK) - of everything you would need to know in order to answer the focal questions. Be as specific as possible, and think as broadly as possible. Remember, you are not being asked to actually answer the questions, just to lay out everything you'd need to know in order to do so. Bring two copies of your type-written list to class, one to turn in at the beginning of class, and the other to use in a small group for the next step.

In-Class:

1. Students turn in their WDYNTK list and the instructor facilitates class discussion to categorize related items on the list to create components of the system.
2. Expert groups (5 per group) are formed based on the components/categories created in step 1. Students will be given the choice to select expert groups based on their interest.

3. Each student within their expert group share WDYNTK ideas. Write down each item onto individual post-it notes. On a white/black board organize the post-it notes into categories or groups that make sense to you and your group. Feel free to re-write, modify or refine the items as you go. You may want to move the post-it notes around several times to see which spatial arrangements best represent the ideas and relationships you think are important.
4. Based on the arrangement of the post-it notes, create a "systems map" that shows how the items (groups or categories) relate to each other and to the focal questions. Draw lines between ideas that are related (i.e. articulate relationships among systems components) and write a brief (2-3 words) description next to each line that defines the nature of the connection. Ideally, your diagram will show your best thinking about the system that applies to our focal question.
5. Divide task within your 'expert group' to gather information/data on the components you identified on your systems map
6. Begin working on expert group assignment.

Out-of-Class:

Continue working on the systems map components. Individually, students will gather information/data specific to the systems component (climate or land use, social or policy/politics groups) they are assigned to.

Week 2:

In-Class:

1. Expert groups continue to gather information/data relevant to their focus of study and explain how these component affect water quality in the reservoir.
2. Start working on expert group's report and presentation.

Out-of-Class:

Continue working on data gathering, analysis, report and presentation

Week 3:

In-Class:

1. Turn in your systems map (snap a photo and submit through blackboard link) and your WDYNTK list of the ideas with any additions or

subtractions you made that relate to the questions based on your group's discussion.

2. Turn in expert group report
3. PowerPoint presentation of 'expert' group report
4. Forming synthesis groups. Synthesis groups are formed by taking one 'expert' from each of the expert groups.

Out-of-Class:

The newly formed synthesis groups review the expert group systems maps.

Week 4:

In-Class:

1. Synthesis groups work on their Synthesis assignments

Out-of-Class:

Continue working on gathering additional data and information

Week 5:

In-Class:

1. Synthesis groups continue working on their products
2. Instructions for revising the group systems maps will be provided.

Out-of-Class:

Continue working on synthesis products

Week 6

In-Class:

1. Groups revise systems maps and writes synthesis report
2. Prepare PowerPoint presentation

Week 7:

In-Class:

1. Synthesis group presentations
2. Synthesis group report submitted
3. The whole class discusses on how their ideas have evolved over time. The key discussion question is what did the synthesis groups modify

on the maps they inherited from the expert groups and why did they do it?

Questions for Further Thought and Discussion:

1. How did water quality in the Liberty Reservoir change over the past two decades and how does the SES approach help us to understand the problem?
2. How do land use pattern and climate change affect water quality?
3. What are the existing watershed management policies?
4. How do social-economic factors affect water quality?
5. What are sustainable solutions to mitigate water quality deterioration?
6. Review an article from the journal Science that discusses water quality deterioration and write a one page summary and critique.

References

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Maryland Department of Environment. 2012. Watershed Report for Biological Impairment of the Liberty Reservoir Watershed in Baltimore and Carroll Counties, Maryland Biological Stressor Identification Analysis Results and Interpretation. http://www.mde.state.md.us/programs/Water/TMDL/Documents/BSID_Reports/LibertyRes_BSID_25Jan2012_final.pdf

Articles for reading

Margaret Palmer. 2012. Socioenvironmental sustainability and actionable science. Journal of Biosciences. Vol. 62 No. 1. doi:10.1525/bio.2012.62.1.2 http://bioscience.oxfordjournals.org/content/62/1/5.extract

Cynthia Wei, William Burnside, Judy Che-castaldo. 2014. Teaching socio-environmental synthesis with the case studies approach. Journal of Environmental Studies and Sciences March 2015, Volume 5, Issue 1, pp 42–49. http://link.springer.com/article/10.1007/s13412-014-0204-x#page-1.

Links for data acquisition

1) http://pubs.usgs.gov/sir/2011/5101/pdf/final_sir2011-5101_508.pdf

This link provides a comprehensive (25 years) water-quality monitoring and land use change data for the Baltimore Reservoir System.

2) http://www.mde.state.md.us/assets/document/watersupply/SWAPS/Baltimore%20City/Liberty%20SWA%20Report%20w%20apx%20A.pdf

This link provides land use change and elemental analysis data for liberty watershed

3) https://gis.ncdc.noaa.gov/maps/ncei/normals

This link provides hourly, daily and monthly climate (Temperature and Precipitation) data for local and regional areas

4) http://climate.nasa.gov/

This link provides long term Carbon dioxide and temperature changes at local and global scales

5) http://www.usclimatedata.com/climate-on-your-site.php?id=usmd0591

This link is a US Climate data repository and provides a detailed data on temperature, precipitation, snowfall and solar radiation.

Tools for Assessment of Student Learning Outcomes

Assignment	Student Learning Objective Assessed	Assessment Tool
Pre-systems map	Scientific and Quantitative analysis Critical Analysis and reasoning	Rubric1.doc
Narrative report	Written and oral communication, Information Literacy, Scientific and Quantitative Reasoning	Rubric3.doc
Expert group oral Presentation	Written and oral communication, Critical Analysis and Reasoning,	Rubric2.doc
Synthesis report	Written and oral communication, Critical Analysis and Reasoning	Rubric3.doc
Synthesis group presentation	Written and oral communication, Critical Analysis and Reasoning	Rubric2.doc

NOTES TO FACULTY

Challenges to Anticipate and Solve

Challenge 1. Data acquisition and analysis – Many students have difficulty in acquiring datasets. This can be addressed providing them few data source sites

(please refer to 'links provided for data acquisition' section). Students are expected to obtain multiple years of data on the socio and bio-physical variables (climate, income profile and land use) they are assigned and calculate mean/average and present their results in the form of charts/graphs. Students also struggle conducting the needed analysis due to limited exposure to mathematical concepts. I addressed this issue by refreshing some of basic steps in data acquisition, analysis and interpretation using the following resources (http://www.excel-easy.com/data-analysis.html and http://tutorials.istudy.psu.edu/basicstatistics/). Where more assistance was needed, I referred them to the Math tutorial lab, a student support system on campus.

Challenge 2. Making 'systems maps' - Students were challenged by conceptualizing ideas and showing the interconnectedness between and amongst them. I addressed this issue by providing them a detailed handout on "how to make conceptual maps" https://library.usu.edu/instruct/tutorials/cm/CMinstruction2.htm

Challenge 3. The concept of SES - some students had difficulty in grasping the whole concept of "Socio-Environmental Synthesis" (SES). They tend to forget the notion that SES embraces both the social and bio-physical aspects of an environmental problem. I addressed this challenge by asking them to read an article (https://academic.oup.com/bioscience/article-lookup/doi/10.1525/bio.2012.62.1.2) from the journal BioScience and write a summary and critique.

Module Description

Introducing the Module to Your Students:

I introduce the module 3 weeks after foundational lessons on earth systems, watershed management, water quality and basic concepts of Environmental sciences. During the lectures, I inject some aspects of the SES module and the assignment they should expect. On the day the module officially starts I explain the goals of the module, its approach, expected outcomes, the jigsaw steps and assessment and evaluation of the products.

Comments on the Data Collection and Analysis Methods Used in the Module:

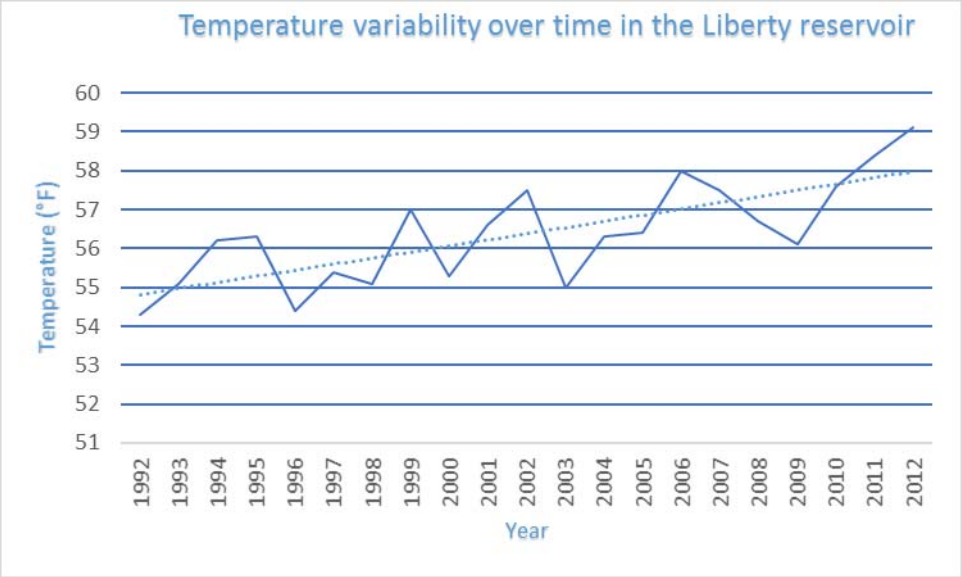
When the module was introduced, I had informed each working group to include data to justify/ explain their argument/claim about issues. Accordingly the climate group collected 20 years of precipitation and temperature data to establish a relationship between climate change and water quality deterioration. Likewise the land use group collected 20 years of land use change data and correlated that with the changes in water quality. The policy/politics group investigated the existence and enforcement of local, state and federal legislations on watershed management. The socio-economic group looked into income inequality, level of education and awareness and their impact on watershed management.

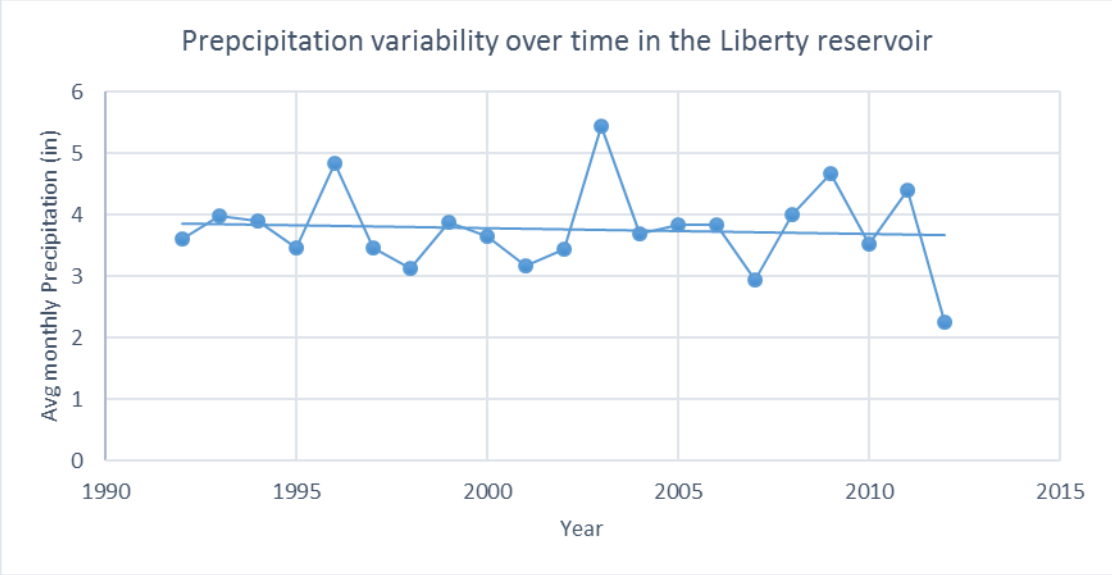
Comments on Questions for Further Thought

I gave the following prompt questions to stimulate discussion amongst working groups.

1) How did the Liberty Reservoir water quality change over the past two decades and how would the SES approach helps to understand the problem and find solutions?
    a. Students could refer to the reports by EPA (Environmental Protection Agency) and MDE (Maryland Department of Environment) to discuss the deteriorating water quality in the reservoir systems of the Baltimore city drinking water supply. Since SES approach is based on a holistic understanding of the problem using large existing datasets, it is a suitable tool for watershed studies.

2) How did the land use pattern and climate change over the past two decades?
    a. By this question, students are hinted to review 20 years of climate and land use data to investigate how these factors affect water quality. Examples given below.





1) What are the existing reservoir water management policies and how did they change over time?
    a. Students are expected to review the state and federal water management policies/legislations and establish a relationship between the current quality deterioration and policy changes. They need to specifically research whether the quality

deterioration is the result of lack of policy or lack of enforcement of existing policy.

2) How do social factors affect water quality?
    a. Students are expected to look into some of the socio-economic factors that affect water quality. Specifically, they need to investigate how education (awareness) on water management and social strata (economic) affect water quality.

3) What are the sustainable solutions to mitigate water quality deterioration?
    a. Students are expected to discuss economically feasible and environmentally sound solutions to avert water quality deterioration.

Comments on the Assessment of Student Learning Outcomes:

A number of student learning outcomes (SLOs) can be measured through the implementation of this module, and customized rubrics to measure each SLO are available. By providing the rubrics to students ahead of time, they understand the competencies they are expected to master and that they are going to be assessed on. Computational competency, critical thinking and reasoning and scientific writing are among the most important SLOs targeted in this module. During the meeting of the working groups it is useful to go around to make sure that students are reminded of these competencies. Peer evaluation of SLOs was an effective approach since students are often more willing to receive constructive feedback from their peers than from their professors.

Comments on Formative Evaluation of this Module:

To understand the impacts of the SE module, a pre- and post-survey was conducted. The pre-survey focused on student demographics and level of comfort with interdisciplinary and/or synthetic thinking as well as how much basic content knowledge students had. The finding of the pre-survey (Pre-systems map survey) gave me an indication that I needed to go deeper on the foundational knowledge of socio-environmental systems. In addition, it also gave me an idea to give students with specific guidelines on how to make systems map.

Once the students submit their pre-systems maps and report, feedback was given before they continued working in the synthesis groups. The feedback helped them to go deeper in their research and analysis of the information they were gathering.

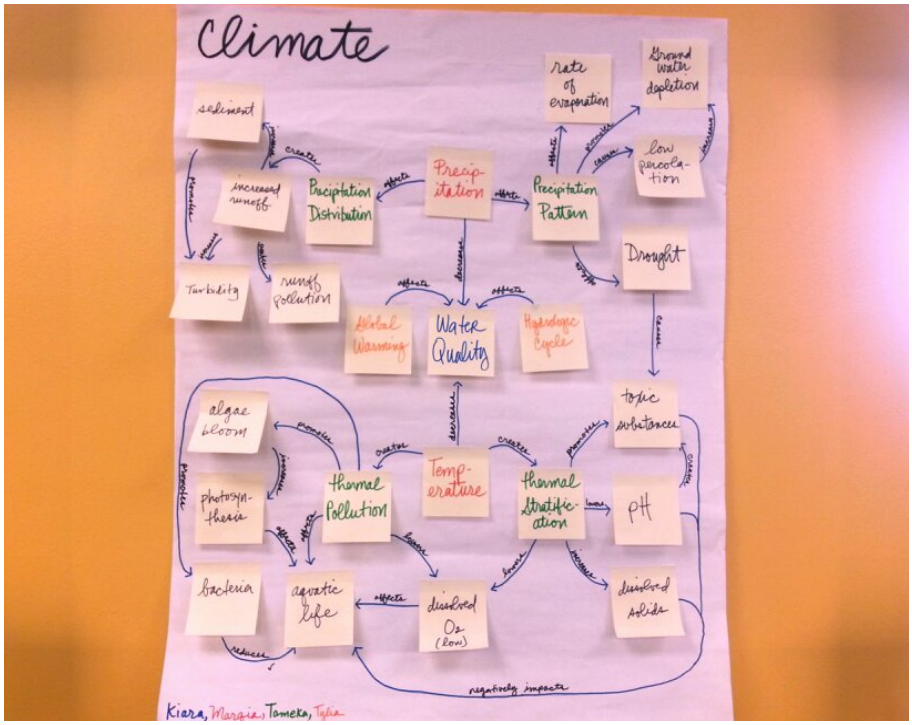
At the end of the synthesis group assignment, students submitted their post-systems map and final report and they were then asked on a post-survey (Post-module survey questions) what changes they observed in themselves after this exercise. Many students responded that they were able to understand the complexity of the problem in the synthesis group than working in the expert group. Students also acknowledged that they are more effective working as a group in-class than outside the class. This feedback helped me to review the schedule of activities and deliverables.

Comments on Translating the Activity to Other Institutional Scales or Locations:

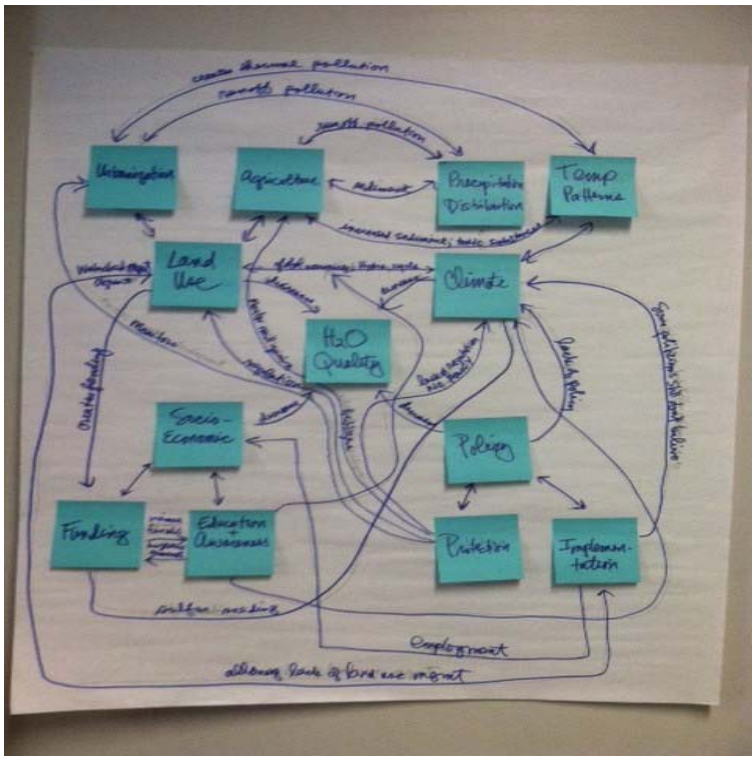
The module is well suited for class sizes between 15 and 25 with a diversity of majors (biology, geography, chemistry, social science). It can be scaled-up to multi-sections but it is important to maintain diversity during group formation. In addition, the module can be introduced in any General Ecology or Environmental Sciences course.

STUDENTS COLLECTED DATA FROM THIS MODULE

Here are samples of pre and post system maps that were produced by the expert and synthesis groups. The first two sets are pre-system maps of the Climate and Policy/politics expert groups during Jigsaw 1 exercise. The climate group analyzed 20 years of precipitation and temperature data and produced a concept-map and the policy/politics groups reviewed significant number of local, state and federal legislations related to watershed management.



Policy/Politics group



Below are examples of two post-systems maps produced by two synthesis groups. The difference between the pre and post systems maps in terms of the level of complexity and the depth of interaction shows how deep students in synthesis groups are able to see the problem.

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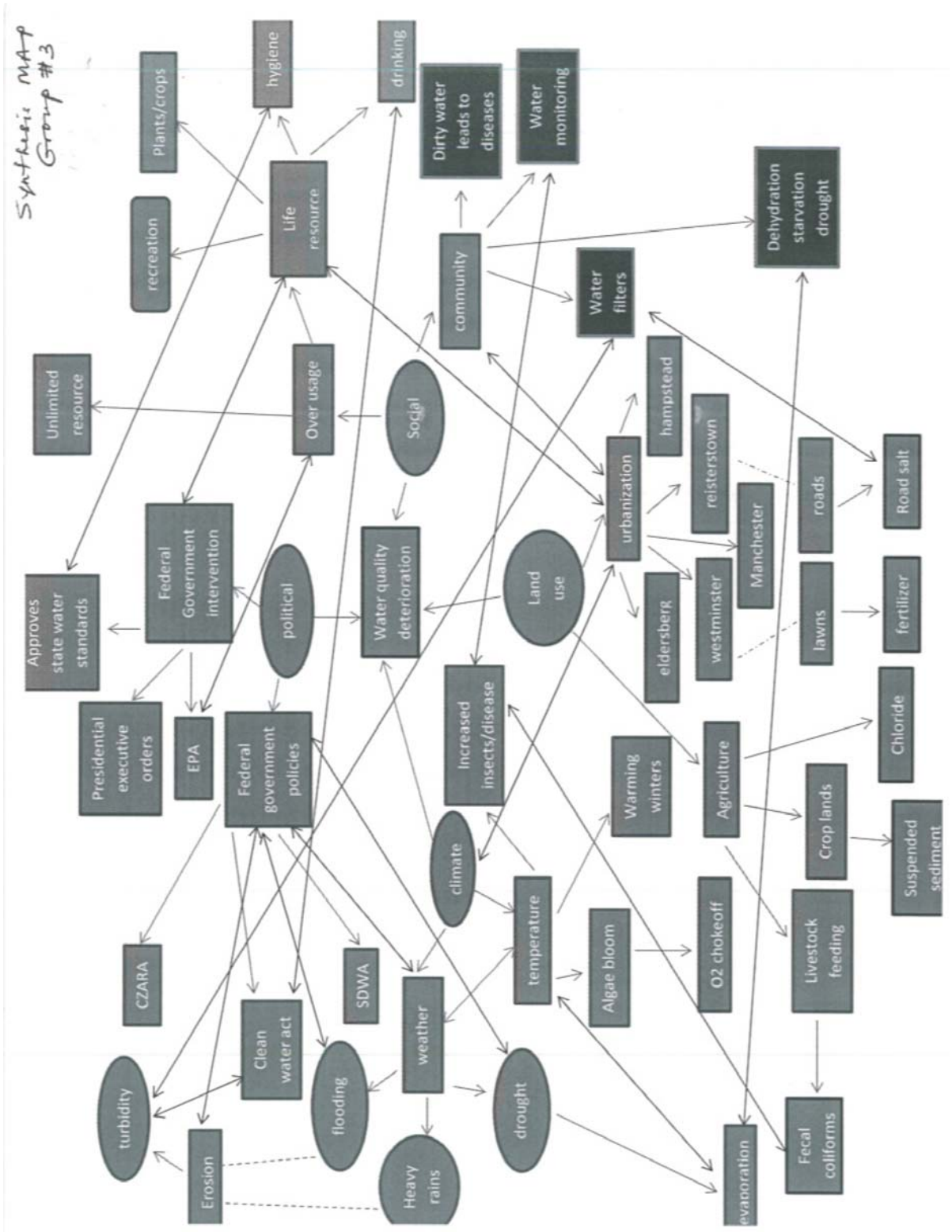

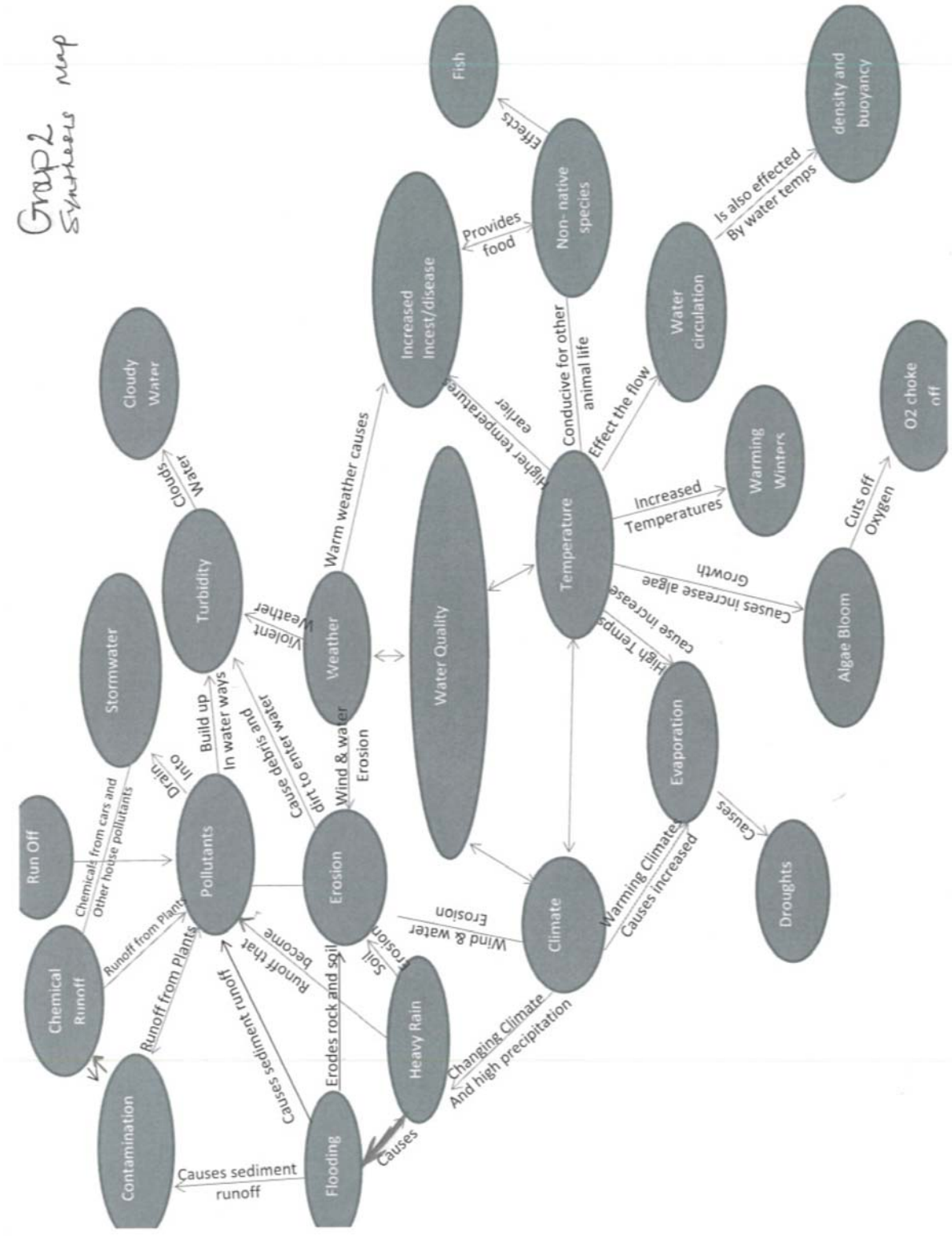

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