TEACHING AND LEARNING PORTFOLIO

by

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I. Portfolio Introduction – Not many, but one "hat".

Here I outline a handful of the experiences that have helped shape how I view teaching, mentoring, outreach, and their interactions in science. We are in unique positions as teachers in science in that we are often tasked with both advancing our understanding of the natural world and communicating our understanding of it. While we push at the boundaries of our own knowledge, we are simultaneously training new generations of scientists, educating students with both science- and non-science-related long-term goals, informing the public of our findings, and working to ensure that our discoveries change how society values and interacts with the natural elements that we study. Some scientists describe this as "wearing many hats". To me though, I see being a teacher in science as an ideal manifestation of who I am and what I am about – to me there is only one hat and that's my own. In science, I get to explore the questions that I find most need answering, I get to encourage and help develop academically young students into the professionals they hope to be, and I get to share my enthusiasm with the many people who's lives overlap, possibly very little and without even knowing it, with elements of my research. If I view science as both discovery and education regarding that discovery, I get to wear *my* hat, and I will always be grateful for that privilege.

The UW Madison Delta Program has been an instrumental force in not only allowing me to wear my own hat, but in helping me decide the traits I value in a hat. Delta has provided numerous resources in the form of mentors, courses, teaching experiences, and community that have shaped who I am today professionally and, I hope, will continue shape who I become in the future. The three Delta Pillars, Teaching-as-Research, Learning Communities, and Learning-Through-Diversity are near-constants that I can apply in any of the professions available to me next. These pillars give me a foundation and a framework for further developing who I am and the hat I choose to wear in the face of a diverse range of professional skills that I hope to acquire. Therefore, in addition to a review of some of the pivotal experiences in my development, the following portfolio is a testament to the utility of the Delta Pillars in an instructional setting, whether that's traditional teaching, mentoring, or outreach.

The Delta pillars are inherently linked to one another and were developed as the basic foundation of good teaching practice. Through the iterative process of **Teaching-as-Research**, I am able to apply the research skills I've developed in my PhD work to advancing my own teaching practices and contributing to the greater teaching community. Most importantly, teaching-as-research ensures that I am continually engaged in improving my own teaching and in maintaining an expertise in current effective teaching practices. **Learning Communities** are developed to promote a collaborative and inclusive learning environment where learners and instructors work toward common learning goals. Developing my understanding of learning communities through my work with Delta has helped me mentor and instruct students who are able to conduct research, teaching, and outreach (their own learning communities) more independently. **Learning-Through-Diversity** has allowed me to capitalize on the strengths, skills, and background that students and teachers bring to learning communities. Diversity forms the substance of effective learning communities. These pillars have served as stitches to knit together pieces of many hats into the hat that I wear and will give me the necessary tools to tailor its fit as my career shifts and changes.

II. Teaching Philosophy

Teaching and learning in science: science in learning and teaching.

Science is pushed forward by researching pioneers and an informed, supportive community. Neither of these is created spontaneously, but each is the result of successful learning and teaching experiences. Through a foundation in undergraduate education, research mentoring, and informal education, we can train scientific pioneers and well-educated citizens capable of solving real world problems. I nest my teaching values in developing general scientific skills that range broadly from the scientific process and how it can be used to learn independently, to clear and effective outreach. Developing these skills enables all students, regardless of their career choice, to think critically about how they process information and how they approach real-world scientific discussions.

Learning through the scientific method – While closely paralleling our current understanding of learning theory, instruction through the scientific method also shapes how students view and approach the world around them. I've developed exercises that teach students to tease apart complexities of problems encountered in an upper-level ecology course. This includes identifying knowledge gaps in scientific literature, forming hypotheses, designing experiments, analyzing results, and effectively collaborating with other researchers. Each exercise goes alongside in-class assignments, integrating teaching the scientific method into already busy course schedules. These exercises can be applied at multiple learning levels (i.e. introductory level to upper level courses), incrementally developing proficiency in the scientific method. In turn, students develop critical thinking skills that improve their ability to direct their own learning, which is particularly important after they move on from a formal academic setting.

Application of learning to real world problems and student values – Acquiring and applying course-specific knowledge exists in a positive feedback loop, particularly if it's in an area of personal value. In limnology, I had students pick a river or lake important to them. Limnological concepts learned through the course were applied to these bodies of water, and they were used as a reference point of interest to assess and apply course material. I also developed a role-playing game that puts students in the shoes of various stakeholders in real-world ecosystem management issues, World of Watershed Management. Students found this to be an entertaining activity that gave insight into the complexity of stakeholder values that influences the outcomes of management decisions. Personal and engaging activities like these better involve students in the learning process and build stronger learning communities among students.

Flexibility and integrating seemingly disparate fields in education - Problem solving in complex, interdisciplinary systems is becoming the norm for scientists. Instructors need to equip students to be integrative, drawing from multiple fields to solve problems. One way I achieve this is an exercise where we hypothesize about how different courses they've taken could overlap to address real world problems. This is particularly effective in introductory courses; students haven't been exposed to many courses, but it helps start the discussion of integrating their whole undergraduate education early in their careers. Students will rarely be asked to solve larger problems using knowledge gained from a

single course, so in class I make sure to involve multiple disciplines that intertwine with ecology-related problems. For example, economics is an excellent complement to ecology. Ecology is an inherently integrative field, however this could be applied to a wide range of biological disciplines, many of which are becoming more connected. Programs like UW's Freshman Interest Groups (FIGs) program are widely utilized at undergraduate institutions. They provide excellent avenues for undergraduates to begin their educations with this integrative philosophy and I aim to build on programs like this with my teaching.

Integrity and Self-Evaluation - Integrity not only includes conducting yourself ethically, critical in science, but also applying yourself to your career. To emphasize this, I include students in progress evaluation. To develop this skill, students need a clear description and rationale of my expectations of "high quality" work, provided in course syllabi, rubrics, and assignment descriptions. This coaches students to set high standards, attainable through progress evaluation, and understand steps to reach those standards. It also teaches students to be "good reviewers" of others, both critical and constructive. This approach has required abundant and frequent feedback from me, but it has paid off in students' awareness of their own learning.

Science in life - The final product of this approach is a young scientist able to utilize general and course specific knowledge in their careers and everyday lives. For many, the journey in research-based science ends with a single "science" course requirement, while others go on to post-graduate studies and/or careers. Instruction must be inclusive of these diverse goals to prepare students for their next steps. It's one of my primary efforts to ensure I'm aware of students' career goals throughout our interaction. This involves both brief surveys at the beginning of a course and taking advantage of one-on-one conversations.

Commitment to outreach and teaching outreach skills to young scientists – In the same way that instructors need to be helpful toward students with a variety of career goals, the field of science as a whole should be sensitive to the diversity of the public. In order to adequately include all the stakeholders in scientific questions and pursuits, outreach is of the utmost importance. Clear and effective outreach is best achieved by introducing young scientists to the skills necessary to conduct it early in their careers, building the foundation of a lifelong commitment to public service. I conduct my own outreach through participation in the Outreach Committee at the UW Center for Limnology, teaching middle school age community courses through the CFL, and engaging with lake associations in Northern Wisconsin about managing invasive species' spread and impacts. I also engage my mentees in many of these same events to help foster a value of outreach early in their education. I hope to participate in or help develop a similar culture of outreach in the next steps of my career.

I strive to shape students into independent thinkers able to deal with diverse problems. By including development of general scientific skills, we equip students to apply their unique understanding and skillset to their careers and to elements of their world that they value.

III. Commitment to Training and Educating Outside of the Classroom

In the following sections I develop the work I've done mentoring undergraduates and high school students, developing and participating in outreach activities, and working to foster a value of outreach in my mentees. Outreach and mentoring are natural extensions of my values and my personality. Because of this, I feel that the work I've done with each has been an integral component of developing who I am and who I want to be as a scientist and a teacher. While I truly enjoy academic research, my work with students and engaged citizens has often pushed me through the inevitable, difficult times in research and also enhanced the times where I've had research successes by giving me an outlet to communicate and share my enthusiasm for my work.

The Delta program has allowed me to further develop my framework for approaching outreach and mentoring by explicitly considering the three Delta pillars in my work with each. I use Teaching-as-Research in developing outreach activities because "outreach" can be completely different given different audiences, venues, and activities. In this regard, teaching-as-research gives me the scaffolding to formally examine my work across all these differences in a consistent and productive way. I have worked very hard to incorporate Learning Communities into my mentoring by mentoring multiple students simultaneously and staggering their training so that students can take an active role in training other students (I am lucky to have relatively straight forward methods in my research). Additionally, I frequently invite my mentees to participate in both helping to develop and execute outreach activities – here they are more "peer" than mentee. The benefits of engaging in outreach to an undergraduate's education are profound and have been extensively described in education literature. Outreach extends the learning community developed by a research group to the public and enabling my mentees to expand their own learning communities in the same way. Finally, Learning-Through-Diversity is most obvious in my mentees diverse career goals and backgrounds that shaped them while developing those goals. Diversity is also obvious in outreach, where activities must be developed for a diverse range of learning styles, familiarity with outreach materials, and values regarding our outreach messages. More importantly both outreach and mentoring work in tandem to give me a pathway to engage diverse learners and communities, improving student and community academic success.

Mentoring

Overview

I love doing science. However, I love doing science with people and helping people further develop their own love for science much more. In any aspect of my life, I feel called to encourage people while they're achieving their long-term goals. Mentoring young researchers gives me the opportunity to do this even in cases where student's long term-goals aren't in science or where they haven't decided on a particular long-term goal. My mentoring philosophy, therefore, has had to be just as flexible as my teaching philosophy to accommodate a diverse range of career goals and personal values held by my mentees.

In my time in the Delta program, I received formal training in mentoring through a semester-long seminar on mentoring course, "Research Mentor Training." The seminar was focused on reading current literature on mentoring, group discussion, and mentoring case studies drawn from present and past students of the seminar. I'm incredibly grateful to my instructor and course-mates and many of the ideas I describe in my mentoring philosophy are a direct result of the discussions we had in the seminar.

Figure 1. Top left: Carly and I sampling Lake Mendota's zooplankton community (photo by Bryce Richter). Top right: Kaity and Jennifer sampling zooplankton for an interview featured in our Center for Limnology Blog (photo by Emily Hilts). Bottom left: Petra and I sampling for freshwater shrimp at 2:00 AM on the eerily deep Green Lake, WI (photo by Emily Hilts). Bottom right: Carly and I (cropped out) in lab processing zooplankton samples (photo by Adam Hinterthuer).

Mentoring Philosophy

In mentoring, I lead by serving to create leaders with unique skill sets that we (my mentees and I) develop specifically for their career goals. Since these skill sets and the goals a mentee builds around them are unique to each of my mentees, I focus primarily on building a research experience that most effectively identifies and develops the skills and goals of the mentee. I believe this places them in the position where they are most likely to succeed, doing what they want to do. To accomplish this for a mentee, I aid them in identifying the skills they bring to the project and how these skills can be applied to meet their goals, help them integrate their unique set of traits into my research, and help them acquire the tools to think critically about their own learning and professional development. My thesis work and the research I envision for my future draws widely from lab and field techniques, data analysis and statistical modeling, stakeholder and community outreach, natural resource management, and high school and undergraduate education. Because of this, I am lucky to have worked with a large number of different mentees who have each shaped how I mentor and how I approach research.

Accurately identify skills and professional goals of mentees - Identifying the skills and professional goals of my mentees establishes the focal point of how I approach mentoring them through their research. Therefore, our ability to identify each is fundamentally important in their success as researchers both for themselves and for their contribution to my own research. The most important element of being able to identify the skills and professional goals of mentees is to create a relationship in which they are both able and willing to communicate them. With the ability and willingness to communicate their skills and goals, we can then work to better define and refine each to better suit them in their development.

The ability of a mentee to communicate each of these is dependent on being equipped with the conceptual knowledge and vocabulary to discuss not only what they have to offer in conducting science, but also what elements of science have triggered their desire to pursue research in the field. By establishing contact with a mentor and revealing information in the initial meetings to discuss potential research projects (requiring well-designed questions and easy conversation), mentees inform the mentor on their general skillset and interests to some extent. Building from this, I develop a loosely organized list of terms and concepts that serves two purposes. First, the mentee conducts a brief review of the literature on each term or concept and, second, we discuss each in an informal assessment of his or her knowledge. This is a great opportunity to determine the strengths of the mentee in addition to where they require additional learning and, more importantly, their research interests.

Similarly, the willingness of a mentee to communicate each of these is dependent on how comfortable they are in expressing thoughts and ideas that likely are not yet fully formed. This is a daunting task, particularly in a conversation with a new mentor. To ensure that the mentee is comfortable communicating these ideas in an honest and open way, I revisit my expectations of them as a mentee and remind them of my primary goal in their research. This helps me communicate to the student that early on in the research process, my expectations of them have much more to do with who they are than what

they have done or what they know (my job is to give them experiences and teach them field-specific material) and that my primary goal in their research with me is to get them to where they want to be. The student has already met my expectations of being who they are (as long as they were open and honest about this) and they assuredly want to end up where they want to be (as long as they are willing to work through and develop their thoughts and ideas concerning their goals). Though I have exceptionally high expectations for those I mentor, I am always eager to point out that it is my pleasure and privilege to work to help mentees reach them.

Incorporate mentees' approach to science into my research program - One of my goals in mentoring is to make sure that the mentees working with me eventually become independent in their own research and education. Therefore I make sure to incorporate as much of their research interest and style into their project as possible. As the mentee defines their own approach to science, the role their own ideas play in defining their research project increases. Concomitantly, I gradually increase the level of independence and ownership the mentee has over the project they are working on. I tailor this approach to the long-term goals of the student (i.e. whether they are looking to conduct their own research in graduate school or develop field and laboratory techniques and experience for entering the workforce) and to the duration of time the student has available to do research. The most rewarding research experiences I have been able to offer have spanned multiple years that culminate in a yearlong, independently designed and conducted project that prepares an undergraduate for the expectations of graduate school.

Promote self-awareness in educational and professional development - Helping a mentee become self-aware of how they are learning and how they are progressing towards their professional goals is one of the most difficult aspects of mentoring. Additionally, a mentee's independence helps me to identify the strengths of an individual mentee rather than simply proceed with fostering the strengths of what a research mentee "should" be. I am most excited about developing my ability to promote this sense of independence both because of how valuable this is to mentees (in particular undergraduates with post-graduate education plans) and because of the simple fact that this is immensely difficult. These abilities seem to come with time as the mentee develops on their own and with a mentor and the reality is that many of these research projects last only one or two semesters. I hope to become more efficient at developing this skill to accommodate short-term mentorships because of this reality.

The way I have been able to accomplish this has been through keeping an open dialogue about my goals for them and the methods I use to help them achieve those goals. Because I am continually striving to become a more effective mentor, I am honest with my mentees about this process and I encourage them to give me feedback on the materials, exercises, trainings and conversations that have been helpful to them. This does in fact help my mentoring, but I have ulterior motives in stimulating this type of conversation. By encouraging students to give me feedback on what has been effective for their own learning and their own development, they start developing the ability to see their education and development as a work in progress (this is also where I try to get them excited rather than terrified of learning and development as an unending process). Most importantly, students develop the ability to discern what is effective for their own

development and recognize that they have control over determining what and how they learn.

Placing mentees where they want to be, doing what they want to do, at a high level - It is of the utmost importance to me that my mentees get closer to achieving their long-term goals in their time working with me. Of course, their aid in conducting my own research is immensely valuable, but as a mentor, it is my job to ensure that the effort each student puts into research and the effort I put into mentoring is multiplied by placing students in positions where they are able to be most effective. I believe that I've done a good job of this so far (see Mentee Profiles) and I am excited to continue improving in this regard.

Mentee Profiles

The following is a table of "Mentee Profiles" which gives a brief illustration of the role I served in mentoring each student who has worked with me and the steps students were able to make as a result of the mentoring experience.

Mentee	Timeline	Project	Next Steps
Bridget	2014 – Present	Senior Thesis	Graduate School: Marine Biology
Samantha	2013 – Present	Senior Thesis	Graduate School: Marine Biology
Laura	2014 - Present	Biology 152[1]	Medical Research
Danielle	2013 – 2014	Senior Thesis	Graduate School: Forensic Science
Michael	2013	Biology 152[1]	Pre-Medicine
Kaity	2013 – 2014	Directed Study	Master's: Natural Resource Management Public Outreach
Jennifer	2013 – Present	Environmental Studies Capstone	Graduate School: Limnology
Sommer	2013 – 2014	Volunteer	Master's at Florida Atlantic University
Carly	2012 – 2014	Directed Study	Physician's Assistant Training
Steve	2013	Biology 152[1]	Pre-Medicine
Ryan	2011 – 2012	Chase-Noland Research Scholarship	Pre-Biology Education
Cristin	2011 – 2013	Senior Thesis	Natural Resource Management and Public Outreach Abroad
Sam	2011 – 2012	Senior Honors Thesis	Master's: UW Water Resources Management
Brad	2010 – 2011	Directed Study	WI Canoe Guide
Henry[2]	2014	Summer Research Project	
Petra[2]	2013	Summer Research Project	Undergraduate program in limnology
Olin[2]	2011	Summer Research Project	Undergraduate program in fisheries management

Table 1. Mentees who have aided in my research at the UW Center for Limnology. More importantly, this table shows how the students who have worked with me have gone on to a diverse range of post-graduate studies and careers.

[1]Biology 152 is a one-semester introduction to independent research. As a mentor in Bio 152, I help students design, carry out and report on their own research projects.

[2]Petra and Olin were high school participants in the Madison Metropolitan School District High School Science Internship program. They designed and carried out a research project over the course of the summer. In the fall they wrote a final report and gave a poster presentation.

Examples of Feedback on My Mentoring

Excerpt from an email from the former director of the MMSD High School Science Internship Program regarding a student's placement in our lab:

"It's going to be a great placement for you [student]. Jake, you're a great mentor. I think the two of you will accomplish a lot this summer and have a good time doing it."

Emails from students:

"Great comments (as usual)! Here is the paper. I have truly enjoyed this entire process, field, lab, data analysis and writing. Obviously, the field work was the best! Thanks for this opportunity. See you next school year, perhaps for some zooplankton identification!"

"I am so happy to say that I have been officially accepted to Florida Atlantic University!!!! This is the first school I applied for, with the adviser who directs the Wild Dolphin Project (Dr. Denise Herzing). This was also my number one choice school and the adviser I wanted to work with the most, so I am thrilled! I'll be doing a photo-ID project with her as part of my Master's Thesis. I am so thankful for not only the recommendation letter you wrote for this school and the others, but also the experience I was able to have working with you in the lab/field that contributed so much to my application! Thank you so so much again, and I will be going to FAU in Fall 2014!"

"Thanks! This was really helpful."
In response to:
"Here's a document to walk you through some of the statistics we did yesterday. Email me if you have any questions (this stuff can take a long time to wrap your head around) or if you'd like me to look over any of your writing. Good luck with writing! – Jake"

Mentoring Reflection

These experiences have given me countless opportunities to succeed and fail at different mentoring techniques and styles, as these are highly dependent on the student. For example, when mentoring Sam Christel (interested in Limnology) I experimented with a lot of the mentoring techniques that I admired in my own mentors. Conversely, working with Danielle Gries (interested in Forensic Science) involved much more time spent developing critical thinking skills, general laboratory skills, and refining her writing technique. Of course, working with high school students (Olin, Petra) and outreach specialists in the making (Kaity, Cristin) also involved very different approaches.

Outreach

Overview

I feel fortunate to have been trained to do science in an era where effective outreach is a mandate of nearly every major granting agency (e.g. NSF's broader impact requirements for funding). I hope to continue to develop a research program that falls in line with the new definition of "good" science – that it must not only be conducted well, but also be communicated well.

Also, the problems facing freshwater resources today are simply too large for research scientists alone to make a difference in addressing them. In the case of lakes, Wisconsin and Minnesota alone account for nearly 30,000 lakes and far fewer freshwater scientists. However, we have several million people in each state that use and value these lakes. Therefore it will be imperative to not only inform the public of our findings and on the issues facing lakes, but also include them in how we discover more about lakes and more effectively manage the lakes that we all care about. My work on invasive species has relied heavily on support from public organizations such as lake associations and lake "friends" groups. These citizen scientists have become invaluable resources for both managers and researchers and were an integral part of my own thesis work.

Finally, outreach improves the science we do. Good outreach activities are clear and simple, but still informative and insightful. We don't "dumb down" our work for outreach, but instead teach ourselves how to describe our research and communicate it most effectively. Not only does this create a useable product for citizens participating in our outreach, it streamlines the work we do, aiding us in determining important messages and concepts that we can in turn convey to funding agencies and key stakeholders of our research.

My work at the Center for Limnology, with invasive species, and with training mentees has shaped how I participate in outreach. Through these experiences I have pieced together different activities that are successful in different outreach venues. Though I will continually be developing new activities for new situations, I am proud of what we have been able to accomplish through our outreach.

Outreach at the Center for Limnology

Outreach at the Center for Limnology has been an excellent opportunity to help connect WI citizens to what's going on in their own lakes and streams (Table 2). WI has a strong history of engaged and informed citizens, so being a part of continuing to engage citizens has been a privilege. In each of the events mentioned above, it was clear that the people that chose to interact with us cared deeply about WI's natural resources and that they were deeply interested in learning more about how to conserve them. The vast majority of WI is made up of a community of outdoor enthusiasts, fishing fanatics, hunters, hikers, campers – the list is nearly endless and represents just how valued are WI's ecosystems. This made our job potentially as simple as making our messages clear. While this is not a simple job, it is certainly made much simpler when it's clear that people *want* to engage and *want* to know more. I hope that wherever I go next that people will be as passionate about their state and protecting the resources they love about it.

Figure 2. UW Day at the Wisconsin State Fair. Here I'm showing a group of fairgoers how to use a Secchi Disk to measure water clarity. Clearly, the group was much more excited about looking at the zooplankton and insects under the microscope than they were about the Secchi Disk or maybe they're just deep in thought about the implications of the tool.

Invasive Species Outreach

Researching an invasive species ensures that I've always had one foot in highly practical science. In particular, the spiny water flea is a small, nearly microscopic animal and its impacts on ecosystems aren't readily apparent. However its predation on native zooplankton species can have a negative impact on fish and, as we discovered in Lake Mendota, has a negative impact on water clarity, a key ecosystem service provided by Madison's lakes. The spiny water flea has only invaded 6 lakes in WI – putting us in a fortunate, but precarious position. Its relatively inconspicuous nature and limited range in WI have contributed to a limited familiarity of WI citizens with the invasive species. Because of this, we have taken every opportunity to "spread the word" about spiny water flea's impacts and how to prevent its spread into other WI lakes. I've worked closely with WDNR and UW Extension to ensure that the spiny water flea's profile is spread across Wisconsin.

Spiny water flea outreach in Northern Wisconsin – The Wisconsin DNR (WDNR) has supported our research in northern WI and because of this partnership we are able to use WDNR's established pathways for invasive species outreach. For example, I give talks and demonstrations 1-2 times per year at WDNR organized events with an audience of local and regional managers, concerned citizens, and lake association members.

Spiny water flea outreach in Madison – The "busyness" of Madison makes it difficult for us to use our outreach model from Northern WI in the city because of the sheer number of events going on. I have been lucky to have had a research advisor who has close ties with the Madison media and have been grateful for this outlet for

communicating our research findings regarding the spiny water flea. We've helped write press releases on our research findings and interviewed for long-format articles that outline how spiny water flea will impact the Madison lakes.

Outreach Events at the UW Center for Limnology

Event	Timeline	Role	Outreach Activities
Wisconsin Institute for Discovery: Science Expeditions	2013 – Present	Lead visitors of all ages through hands-on activities.	"Build your own native plant seed 'bomb'" "The Value of Biodiversity" "Where does the water go? Watersheds, Streams and Lakes."
Winter Limnology	2012 – Present	Co-Instructor (Middle School Aged Students)	Plankton Ecology Field & Lab Experiments
Grandparents University	2012 – Present	Co-Instructor (Elementary – Middle School Aged Students)	Plankton & Invertebrate Ecology Field & Lab Experiments
Wisconsin State Fair: UW Day	2012 – Present	Lead visitors of all ages through hands-on activities.	Microscope activities to learn about invertebrates, plankton and macrophytes of WI's lakes. "Be a limnologist", learning about limnology by learning how to use field equipment.
Party on the Path	2013 – Present	Lead undergraduate visitors through hands-on activities at the UW Lakeshore Path.	How do plankton keep Lake Mendota clear?

Table 2. These are the events that I've participated in as a member of the Outreach Committee at the UW Center for Limnology.

Teaching the Value of Outreach through Mentoring

Figure 3. Cristin and Carly leading the zooplankton and macroinvertebrate outreach table at the UW Hasler Center for Limnology Open House (Photo by Adam Hinterthuer).

A fundamental element of my mentoring style is including my mentees in outreach activities. The primary goal of this is to help foster a value of outreach. However, in my experience, students are quick studies in this and either understand the value of outreach from our first meeting or readily accept invitations to participate in outreach. In addition to helping create young scientists who value outreach, I also include them in outreach because it helps them learn about the systems we research through teaching about them, it helps them maintain enthusiasm for science through research struggles, and young researchers have many qualities that simply make them really good at outreach (*e.g.* enthusiasm and a perspective uncomplicated by years of familiarity with the system).

Most importantly, I think this helps mentees both as an authority on a topic and as members of the research communities they're a part of rather than simply "research assistants". For students who don't go down the research path, this authority will translate to community-level discussions on ecology-related issues in their future.

IV. Teaching and Learning Through the Scientific Process

Overview: Course Revision

In 2013, I lead the revision of an introductory limnology laboratory course. The following is a syllabus of the lab exercises that I created and improved upon (Table 3). Also, I made a point to include a skill development section with each lab activity where students were asked to develop a skill essential to the scientific process ("Beyond Limnology" Skill). These skills are by no means a comprehensive list of the skills necessary to "be a scientist" but are instead a sampling of the areas where we felt the students from previous years needed the most additional development based on evaluations of their written scientific reports of group and individual projects (described below). Many of these skills have to do with the appropriate application and interpretation of statistics, particularly in Excel, however there are some that build on the already strong communication skills (writing and speaking) labs.

These skills fit into the larger course topic of the scientific process that is taught primarily through their Individual and Group studies. In the individual studies, students utilize a dataset developed in a weekend-long field trip in Northern Wisconsin to develop and test hypotheses regarding Wisconsin's lakes. On the trip, the class was responsible for surveying physical, chemical, and biological characteristics of 20 lakes, as well as building a dataset to provide the foundation of their hypotheses. The Group studies are conducted over the course of the semester. Groups of 4-6 students develop hypotheses that they can test in the lakes and streams in and near Madison, WI. Instructors help groups refine hypotheses, design field surveys, and analyze and interpret data. Both group and individual projects result in formal scientific reports that are prepared as if they were to be submitted for publication in a journal. The group project is presented orally on the last day of lab. Each project gives students a full iteration through the scientific process--starting with an idea from a literature review, developing, testing, and evaluating hypotheses, then presenting their findings.

I included the "Biological Communities Lab" as a specific example of a lab activity that I developed and it attached as an appendix to this document; including the Beyond Limnology Skills associated with that lab section. The major revision of this lab involved turning a lab that worked like a biological survey of Lake Mendota to an observational experiment comparing two unique sub-habitats of the lake (the littoral and pelagic invertebrate communities).

Table 3. Course syllabus of a major course revision for Limnology Lab.

Lab	"Beyond Limnology" Skill	My Role
Physical Limnology	Histograms, Means, Variance, Barplots and Vertical Profiles in Excel	1, 2
Chemical Limnology	T-tests in Excel (a) Using Web of Science and Google Scholar to find Primary Literature(b)	1, 2a
Nutrients		
Stream Bio-Indicators (WDNR Guest Speaker)		
Biological Communities	Common Statistical Tools and the Types of Questions/Hypotheses They Help Answer Hypothesis Generation & Selecting Statistics for Different Case Studies Conducting common analyses in Excel	3, 2
Chlorophyll		
Fundamentals of Scientific Writing		3
Limnology Through Space and Time	How to give a good talk	
Peer Review	Critiquing and Improving Writing	1
Trout Lake Field Trip Weekend		4

1 – Streamlined lab manual content, provide reflection questions embedded in text, highlight key terms and wrote "goals" section at beginning of each section.
2 – Developed Beyond Limnology Skill and associated lab questions.
3 – Complete re-write of lab section.
4 – Co-lead a re-design of the trip experience by designing new field experiments and providing more structured activities to the weekend schedule. This was a major strength of the lab, but was incredibly unorganized and students were often torn between loving the trip and hating the mayhem of the trip.

Reflection

Though the course revision experience taught me many things, I'd like to focus on one here, and that is the value of well-defined goals in curriculum development. As we were revising the course, we had four goals: 1) To make the Lab Manual a useful reference for students, 2) To clarify overarching course goals and lab-specific goals in the Lab Manual, 3) To streamline the Trout Lake Field Trip, and 4) Provide more content both in the form of additional labs to fill empty lab periods and more engaging/enriching assignments. While these actually proved to be too broad in scope, they were an excellent reference for decision-making in the course revision.

V. Application of Learning to Real-world Problems: Delta Internship

Though I go into much deeper reflection regarding the Delta Pillars, I would like to touch on them here, prior to the report summary of my Delta Internship. This Teaching-as-Research project is an excellent example of how effective evaluating teaching can be in course development. Here, Diversity is most obvious in the stakeholder roles of the role-playing game and in the diverse range of expertise students are asked to draw on to solve problems. Finally, this activity capitalizes on one of the key strengths of the Limnology Lab: a strong learning community. The lab course involves a large amount of group work, daylong and weekend-long field trips, and peer review of writing – all facilitated by enthusiastic, easygoing, encouraging, but also tough TAs (at least, all the TAs I have known for this class possess those qualities). By the time in the semester where students are asked to participate in this activity, they have developed strong bonds and already have experience helping one another learn in the lab.

World of Watershed Management (WOWM): A role-playing game to teach the complexity of socio-ecological systems and problems.

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Special Thanks to Limnology Lab Instructors: Bryan Althouse, John Crawford, Ben Kraemer, Luke Loken, and Sam Oliver

Abstract

The complexity of real world socio-ecological problems and the diversity of the stakeholders who are interested in solving those problems make teaching application in ecological education particularly difficult. Role-playing games that place students in roles of stakeholders in ecosystem management scenarios offer a potential tool to aid in the introduction of applied ecological problems. In this context, role-playing is an active and collaborative learning tool that promotes critical thinking and empathy, which are essential problem solving skills. Broadly, role-playing helps bridge the education gap between knowledge acquisition and application of that knowledge to solve real world problems. We developed a role-playing game (World of Watershed Management or WOWM) that places students in the roles of stakeholders in aquatic ecosystem management scenarios like water clarity management in lakes and statewide aquatic invasive species management. In this study we evaluate WOWM as a teaching tool in two ways; first, whether it aids in student's appreciation of the diversity of opinions and values held by stakeholders in ecosystem management and second, assessing student's confidence and proficiency in applying course knowledge to real world examples. Students unanimously agreed that the activity should be included in future iterations of the course. Also, we found that WOWM was directly responsible for improving student

attitudes regarding role-playing activities as a teaching tool. Finally, students reported an increased understanding of stakeholder diversity and that they appreciated being given an arena in which to apply their course knowledge in ecosystem management scenarios.

Introduction

The gap between raw knowledge acquisition and the application of that knowledge to solve real problems is a significant hurdle in undergraduate education (Ruben 1999). In ecology education, the combined human and ecological elements of real world socio-ecological problems are extremely complex, involving multiple stakeholders and using information from several disciplines. Introducing these complex decision-making processes in a classroom setting has proven to be an interesting challenge for instructors because of the difficulty associated with asking students to integrate knowledge from a wide breadth of subjects. This is particularly true when students have little or no experience with fields outside of their academic major. Never-the-less, this exposure is necessary for training post-graduate ecologists to problem solve, either as career ecologists or as one of the many essential voices that contribute to problem-solving discussion for a particular local ecological issue. Role playing games are a learning tool that can help students' transition from understanding information to applying it as they would in a future career. Role-playing also encourages students to understand ecosystem services from multiple angles by allowing them to pose as stakeholders in management case studies.

Ecosystem management has become increasingly viewed in the context of both the social and economic factors that are linked to ecosystems (Chapin et al. 2011, Wetzel 2011, Walker and Salt 2012). Therefore, in this modern era of ecosystem management, the social scientist and the economist have become equally as important as the ecologist. Similarly, the human diversity of stakeholder groups that are impacted by ecosystem management decisions reflects this increase in field breadth of management problem-solvers. However, this real world texture and depth of these problems are often lost in the details of higher education courses in ecology and environmental studies. Many report that students fail to grasp the integrative and cumulative nature of each science in real world application (Wetzel 1991, 2011, Melack 1997). In other words, "losing the forest in the trees" is a common problem as students transition from introductory to more specialized coursework.

One of the most effective tools for teaching students the complexity of these systems has been role-playing ecosystem management scenarios (Byers 1979, Fox and Loope 2007, Washington-Ottombre et al. 2010, Paschall and Wustenhagen 2012, Gaydos and Squire 2012). Role-playing as a learning activity is an active, collaborative means to promote discussion in a more entertaining and meaningful format than traditional lectures or readings--qualities that contribute to its success as a learning tool (Chuck 2011). Students are able to immerse themselves in a game-like scenario while working alongside their group members to build solutions to problems through discussion as character roles with differing opinions and values. Because of this, role-playing promotes critical thinking and empathy (Ertmer et al. 2010, Shapiro and Leopold 2012), lies at the core of the progressively more prominent and relevant video game based education (Gaydos and Squire 2012), and role-playing allows learners to experience multiple perspectives

(Howes and Cruz 2009). Likewise, role-playing mirrors real world management scenarios by allowing for multiple viewpoints to be considered simultaneously in the conversation on ecosystem management (Washington-Ottombre et al. 2010, Leaman and Flanagan 2013). In these scenarios, the debates and struggles (and collaboration) that students encounter while role-playing often mirror the challenges that face management decision makers. This in turn effectively puts students in the shoes of careers they may one day fill.

Role-playing as a teaching tool draws from situated learning theory, which makes it a highly useful tool in transitioning early career ecologists into their community of practice (*e.g.* ecosystem managers or researchers) (Leaman and Flanagan 2013). In particular, role-playing has been commonly and effectively used in preparing pre-professional students to enter their community of practice (such as nursing, medicine and teaching). In the same way, role-playing in ecology allows students to place themselves in the roles they may someday fill where they will be asked to balance the human and ecological elements of management decision-making. In particular, if students are asked to formulate a realistic management plan for a given ecological scenario, they need to be able to practice this balancing act while applying their expertise to problem solving. Furthermore, through role-playing, they can evaluate their own decisions in the context of decisions made in the real world, which also gives them a foundation to critique historical management decisions. Inserting themselves into their future roles through role-playing in this way is an essential step in training, as students are more actively preparing themselves to enter a community of practice either as scientists, managers, business owners, or actively participating citizens.

Here we develop and evaluate a role-playing game, World of Watershed Management (WOWM). The purposes of this study are to, 1) evaluate student perception of the role-playing activity as a teaching tool for an upper level ecology course, 2) determine whether role-playing helps students appreciate the essential role of other fields in solving classically "scientific" problems and 3) determine if role-playing helps students gain confidence in applying course-specific knowledge to real world examples of problems nested within socio-ecological systems (Table 1). As a role-playing game, WOWM will help develop the next generation of ecological problem solvers, regardless of career trajectory, and introduce them to the necessary tools used to approach these complex issues.

Methods & Approach

Course Setting

The Introduction to Limnology Lab at the University of Wisconsin – Madison is an upper level biology lab elective that is separate from the lecture course. The lab meets once per week for four hours and consists of three lab sections of 23 students, each taught by a graduate student teaching assistant. Course material covers basic lab techniques, field techniques and concepts of limnology as well as group and individual projects that coach students through the scientific process toward a "publishable" report on their work. The role-playing activity was developed to encourage application of concrete skills acquired during the class. The game was implemented during a single four-hour lab

session midway through the semester, as to capitalize on the established learning community of the lab section.

Role-Playing Activity

WOWM is a scenario-based game that draws from the classic tabletop role-playing framework. We developed the game particularly for group discussion and problem solving using examples of real world management problems and success stories of freshwater ecosystems (Appendix A). Students role-play as the various stakeholders that participate in the real life discussion on ecosystem management (Appendices B and C). The primary objective of WOWM is to come up with a management plan for a presented scenario that best serves the diverse needs and values of the gaming group. However, individual players are also asked to ensure that the management plan best serves their character role. This mirrors the tension of group decision-making and problem solving in real world socio-ecological systems. Each stakeholder role will not only differ by their individual management goals, but also by the skills, information and management strategies they bring to the group, their capacity for collaboration with other group members and, as determined by each student playing the character, their personality. The stakeholder roles were selected to do the following: 1) re-produce the diversity of the real world community that worked toward a management plan and 2) to balance cooperative and competitive elements of discussion. Finally, students are able to evaluate different solutions while writing up their group's "Final Management Plan" (FMP) that is presented to the group preceding a group discussion on the merits and challenges associated with each management plan (Appendix D).

Survey

We developed a 19-item survey administered before the activity (pre-survey; Appendix E) and a 35-item survey administered after the activity (post-survey; Appendix F). Students' background information was collected in the pre-survey and included gender, ethnicity, academic year, academic major, career goals, previous exposure to role-playing and interest in course material. Students' names were only used to match pre- and post-surveys. Surveys results were not evaluated until after the conclusion of the semester and after students had received their final grades for the lab. Grades for the lab section were based solely on participation in the activity.

Student attitudes that were anticipated to change with the activity were collected in both surveys and included the following: (a) attitudes regarding role-playing as a learning tool, (b) the role of non-STEM (science, technology, engineering and mathematics) fields in ecosystem management, and (c) students' confidence regarding their ability to apply course knowledge to real world ecosystem management problems.

The post-survey also included items to evaluate students' attitudes regarding the activity and included the following: (a) whether the activity helped students understand limnology-specific course material, (b) whether the activity helped students appreciate the role of different fields in ecosystem management problem solving, (c) elements of the activity that students liked most and least, (d) elements of the activity that made students feel most and least comfortable with role-playing, (e) confusing aspects of the game and (f) a brief reflection on why the activity should or should not be included in the lab syllabus for subsequent years. Finally, the post-survey also included items that assessed

how students played the game including students' perception of individual and group participation, students' and students' character roles' satisfaction with the Final Management Plan and students' perception of the most challenging aspects of writing the Final Management Plan.

Stastistical Analysis

The effect of student background and the activity on student responses to survey items included in both pre- and post-surveys were evaluated by a paired MANOVA. The effect of student background on items only included in the post-survey was evaluated by an additional MANOVA (alpha = 0.05). The roles of ethnicity, academic year, major and career goals were not included in the analysis due to dramatically unbalanced sample sizes within each factor.

Qualitative information of students' attitudes regarding the activity were categorized and summarized by common topics reported in the short answer survey items. Since students were allowed to provide more than one response per short answer question, the total number of responses can exceed 100% in each question.

Results

Demographic Information

57 students responded to the pre-survey, 56 students responded to the post-survey and 53 students responded to both the pre-survey and the post-survey. Of the 53 students that responded to both surveys, 51% were male and 49% were female (Table 2A). The vast majority of the class identified as white (91%) with 9% identifying as Asian or Pacific Islander, 6% identifying as African American or Black and 6% identifying as Hispanic or Latino (students were allowed to select more than one response; Table 2B). All students were third year undergraduates or higher and their majors were primarily related to biology (85%), followed by environmental studies (11%; Table 2C). There were three graduate students in the class as a part of the master's level Water Resources Management program. The majority (58%) of student's career goals were related to medicine or health care, with only 13% and 11% related to natural resources management and research, respectively (Table 2D).

Of the two ecosystem management scenarios, 55% participated in the invasive species management scenario and 45% participated in the water clarity management scenario—the number of groups assigned to each scenario was equal, but group sizes were not equal (Table 2E). The majority of students were familiar with role-playing-based activities before WOWM (76%), primarily through videogames (32%), pre-professional training (18%), and tabletop role-playing games (14%; Figure 1).

Factors Explaining Student Attitudes

Only the response to *I think role-playing is a fun way to learn* significantly increased in overall agreement (4 = Strongly agree, 1 = Strongly disagree) after the WOWM activity, increasing by 15% ($F = 4.09$, $p = 0.0005$; Figure 2; Table 3). Changes in agreement with each statement included in both surveys were otherwise unrelated to the WOWM activity, gender, scenario or exposure to role-playing (Table 3).

Student Attitudes – Both Surveys

Students were overwhelmingly positive in their attitudes regarding their interest in the conservation of aquatic resources ($\mu_{pre} = 3.55 \pm 0.07$, $\mu_{post} = 3.57 \pm 0.08$), limnology ($\mu_{pre} = 3.26 \pm 0.06$, $\mu_{post} = 3.23 \pm 0.07$), their attitudes regarding their comfort with role-playing ($\mu_{pre} = 3.15 \pm 0.09$, $\mu_{post} = 3.27 \pm 0.07$), and role-playing as a learning tool ($\mu_{pre} = 2.91 \pm 0.10$, $\mu_{post} = 3.34 \pm 0.07$) both before and after the WOWM activity (Table 4). Students also indicated positive attitudes both before and after the activity regarding the role of non-STEM sciences in ecosystem management ($\mu_{pre} = 3.36 \pm 0.09$, $\mu_{post} = 3.49 \pm 0.07$) and their confidence in applying the knowledge they gained in the limnology laboratory course ($\mu_{pre} = 3.28 \pm 0.07$, $\mu_{post} = 3.17 \pm 0.06$; Table 4).

Student Attitudes – Post-Survey

Overall students agreed that the role-playing activity was entertaining ($\mu = 3.38 \pm 0.07$), that it helped them further grasp course material ($\mu = 3.04 \pm 0.09$; Table 5), and that it helped them to learn how different fields play a role in managing ecosystems ($\mu = 3.35 \pm 0.08$). Attitudes were not significantly related to gender, scenario, or previous experience with role-playing (Table 6).

Student Attitudes Regarding WOWM – Quantitative

Students felt that they remained in character consistently throughout the WOWM activity ($\mu_{post} = 3.25 \pm 0.07$) and that group members contributed equally through the role-playing discussion ($\mu_{post} = 3.92 \pm 0.17$; 5 = Equally, 4 = Somewhat equally, but everyone participated consistently, 3 = Somewhat equally, but one or two players did not participate consistently, 2 = Not equally, over half of the players did not participate consistently, 1 = Not equally, discussion was consistently dominated by one person; Table 5). Group participation varied among scenarios but was at least "somewhat equal participation" in both ($F = 8.53$, $p = 0.005$; μ Water Clarity $= 4.06 \pm 0.12$, μ Invasive Species $= 3.39 \pm 0.18$; Tables 5, 6; Figure 3). Both students and their characters were satisfied with the Final Management Plan proposed by their group ($\mu = 3.11 \pm 0.08$, $\mu = 3.11 \pm 0.07$, respectively; Table 5).

Student Attitudes Regarding WOWM – Qualitative

Students reported that their favorite elements of the WOWM activity were role-playing (24%) and witnessing the reality of stakeholder diversity in ecosystem management (28% of students; Table 7A). Students' least favorite element of the activity was, primarily, their limited understanding of character roles and scenario background information (33%; Table 7B).

Students felt that having a character sheet and understanding the difference between role-playing and personal belief made them feel most comfortable with the activity (22%, 13%, respectively; Table 7C) and suggested that more time to research character roles and scenario background information would help them feel more comfortable (28%; Table 7D).

Many students reported experiencing no confusion during the activity (22%). However, the character sheets and scenario background information confused some students at the beginning of the activity (19%; Table 7E).

Students reported that the most difficult aspect of writing the Final Management Plan was getting everyone to agree on FMP content (43%) and consolidating ideas (17%). Here, 17% of students also reported that more information on management techniques prior to the activity would have helped in writing the FMP (Table 7F).

All students reported that they would like to see WOWM included in the lab syllabus as a lab in subsequent years (100%; Table 7G) because it was fun and entertaining (38%), gave them an understanding of stakeholder diversity (31%), allowed them to apply limnology to real-life situations (31%), and was a change from normal lab activities (13%; Table 7H).

Discussion

Student attitudes toward WOWM as a teaching tool were unanimously positive with students reporting that the activity should be included in future iterations of the course. More importantly, students felt like WOWM helped them further understand stakeholder diversity of real world ecological problems and gave them an arena in which to play with and apply knowledge gained from course and lab content. The activity also significantly affected a change in student attitudes regarding role-playing as a teaching tool. One student summed it up well,

> *"While I already had an idea that public decisions are tugged at from all sides before they finally settle, this lab did a good job of illustrating that. Plus, classes are often too focused on teaching students to become researchers. Not every student wants to be a researcher. If someone wants to deal with management or public affairs, for example, this lab might be more applicable to their career goals than anything else we've done thus far."*

Touching on many of the primary goals of this study, the student makes a compelling case for including WOWM in limnological syllabi.

WOWM as a Teaching Tool

Students thought the role-playing activity was an entertaining and light-hearted way to tackle the more difficult elements of synthesizing and applying pieces of limnological knowledge to real world examples of socio-ecological problems. As one student wrote in the evaluation,

> *"I thought the activity was a fun, engaging, and new way to learn. I liked how the activity made us see that there is so much more to conservation efforts and management. There are many factors to look at in conservation and science doesn't always win out. The activity showed that there isn't always an easy or right solution to a conservation problem."*

While it is likely that a whole semester of role-playing would not effectively teach course material, the role-playing exercise complements the lab setting where focus is on course content, technique and the scientific process.

Students were optimistic about role-playing as a teaching tool before doing the activity and WOWM helped increase this optimism. There was surprisingly little skepticism and anxiety regarding role-playing before the activity and the skepticism that was expressed was often relieved after the activity,

> *"I liked how in the beginning we got to draw out characters. It helped us get in the part we were playing. I was skeptical of the activity but it turned out to be a great way to learn."*

Getting into a well-defined character role with the understanding that a student's role did not reflect their personal opinions and that all students in the class were "forced to role-play" helped alleviate anxiety about the role-playing activity. Though teaching assistant efforts to facilitate a positive role-playing environment, like moderating arguments and helping maintain casual, light-hearted role-playing, were only mentioned in several evaluations, it is likely that they played a large role in developing the "light-hearted" and "informal" environment that was often mentioned in the evaluations.

> *"I enjoyed the light-hearted nature of the activity. Everybody was comfortable with the role-playing which made it a fun and relaxing environment for learning."*

Similarly, students often reported that the "Dungeon Master" (i.e. the group's discussion leader) was an essential role in each group, keeping conversation on track and allowing students the freedom to go deeper into their own roles.

The course also appeared to be particularly well suited for the activity. Students were more comfortable with one another after a semester of lab activities and field trips, students were familiar with the course content required to discuss each scenario through both previous coursework and the semester of limnology coursework, and the class size was small. For example:

> *"That our class is small and we've worked with the same small number of students. We're gone on a field trip together, presented a project in front of each other, it makes it easy to talk openly."*

The Final Management Plan played an integral role in formalizing the game as a teaching tool (and not solely a game). Students reported issues with writing the final management plan that are typical to problem solving for each of these scenarios in the real world (e.g. group consensus, consolidating ideas, yielding measurable results for the ecosystem, and budget and time constraints). The whole-class discussion on group's FMPs also gave students the opportunity to critique and evaluate one another's plan, building to the highest order learning domains of synthesis and evaluation (Table 1). Students were able to highlight material learned previously in class and from the activity while formulating their FMPs (Figure 4).

However, there were some improvements that need to be made before the activity is implemented again. The most widely reported deficiency of the activity was the lack of time provided to students to prepare for their roles and their scenarios and providing this time was the most widely suggested improvement to be made to the course. In the future,

students will be provided a week to prepare for their roles and research their scenarios. Students also reported unbalanced character roles and some character roles that were inappropriate for a scenario (e.g. the farmer in the invasive species scenario). This may also explain the unequal participation reported between scenarios (Figure 3). Continuing to develop and refine the character roles, while eliminating unnecessary roles should address this.

Also, one international student reported feeling confused by the concept of a "role-playing" activity. Despite being only one report, this is likely to reoccur given the increasing number of international students in the course and the likelihood of other students (including students from the US) not reporting this despite feeling similarly. Continuing to streamline the directions and make the activity friendlier to students unfamiliar to role-playing subculture will help to alleviate this. Consulting the literature developed for pre-professional trainings (like nursing, teaching and business) may help identify techniques that could make the activity more widely appealing to students. Also, there may be opportunities for diversifying the language describing the activity (e.g. using "simulation" instead addition to "role-playing game").

Student Appreciation of Stakeholder Diversity

Students were able to pick out one of the more obscured, yet incredibly important, learning goals of the activity and frequently mentioned how WOWM helped them appreciate the diversity of opinions and values that go into this kind of real world problem solving. Students' comments in the post-activity survey are consistent with this.

> *"I really liked how there was an emphasis placed upon having stakeholders that were very different from one another. This enabled our group to consider multiple perspectives and work together to come up with a plan that benefited everyone rather than unconsciously formulating a plan that benefited some groups much more than others."*

> *"I enjoyed being forced into a position on the subject whether you personally agreed with it or not it still managed to make you think about the problem in a whole new way and perspective."*

This could form the foundation of in-class discussions on the topic of the socio-economic factors that play into the decisions people make regarding the management of natural resources.

Future Directions

This study has only scratched the surface of questions regarding role-playing and higher order learning domains. A more complete experimental design will no doubt aid in determining whether activities like this can be responsible for learning gains in these domains. Also, more concrete information about the actual effects of role-playing on student learning (and not just student perceptions) is needed to effectively evaluate this activity. As originally designed here, an obvious next step would include a pre-activity exercise that evaluates students' ability in higher order learning domains. There is also opportunity for establishing control and experimental groups within the three lab

sections. However, this design would come at the cost of a subset of students not participating in the activity. If there is more flexibility in the course schedule in subsequent years, it could be possible to set up a design where the timing of the activity is altered through counterbalancing of a repeated measures design. There is also potential to use role-playing as a research technique for understanding how students perceive stakeholders and ecosystem management in general.

Conclusion

This study demonstrated that students are likely to be open to role-playing as a teaching tool and such activities could be complementary additions to traditional ecological education. In particular, role-playing helped students better understand the diversity associated with stakeholders involved in real world problem solving and helped students apply course knowledge to real world scenarios. With the increasing complexity of socio-ecological systems, the need for scientists and citizens with an understanding of this complexity is growing. Role-playing may offer an interesting and engaging opportunity for educating undergraduates to be able to apply the knowledge they have gained in ecology courses in addressing this complexity. This ecological example also highlights the general utility of role-playing as a tool to approach the gap between knowledge acquisition and application.

Figures and Tables

Figure 1. Student exposure (grey = previous experience, white = no previous experience) to role-playing is plotted with percent of student responses above each bar. Previous experience is broken up into source with a key at the top-right corner of the figure.

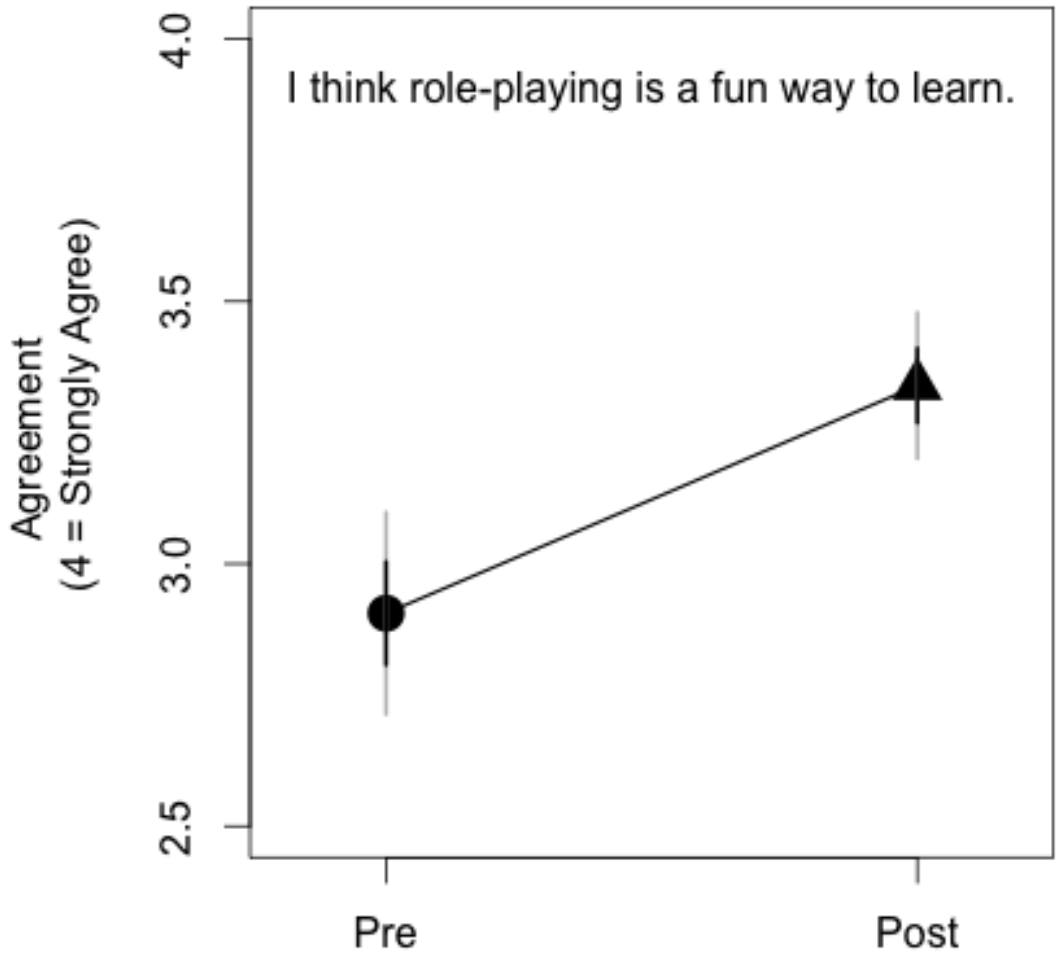

Figure 2. Mean student agreement (1 = Strongly Disagree, 2 = Disagree, 3 = Agree, and 4 = Strongly Agree) ± 1 S.E. (black) and ± 1 95% confidence interval (gray) to the statement "*I think role-playing is a fun way to learn"* before (Pre, solid circle) and after (Post, solid triangle) the WOWM activity.

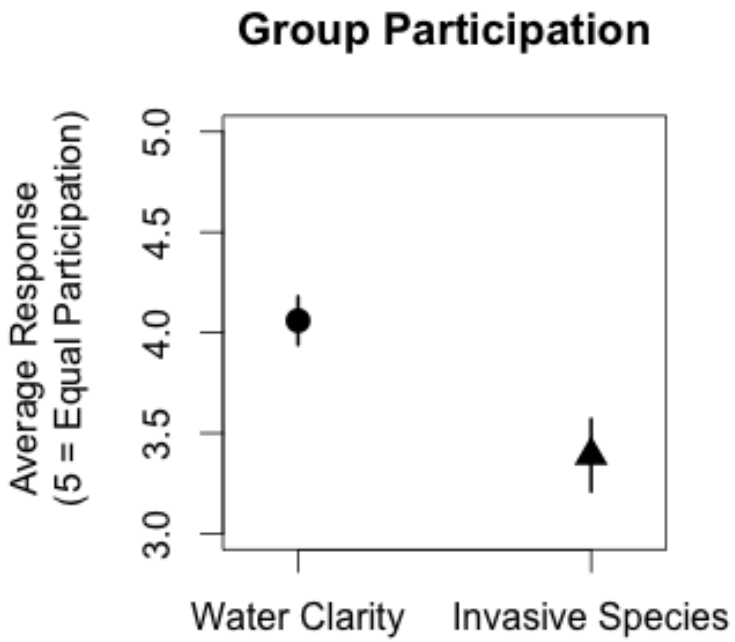

Figure 3. Average response (± 1 S.E.) to the statement "*Group members contributed to the role-playing discussion _____"* split by ecosystem management scenario. The responses are rated as follows: 5 = equally; 4 = somewhat equally, but everyone participated consistently; 3 = somewhat equally, but one or two players didn't participate equally; 2 = not equally, over half of the players didn't participate consistently and 1 = not equally, discussion was consistently dominated by one person.

Student Group Final Management Plan (FMP) Example

Invasive Species Scenario

Goal: Lessen the burden of Dreissenid Mussels [*chosen over 4 other invasive species*]

Methods:

1. Most important – prevent spread via educational signage and patrolling by wardens.
    a. Funding from DNR licenses at boat ramps
    b. Local support (funding/volunteering) from local Lake Associations
2. Remove mussels from existing areas (docks) - physical removal by trained professionals.
    a. Money from increased property taxes
3. Install protective covering over pipes [*mussels cause huge amounts of damage by clogging pipes in power plants*].

Target:
Every lake in WI [*a lofty goal given 15,000+ lakes in WI*].

- Focus on highly susceptible lakes ID'd by DNR researcher [*follows the "smart prevention" model of invasive species management that students likely learned in class and the DNR Researcher is given a framework for evaluating a lake's vulnerability to mussel invasions*].

Timeframe:
1 Year – have majority of educational signage up
5 Years – reconvene with data about progress
15 Years – have majority of invaded lakes free of mussels and reintroduce native mussels

Cost:
Increase property taxes, cost of fishing licenses, cost of sewerage and water fees, contribution from Lake Associations [*each of these are likely contributions from individual player characters being willing to provide "funding" to solving this issue*].

Figure 4. Example of a Final Management Plan developed by a role-playing group in class. Italicized text inserts are notes to provide context for the students' comments.

Bloom's Taxonomy of Learning Domains	World of Watershed Management
Knowledge & Recall	Limnology Course and Lab Content
Comprehension & Understanding	
Application	Ecosystem Management Scenario
Analysis	
Synthesis	Final Management Plan
Evaluation	Group Critique of Final Management Plan

Table 1. Conceptual diagram of the role of WOWM in developing higher order learning domains.

A - Gender	
Male	50.9 (27)
Female	49.1 (26)
B - Ethnicity	
White	90.6 (48)
Asian or Pacific Islander	9.4 (5)
African American or Black	5.7 (3)
Latino or Hispanic	5.7 (3)
Indian	1.9 (1)
C – Academic Major	
Biology Related	84.9 (45)
Environmental Studies	20.8 (11)
Water Resources management	5.7 (3)
Other (1 response each): Biochemistry, Pre-Pharmacy, Spanish, Mathematics, Chemistry, Geoscience	11.3 (6)
D – Career Goals	
Medicine or Health Care	58.4 (31)
Natural Resources Management	13.2 (7)
Research	11.3 (6)
Secondary Education	5.7 (3)
Business/Finance	5.7 (3)
Environmental Engineering	3.8 (2)
Community Organization	1.9 (1)
Undecided	9.4 (5)
E - Scenario	
Agriculture, eutrophication and water clarity	45.3 (24)
Invasive species management	54.7 (29)

Table 2. Aggregate background information for the 53 student participants that completed both the pre- and post- surveys as a percentage of students responding within each category. Total responses are in parentheses. Students were able to select more than one response in each section, so percentages can sum to over 100%.

Model (*Question* ~ Factors)	F	*p*
I am interested in the conservation of aquatic resources~		
Activity (Pre/Post)	0.02	0.89
Gender	0.15	0.70
Scenario	0.05	0.82
Experience with RP	0.01	0.92
I am comfortable with role-playing in my group~		
Activity (Pre/Post)	0.59	0.44
Gender	1.90	0.17
Scenario	1.23	0.27
Experience with RP	2.36	0.13
I consider myself to be extroverted~		
Activity (Pre/Post)	1.10	0.30
Gender	0.43	0.51
Scenario	0.10	0.75
Experience with RP	3.58	*0.06*
I am interested in limnology~		
Activity (Pre/Post)	0.00	0.98
Gender	0.01	0.91
Scenario	0.33	0.56
Experience with RP	1.63	0.21
I think role-playing is a fun way to learn~		
Activity (Pre/Post)	4.09	**0.001**
Gender	0.59	0.44
Scenario	0.20	0.66
Experience with RP	1.18	0.28
Non-STEM sciences are an integral part of ecosystem management~		
Activity (Pre/Post)	1.50	0.22
Gender	0.41	0.52
Scenario	0.03	0.85
Experience with RP	0.38	0.54
I am confident that I could take part in the discussion of real world limnological issues using the knowledge I've gained in this course.~		
Activity (Pre/Post)	0.99	0.32
Gender	0.10	0.75
Scenario	0.08	0.78
Experience with RP	0.98	0.33

Table 3. Results of the MANOVA investigating the role of the WOWM activity (before or after), gender (male or female), scenario (water clarity or invasive species) and experience with role-playing (no experience or experience) on the agreement with each of the questions (italicized). Significant values at an $\alpha = 0.05$ *p*-values are bolded, values at an $\alpha = 0.10$ are italicized.

	Pre-Survey	Post-Survey	T	*p*
I am interested in the conservation of natural resources.	3.55 (0.07)	3.57 (0.08)	-0.18	0.86
I am interested in limnology	3.26 (0.06)	3.23 (0.07)	0.39	0.70
I am comfortable role-playing with my group.	3.15 (0.09)	3.27 (0.07)	-1.01	0.31
I consider myself to be extroverted.	2.77 (0.10)	2.91 (0.11)	-0.93	0.35
I think role-playing is a fun way to learn	2.91 (0.10)	3.34 (0.07)	-3.58	**0.0005**
Non-STEM sciences like sociology, economics and political science are an integral part of ecosystem management.	3.36 (0.09)	3.49 (0.07)	-1.16	0.25
I am confident that I could take part in the discussion of real world limnological issues using the knowledge I've gained in this course.	3.28 (0.07)	3.17 (0.06)	1.21	0.23

Table 4. Mean agreement (±1 S.E) to each statement before (Pre-Survey) and after (Post-Survey) the WOWM activity and *t*-test results comparing agreement before and after the WOWM activity. Significant ($\alpha = 0.05$) *p*-values are bolded.

General Questions	*Mean Response Value*
I thought the role-playing activity was entertaining.	3.38 (0.07)
This activity helped me learn how different fields (like sociology, economics and political science) play a role in managing ecosystems.	3.35 (0.08)
This activity helped me understand limnology-specific course material.	3.04 (0.09)
Participation Questions	
I was consistently in character during the scenario.	3.25 (0.07)
*Group members contributed to the role-playing discussion _____.	3.92 (0.17)
Final Management Plan Related Questions	
My character was satisfied with the FMP.	3.11 (0.09)
I was satisfied with the FMP.	3.11 (0.08)
**How much of a role did your character play in writing the FMP?	3.92 (0.17)

Table 5. Mean agreement (± 1 S.E.) to statements included in only the post-survey.

*Not along agreement scale. 5 = Equally, 4 = Somewhat equally, but everyone participated consistently, 3 = Somewhat equally, one or two players didn't participate consistently, 2 = Not equally, over half of the players didn't participate consistently, 1 = None of the above, discussion was consistently dominated by one person.

**Not along agreement scale. 6 = More than 40%, 5 = 40%, 4 = 20%, 3 = 10%, 2 = 5%, 1 = 0%

Model (*Question* ~ Factors)	F	*p*
I thought the role-playing activity was entertaining~		
Gender	0.01	0.91
Scenario	2.15	0.15
Experience with RP	2.08	0.16
This activity helped me learn how different fields play a role in managing ecosystems~		
Gender	0.17	0.68
Scenario	0.59	0.45
Experience with RP	1.97	0.17
This activity helped me understand limnology-specific course material~		
Gender	0.00	0.99
Scenario	1.09	0.30
Experience with RP	1.47	0.23
I was consistently "in character" during the scenario~		
Gender	0.36	0.55
Scenario	0.07	0.79
Experience with RP	0.19	0.67
My character was satisfied with the final management plan~		
Gender	0.06	0.81
Scenario	1.70	0.20
Experience with RP	0.00	0.96
I was satisfied with the final management plan~		
Gender	0.05	0.83
Scenario	0.15	0.70
Experience with RP	0.07	0.79
My character played an equal role in writing the FMP~		
Gender	0.05	0.83
Scenario	0.33	0.57
Experience with RP	0.06	0.80
Group members contributed equally to the role-playing discussion~		
Gender	0.02	0.88
Scenario	8.53	**0.005**
Experience with RP	0.06	0.80

Table 6. Results of the MANOVA investigating the role of gender (male or female), scenario (water clarity or invasive species) and experience with role-playing (no experience or experience) on the agreement with each of the questions (italicized) in the post-survey. Significant ($\alpha = 0.05$) *p*-values are bolded.

A - *What did you like most about the activity?*	*Percentage of Responses*
Stakeholder diversity and problem complexity	27.6 (16)
Role-playing	24.1 (14)
Fun interaction with classmates	17.2 (10)
Discussion	15.5 (9)
Real world Application	12.1 (7)
Easy, relaxed and light-hearted	10.3 (6)
Compromise, negotiation and cooperation	10.3 (6)
Scenario materials	8.6 (5)
Engaging	8.6 (5)
Different from other labs	6.9 (4)
Conflict	5.2 (3)
Other (two or fewer responses each)	13.4 (8)
	160.0 (93)

B - *What did you like least about the activity?*	
Limited understanding of character roles and scenario background	32.8 (19)
None, liked everything	12.1 (7)
Confusing game set-up	10.3 (6)
Unequal participation	8.6 (5)
Rushed, limited time	6.9 (4)
Filling out character sheets	6.9 (4)
Unbalanced character roles	5.2 (3)
Other (two or fewer responses each)	17.2 (10)
	100.0 (58)

C - *Which elements of the exercise helped you feel more comfortable with role-playing in a group?*	
Character sheet	22.4 (13)
Freedom to choose role-playing style, not contingent on personal beliefs	13.4 (8)
Group character introductions	12.1 (7)
Bonding with classmates over semester	10.3 (6)
Already comfortable with role-playing	6.9 (4)
Grasp of limnological content	5.2 (3)
Other (two or fewer responses each)	13.4 (8)
	93.1 (54)

D - *What could have been done to make you feel more comfortable about role-playing in a group?*	
Nothing	32.8 (19)
More time to research character role and scenario background	27.6 (16)
Staying with usual lab groups	8.6 (5)
More scripted gameplay	5.2 (3)

Other (two or fewer responses each)	13.4 (8)
	87.9 (51)

E - *What were the most confusing elements of the activity?*	
Not confused	22.4 (13)
Character role and scenario background	19.0 (11)
Special ability or attributes on character sheet	12.1 (7)
Rules	10.3 (6)
Gameplay mechanics of "funding"	5.2 (3)
Limnology specific scenario content	5.2 (3)
Other (two or fewer responses each)	6.9 (4)
	81.0 (47)

F - *What was the hardest part of writing the Final Management Plan?*	
Getting everyone to agree on FMP content	43.1 (25)
Not enough prior knowledge of management techniques	17.2 (10)
Consolidating ideas	17.2 (10)
Trying to find best solution for ecosystem	13.4 (8)
Budget/Funding constraints	12.1 (7)
Class time	6.9 (4)
Other (two or fewer responses each)	6.9 (4)
	117 (68)

G - *Reflect on WOWM as a learning tool in the lab. Should we include it as a lab again next year?*	
Yes	100.0 (58)
No	0.0 (0)
	100.0 (58)

H – *Why should we include WOWM as a lab next year?*	
Fun and entertaining	37.9 (22)
Understanding stakeholder diversity	31.0 (18)
Application of limnology in real-life situations	31.0 (18)
Change from normal lab activities	13.4 (8)
Interactive and engaging	5.9 (4)
Informative	5.9 (4)
Practice developing arguments	5.2 (3)
Other (two or fewer responses each)	10.3 (6)
	141.4 (82)

Table 7. Aggregated and categorized (by common theme or topic) results from qualitative short answer responses in the post-survey are presented in percent of students responding with that topic. Total responses in a given topic are in parentheses. Many students provided responses that touched on more than one topic, so total percentages may add up to greater than 100%.

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World of Watershed Management Appendices

A - WOWM
B - Character Role Summaries
C - Students' Character Sheets
D - Characters' Final Management Plan Goals
E - Pre-Survey
F - Post-Survey
G - Selected Short Answer Quotes from Students

Appendix A – World of Watershed Management

World of Watershed Management (Beta Testing Version)

"World of Watershed Management" (WOWM) is a role-playing game where *you* have a stake in watershed management decisions (just like real life except way easier and with less voting). Will your character get what he or she wants or will they be doomed to live with the management decisions of their greatest adversary?

In WOWM the individual objective of the game is to come up with a management plan that best serves your character. However, many characters will have legitimate opposing wants and needs, so "winning the game" may be a unique challenge for you as you attempt to assert the will of your character on the other player characters. WOWM can be played cooperatively… or not. WOWM is a role-playing game, so you select a role and stick to it. This brings us to the first and most important rule of WOWM:

STAY IN CHARACTER

And here are some other, less important (but still important), rules and directions:

Select a gaming scenario

Luckily there are many problems in WOWM, which means the game is different depending on the scenario you select. First select a game scenario (or management problem) for your group, there should be an equal number of each scenario in each lab section (ex: 3 and 3 if you have 6 total lab groups):

1. Agriculture, Eutrophication and Water clarity
2. Aquatic Invasive Species Management

Don't forget to grab your scenario's corresponding information sheet (useful for the dungeon master… we'll get to what a dungeon master is, if you don't already know).

Select a dungeon master

Even though there are no dungeons to be plundered and conquered in WOWM, there is a dungeon master. Skills that make a good dungeon master are: creativity, previous experience with tabletop RPGs, good sense of humor, deeply-seeded belief in fairness and justice, cat-herding ability, attention to detail and intense nerdiness. The dungeon master will be responsible for:

1. Keeping the party (group of player characters) on topic and in character
2. Chronicling the adventure (take notes on the events that transpire during the game)
3. Executing in-game events that occur at the designated time points in the scenario
4. Writing the final management plan based on each player character's performance and the conversations had in the group. You're kind of like Drew Carey in "Whose line is it anyway?" - you pretty much just have to do your best to be fair and inclusive in writing your final management plan, but it's pretty subjective.
5. Summarize and give a brief overview to the class of the major events and topics of the scenario at the end of the game. Also, present the terms of the final

management plan and the reasons the dungeon master decided on those terms. The presentation can be done as a group.

6. **Keeping the party on topic and IN CHARACTER.**

If the term "Dungeon Master" is confusing to you, you can think of yourself as The Journalist (since you'll be keeping track of the events and conversation of the scenario), The Governor (since you'll be making the final decisions with the group about the Final Management Plan) or Mother Nature (since you'll be cueing different events in the scenario).

Oh and you can reward/penalize (within reason) good/bad role-playing.

Select your character and fill out your character sheet

The greatest part of any tabletop role-playing game is character creation (though arguments could be made for character/story development, leveling and looting). This is where you get to be as creative as you want (be respectful though). You have your character and you know what they're capable of, now how do you make them as unique and awesome as you are? The only rule here is to be respectful and… stay in character once you've completed this step.

Keep in mind that you might want to pay attention to the player characters being selected in your group and build a team that collaborates well (e.g. the holy trinity, "damage dealer – healer – tank", from the less-creative RPG videogames). Take a second to double check that all "Mandatory Player Roles" from your scenario sheet are covered in your party.

Here the DM can start to get familiar with the scenario (DM – the scenario sheet is basically your character sheet, don't let the power get to your head).

Scenario Introduction

The dungeon master introduces the scenario by following the directions on the scenario information sheet. This typically involves reading the description aloud, identify the "mandatory player roles" and setting the stage (What year is it? Where are we? Who's here? What do we know already?).

Character Introductions

Go around the table and introduce your character to the group. What's your name? What do you do? What do you look like? Why is this management problem important to you? What are your motives? Or at least, what are the motives you want to reveal to the party?

Gameplay

Discussion and Debate

Here you are encouraged to stay as in character as possible and have fun with the character you selected. The discussion starts when the first person suggests something they feel should be included in the management plan. You have 1 hour and 30 minutes to discuss and deliberate, so plan your time accordingly because you'll need 15 - 30 minutes to write up your group's Final Management Plan.

Role-playing tips:

- Just because you know something, doesn't mean your character knows something
- You might not have the same opinions as your character; likewise, your group member might not have the same opinions as their own character (role-playing is, by definition, not personal).
- A person playing a character might seem really annoying and counterproductive, as long as they're playing their character, this is okay – don't let this game get personal!
- Dungeon Masters will reward good role-playing which includes:
    - Doing or saying things your character would do and not doing or saying things they wouldn't (stay in character).
    - Particularly if doing or not doing that thing makes the game harder for you

Challenges & Other Mid-scenario events

Just like in real-life, problems aren't static, they change and shift, get better or worse, more problematic for some people or less problematic for others. However, the game isn't outrageous with these, they're usually grounded in how these scenarios played out in real-life.

Writing the Final Management Plan

This should take place over the course of the 1.5-hour gaming session, with one final push in the last minutes of the session to write out the management plan. As your group is writing the final management plan with the DM, you may step out of character to make sure that the group agrees on what should go into the management plan based on how each player character performed during the game. Players who stuck to their character the most, role-played the most interesting characters and, most importantly, provided the most convincing arguments for their cause should have more sway in the FMP than other players.

If you don't come up with a final management plan, your group loses the game and you lose all the prize money… every penny of it.

Things that you might consider including in your Final Management Plan:

- Brief (1-2 sentence) statement of the problem (may change depending on which player character "defined" the problem for the group)
- Management strategies
- Mitigation of possible problems caused by your management plan
- Measures of success (how do you know your plan is working?)
- Costs associated with your plan (economic or ecological or any other costs you can think of)

Investigating the real-world Management Plans for your topic

Each of your group members should have located one real-world management plan that has been developed for your topic. Go around your group and have each

member discuss how the management plan they found differed from your group's management plan.

Presenting the Final Management Plan

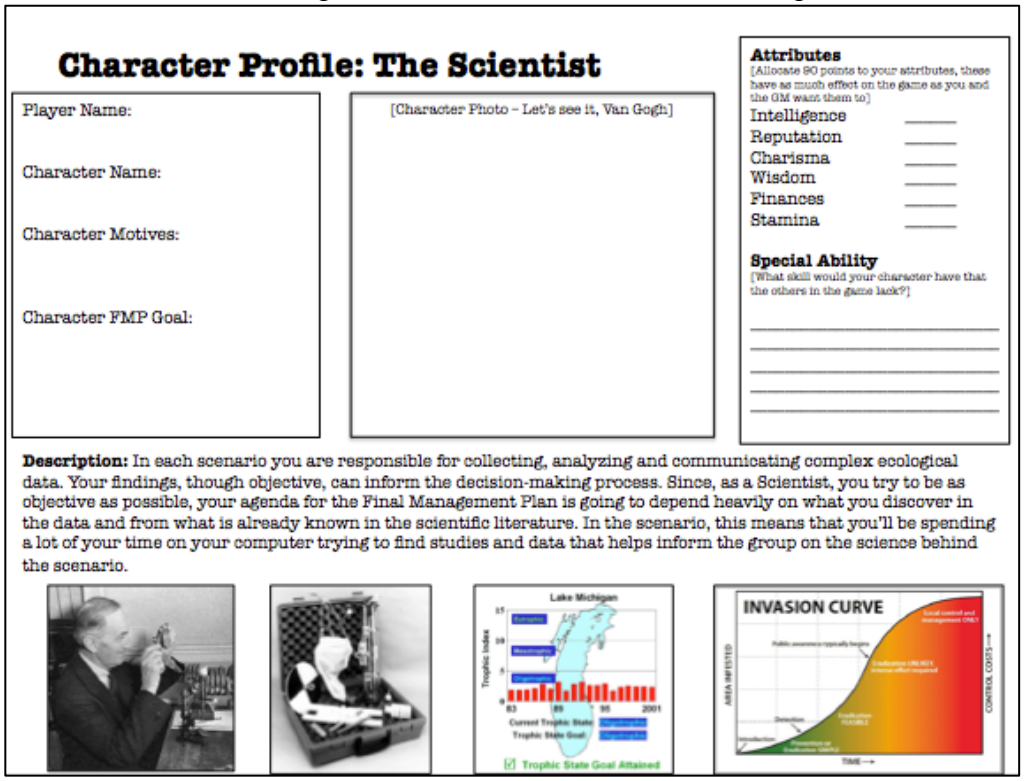
As a group, you can determine who presents what, but make sure to include the following:

- A brief introduction to your scenario and your characters
- Your Final Management Plan (this should only be a paragraph or two, so you can just read it word for word)
- Why you decided to include what you did in your Management Plan
- Who influenced your plan the most (i.e. who "won") and why
- Role-Playing successes and failures
- How your management plan stacks up to the real-world management plan
- Answer class/TA questions about your gaming session

Shoot for 5 minutes of presentation, leaving some time for class discussion on your topic.

Appendix B – Character Role Summaries

Character role summaries were presented on a character sheet with a photo and room for students to flesh out and personalize their character. For example:



Character Profile: The Scientist

Player Name:

Character Name:

Character Motives:

Character FMP Goal:

[Character Photo – Let's see it, Van Gogh]

Attributes

[Allocate 80 points to your attributes, these have as much effect on the game as you and the GM want them to]

Intelligence _____
Reputation _____
Charisma _____
Wisdom _____
Finances _____
Stamina _____

Special Ability

[What skill would your character have that the others in the game lack?]

_____
_____
_____
_____
_____

Description: In each scenario you are responsible for collecting, analyzing and communicating complex ecological data. Your findings, though objective, can inform the decision-making process. Since, as a Scientist, you try to be as objective as possible, your agenda for the Final Management Plan is going to depend heavily on what you discover in the data and from what is already known in the scientific literature. In the scenario, this means that you'll be spending a lot of your time on your computer trying to find studies and data that helps inform the group on the science behind the scenario.

The Scientist - In each scenario you are responsible for collecting, analyzing and communicating complex ecological data. Your findings, though objective, can inform the decision-making process. Since, as a Scientist, you try to be as objective as possible, your agenda for the Final Management Plan is going to depend heavily on what you discover in the data and from what is already known in the scientific literature. In the scenario, this means that you'll be spending a lot of your time on your computer trying to find studies and data that helps inform the group on the science behind the scenario.

The DNR Research Specialist - In each scenario you are responsible for collecting, analyzing and communicating complex ecological data specific to the problems facing your State's natural resources. Your findings are unique from the Scientist's in that the higher-ups in the State department (Grant Managers – for the purpose of this game) occasionally direct your research, giving you less flexibility in determining your research topics. However your research project goals are almost always focused on solving applied problems. In the scenario, this means that you'll be spending a lot of your time on your computer trying to find studies and data that helps inform the group on the science behind the scenario.

The State Manager - In each scenario, you are responsible for funding projects that you feel best serve the State and its natural resources. This increases the effectiveness of the Player Characters working on those projects and thus gives you an indirect route to

modify the outcome of the Final Management Plan. Funding has to be within the limits of reality (the State isn't exactly bursting at the seams with money) and there are some suggestions for each scenario, but feel free to get creative with how you allocate funds to solving problems. In the scenario this will play out as you helping other player characters by helping them find necessary info online, giving them an extra voice in group discussion or helping "fund" expensive management solutions. The DM should give extra weight in the FMP to whichever player character you decide to support.

The Property Owner - You own property on or near the ecosystem of the scenario. It is your job to determine your property owner's motivations because these can range so widely in the real WOWM. As a property owner, you must balance how much money and time you're willing to invest in a management plan, what you value in your ecosystem, what you're willing to do to make sure you can continue enjoying it and where your values lie in the stewardship of this ecosystem. This is all in addition to, of course, what the management plan will do to your property value (both it's dollar value and value to you the property owner). Like the President of the Lake Association, you're a public citizen invested in the outcome of this management plan because you value this ecosystem (or what it does for your property value).

The Farmer - Farming is hard, expensive, unpredictable and a very important part of, you know, keeping people fed/alive and you're the one who's tasked with doing it. Your bottom line is getting consistent harvests or yields, year in and year out. You do this by working yourself like a dog and spending money on farming strategies that you know for a fact are effective. There isn't a lot of wiggle room for failure in farming, whether you spend money on an ineffective strategy or a crop fails, you're responsible for keeping your farm going.

In Wisconsin you use manure to fertilize your crops, but manure is rarely in short supply because of your emphasis on dairy farming (cows produce a lot of manure). Therefore, you spend a lot of time trying to utilize your manure from dairy farming to produce other crops. Any manure you don't use runs the risk of being washed into drainage ditches and then into streams and lakes if left alone. Therefore, when you have a surplus of manure (which you most certainly will if you're a dairy farmer), you need to figure out how you're going to keep it on your farm (google in-field manure best management practices) or how you're going to dispose of it.

Your job is to convince people that don't see the behind the scenes work that goes into food production of the importance of every detail of your farming process, as well as navigate the convoluted world of farming in the 21st century. Of course, you care about the environment, but so do city-people and they drive around in fossil-fuel guzzling cars all day.

The Fisherman - Your role in most of these scenarios is fairly obvious, you like using each ecosystem for fishing, so you care about 1) catching fish and 2) having a good time while you're doing it. Since catching fish is relatively rare (but really important to you), it is important that the time you spend on the water is enjoyable. Regulations can limit what you fish for, how you fish for it, where you can fish for it and the fines associated with breaking those regulations. However, you understand that it takes work to maintain a

productive fishery; you just don't necessarily want to be the person making sacrifices to maintain it (or maybe you're all about solidarity and personal sacrifice – it's really your call, which is the great part of role-playing).

As a fisherman, you are a crucial cog in the economy surrounding your ecosystem. You spend money for lodging, food and supplies each time you go fishing. You also contribute to management funding through purchasing your fishing license. Though this is contribution is relatively small on your end if you're a Wisconsin fisherman, this really adds up for the Wisconsin DNR.

The Outdoors Enthusiast - Of all the player characters (even the fisherman or the property owner) you probably have the most flexibility in how you play your character. You can choose what you're enthusiastic about (including but not limited to; bird watching, hiking, bicycling, camping, bug collecting, cross-country skiing or even a combination of these). The only thing you have to keep track of is whether your outdoor activity(ies) make sense in your scenario's ecosystem.

You have the unique ability to form clubs or associations that meet up to do or talk about the thing you're enthusiastic about. This can greatly increase the influence you have over the management plan. However, there is a high turnover rate in these kinds of groups and more often than not, you'll have to do all the work. Otherwise your groups can assist in manual labor type projects, can donate funds, lobby at events, etc (be creative in how your group works). This plays out as additional support to ideas proposed by you or other player characters for the FMP.

The President of a Lake Association - As the President of a Lake Association, you are a citizen (probably living on or near the lake) that has invested so much in your lake and value it so much that you decided to take a leadership role in its stewardship. Your goals can vary from ensuring the lake has a "healthy" ecosystem, to working towards a more stable fishery, to improving the value of the properties owned by all the members of the lake association.

Luckily, lakeshore property is expensive and though some of your members might not live on the lakeshore, many of them live there for at least a part of the year. This means that you should have a relatively stable flow of money that can help fund research grants, management projects and public outreach (be creative in how you can allocate funds). You also have some ability to bring together the Lake Association and the local community in contributing to these grants and projects either through manual labor or planning and organization. You also often act as the go-between for managers or scientists and the local community by organizing meetings and events or distributing research and management information.

Your biggest challenges lie in managing your Lake Association Members. You're tasked with the notoriously awkward task of fund-raising and the seemingly impossible task of making sure everyone in the association has the same goals, understands how to achieve them and is willing to assist in achieving them. Also, odds are 100% that you are either a) retired or b) have another job. Being the President of a Lake Association doesn't really pay, so the time and money you invest in this is completely out of the goodness of your heart and you'll have to balance it with your personal and professional lives.

The Recreational Boater - You enjoy using the lake for a wide range of purposes, but all of them have one thing in common: your boat. You and the people you bring out on your boat might enjoy fishing, water skiing, tubing, swimming, diving/snorkeling or just sitting out and enjoying what your lake or river has to offer. Of course, there are ecosystem services associated with each of these activities - diving and snorkeling require clear water, fishing requires a halfway decent fishery, tubing and swimming require water clear of macrophyte mats and toxic algal blooms and sitting and enjoying a lake is less enjoyable when you have to listen to a highway running past it.

However, one of the primary interfaces that links you to management problems lies at the boat launch. You've seen the signs about invasive species, fish species catch limits, mercury advisories, feeding ducks and, if you're lucky, you've talked to a spunky high school student with a clipboard about each of them. You probably care about these issues because it's relatively clear that they can impact how much fun you have with your boat out on the lake, but the lengths you're willing to go to follow the rules posted at each boat launch limit your investment in these issues. For example: cleaning invasive plants off of boats sounds awesome, unless there are a ton of plant fragments, they're wedged in all sorts of hard to reach places and you're 75 years old (being retired can involve a lot of boating).

The Park Ranger - It's your job to locally enforce the management plans and policies put forth by your local management agency. You are likely incredibly limited in your budget (money available to enforce policies), your staff (man hours available to enforce policies) and in what you're able to do to enforce. Rather than simply dishing out tickets at every infraction, you've considered getting out ahead of new policies by educating the public on new laws, why they're important and how they can follow them.

In the scenarios, it is your job to make sure that any laws or policies put into effect are feasible to enforce at the local level. You need to figure out how many staff and how much money it will take to enforce a given policy or law in your group's Final Management Plan.

The Director of the Sewerage Department - As a regional director of the sewerage department you sit at the crossroads of waste, waste management and laws regarding waste management. Decision-makers give you numbers (typically concentrations) to regulate the levels of phosphorus, suspended solids, mercury, et cetera in water and it's your job to make sure you meet those numbers. The most straightforward (but expensive) way to do this is to build water treatment plants to treat water before it goes into lakes and rivers.

So, it is your job to find cost effective methods to meet regulatory compliance standards. You can work "at the pipe" to treat water or you can work at the source of the problems facing water quality (ex: helping fund manure management strategies in the watershed of the water bodies you're tasked with keeping clean). You stand on a foundation of highly successful strategies to divert point source pollution into lakes and rivers, so you set forth on your quest looking to build off those successes with innovative new solutions for water quality issues.

Appendix C – Students' Character Sheets

Character Profile: The State Manager

Player Name:
[redacted]

Character Name:
DNR DAN

Character Motives:
To allocate state resources to create a functional plan to help save the aquatic resource and eliminate the invasive by whatever means necessary.

Character FMP Goal:
To find a cost effective and functional solution to the invasive problem.

[Character Photo – Let's see it, Van Gogh]

Attributes
[Allocate 90 points to your attributes, these have as much effect on the game as you and the GM want them to]

Intelligence	20
Reputation	15
Charisma	10
Wisdom	10
Finances	30
Stamina	5

Special Ability
[What skill would your character have that the others in the game lack?]

Ability to see creatures in despare and being affected by invasives. Also has state funds I suppose to fund a project to remove or prevent spread of invasives.

Description: In each scenario, you are responsible for funding projects that you feel best serve the State and its natural resources. This increases the effectiveness of the Player Characters working on those projects and thus gives you an indirect route to modify the outcome of the Final Management Plan. Funding has to be within the limits of reality (the State isn't exactly bursting at the seams with money) and there are some suggestions for each scenario, but feel free to get creative with how you allocate funds to solving problems. In the scenario this will play out as you helping other player characters by helping them find necessary info online, giving them an extra voice in group discussion or helping "fund" expensive management solutions. The DM should give extra weight in the FMP to whichever player character you decide to support.


Image: ICE

WISCONSIN
DEPT. OF NATURAL RESOURCES

Character Profile: The Scientist

Player Name: [redacted]

Character Name: Nell I. Pothesis

Character Motives: to support & influence DNR recommendations,

Character FMP Goal:

to prevent lake degradation by invasive species & get more funding for invasive species research

[Character Photo – Let's see it, Van Gogh]

Attributes

[Allocate 90 points to your attributes, these have as much effect on the game as you and the GM want them to]

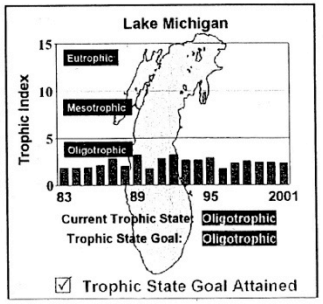
Intelligence	30
Reputation	10
Charisma	10
Wisdom	20
Finances	10
Stamina	10

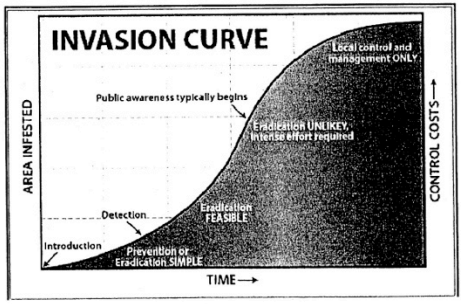
Special Ability

[What skill would your character have that the others in the game lack?]

Most objective, thinks in the long term & backs up claims with evidence

Description: In each scenario you are responsible for collecting, analyzing and communicating complex ecological data. Your findings, though objective, can inform the decision-making process. Since, as a Scientist, you try to be as objective as possible, your agenda for the Final Management Plan is going to depend heavily on what you discover in the data and from what is already known in the scientific literature. In the scenario, this means that you'll be spending a lot of your time on your computer trying to find studies and data that helps inform the group on the science behind the scenario.





Character Profile: The Recreational Boater

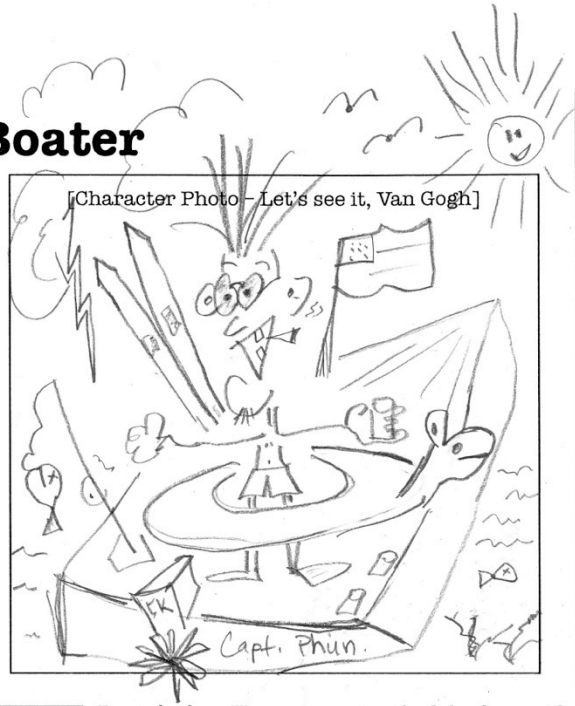
Player Name: [redacted]

Character Name: Beavis P. Mc. Sliver

Character Motives:
"Clean" water for swimming/boating
"clean" docks, no algae - hate boater rules

Character FMP Goal:
Regular weed removal @ docks
Reduced Algae blooms
Fish- don't care what kind
Fun • Fish • Freaky Clean Docks

[Character Photo – Let's see it, Van Gogh]

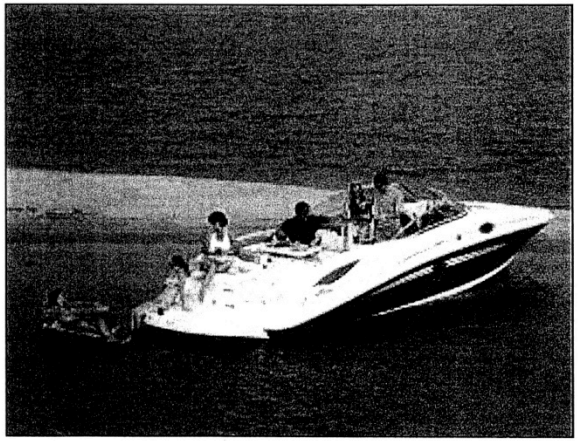


Attributes
[Allocate 90 points to your attributes, these have as much effect on the game as you and the GM want them to]

Intelligence	10
Reputation	15
Charisma	15
Wisdom	5
Finances	40
Stamina	5

Special Ability
[What skill would your character have that the others in the game lack?]

$, loud voice
Well Connected
Beer



Description: You enjoy using the lake for a wide range of purposes, but all of them have one thing in common: your boat. You and the people you bring out on your boat might enjoy fishing, water skiing, tubing, swimming, diving/snorkeling or just sitting out and enjoying what your lake or river has to offer. Of course, there are ecosystem services associated with each of these activities - diving and snorkeling require clear water, fishing requires a halfway decent fishery, tubing and swimming require water clear of macrophyte mats and toxic algal blooms and sitting and enjoying a lake is less enjoyable when you have to listen to a highway running past it.

However, one of the primary interfaces that links you to management problems lies at the boat launch. You've seen the signs about invasive species, fish species catch limits, mercury advisories, feeding ducks and, if you're lucky, you've talked to a spunky high school student with a clipboard about each of them. You probably care about these issues because it's relatively clear that they can impact how much fun you have with your boat out on the lake, but the lengths you're willing to go to follow the rules posted at each boat launch limit your investment in these issues. For example: cleaning invasive plants off of boats sounds awesome, unless there are a ton of plant fragments, they're wedged in all sorts of hard to reach places and you're 75 years old (being retired can involve a lot of boating).

Appendix D – Characters' Final Management Plan Goals

At the beginning of the activity, students were asked to select their character's goals for the Final Management plan. Below are selected quotes from students' character sheets that highlight how students perceived and role-played their character roles.

Character Role	Selected Quotes
Scientist	*"Help make educated decisions based on scientific literature."*
Recreational Boater	*"Fun. Fish. Freaky Clean Docks."* *"Water clarity and diverse fishery."*
State Manager	*"Have funding to help keep out invasive species. Allocated these funds appropriately to help keep invasive species out."* *"Solve EWM problem in the most natural way possible, no herbicides."*
President of a Lake Association	*"To be a voice for Lake Association and local community."* *"Maintain the beauty and recreational value of the lake. Improve property values of members."*
Park Ranger	*"To enforce the management plans and policies put forth by my local management."*
Farmer	*"Use most efficient farming techniques."* *"I will limit my manure use."* *"Plans for strategic farming. Educate about farming process, details about food production are important. Remain up to date with modern farming technology."*
Fisherman	*"To preserve fishery. Reasonable fishing and boating regulations. DNR management, low civilian cost."* *"No extreme sacrifices to recreation through regulation. No unnecessary development. Eliminating algae blooms to make fishing more enjoyable."*
Property Owner	*"Want what is good for ecosystem. Want my property's value to stay same or improve. Want project to be finished as quickly as possible."* *"Blame it on the farmers – have them and the state pay for expenses."* *"I'm rich! And cheap!"* *"Stop everything. Limit the government."*
DNR Research Specialist	*"Getting my way."*
The Director of the Sewerage Department	*"To find a cost effective method to meet regulatory compliance standards."*

Appendix E – Pre-Survey Contents

The survey was conducted on-line using Qualtrics via survey.wisc.edu. The following is a summary of the survey's contents.

Introduction

In the emails you received from your TA, you should have been assigned a game scenario in the "World of Watershed Management" role-playing game. We'd like you to complete a short survey to help us improve this exercise for next year and to help you prepare for the activity. The personal information you include in this survey will only be used to improve this course and will be collected confidentially (your names will only be used to match this survey to a post-activity survey). Your TAs will not see your responses until after the course is completed and your grades finalized, then your responses will be made available but they will not be linked to your name. This assignment will only be graded on completion, but take time to answer questions thoroughly and honestly because of how useful your responses will be to improving this activity for future years.

Personal Information

- Name (First, Last)
- Gender (Male, Female)
- Ethnicity (Select all that apply: American Indian or Alaskan Native, Asian or Pacific Islander, African American/Black, Latino/Hispanic, White, Other: please specify)
- Academic Year (First, Second, Third, Fourth, Fifth, Graduate Student, Other: please specify)
- What is your major? (Open short response)
- What are your career goals? (Open short response)
- What is the primary reason you're taking this course? (Open short response)
- Ecosystem Management Scenario (Water Clarity, Invasive Species)
- Where have you been exposed to role-playing before? (Select all that apply: No experience, Pre-professional trainings (nursing, teaching, etc.), Psychology, Videogames (World of Warcraft, Skyrim, etc.), Tabletop role-playing games or Live-action role-playing games (Dungeons and Dragons, etc.), Other: please specify)

Agreement Questions

4 = Strongly Agree, 3 = Agree, 2 = Disagree, 1 = Strongly Disagree

- I am interested in the conservation of natural resources
- I am comfortable role-playing with my lab group
- I consider myself to be extroverted
- I am interested in limnology
- I think role-playing is a fun way to learn
- Non-STEM fields like sociology, economics and political science are an integral part of ecosystem management

- I am confident that I could take part in the discussion of real world limnological issues using the knowledge I've gained in this course

The following questions will be based on the knowledge you've gained in class, the scenarios paper you've read for class today and your understanding of the rules of WOWM (sent out by your TAs).

- As mentioned in the email from your TA, WOWM is a scenario-based role-playing game and the objective of the game is to come up with a "Final Management Plan" that best serves the stakeholders in your scenario group while making sure that your character has the most say in the content of the "Final Management Plan" (FMP). What do you think the three most important concepts will be in your group's FMP? Why? Provide 2-3 sentences for each concept explaining why your group would include it in the FMP.
- For the Water Clarity Scenario Group: Explain what factors influence water clarity and why water clarity might be important for a lake ecosystem
- For the Invasive Species Scenario Group: Explain how invasive species impact ecysystems and why it might be important to control invasive species and mitigate their impacts.

Appendix F - Post-Survey Contents

The survey was conducted on-line using Qualtrics via survey.wisc.edu. The following is a summary of the survey's contents.

Introduction

Now that the role-playing scenarios are over and the world has been saved, it's time for you to take some time to reflect on your experience. The personal information you include in this survey will only be used to improve this course and will be collected confidentially (your names will only be used to match this survey to a post-activity survey). Your TAs will not see your responses until after the course is completed and your grades finalized, then your responses will be made available but they will not be linked to your name. This assignment will only be graded on completion, but take time to answer questions thoroughly and honestly because of how useful your responses will be to improving this activity for future years.

Personal Information

- Name (First, Last)
- Group Members
- Ecosystem Management Scenario (Water Clarity, Invasive Species)
- Character Role
- What are your career goals? (Open short response)
- What is the primary reason you're taking this course? (Open short response)
- Where have you been exposed to role-playing before? (Select all that apply: No experience, Pre-professional trainings (nursing, teaching, etc.), Psychology, Videogames (World of Warcraft, Skyrim, etc.), Tabletop role-playing games or Live-action role-playing games (Dungeons and Dragons, etc.), Other: please specify)

Agreement Questions

4 = Strongly Agree, 3 = Agree, 2 = Disagree, 1 = Strongly Disagree

- I am interested in the conservation of natural resources
- I am comfortable role-playing with my lab group
- I consider myself to be extroverted
- I am interested in limnology
- I thought the role-playing activity was entertaining
- I think role-playing is a fun way to learn
- This activity helped me learn how different fields play a role in managing ecosystems.
- This activity helped me understand limnology-specific course material
- Non-STEM fields like sociology, economics and political science are an integral part of ecosystem management
- I am confident that I could take part in the discussion of real world limnological issues using the knowledge I've gained in this course

World of Watershed Management Evaluation

- What did you like most about the activity? (Open essay response)
- What did you like least about the activity? (Open essay response)
- Which elements of the exercise helped you feel more comfortable about role-playing in a group? (Open essay response)
- What could have been done differently to make you feel more comfortable about role-playing in a group? (Open essay response)
- What were the most confusing elements of the activity? (Open essay response)

Critique of Group's Final Management Plan

- My character was satisfied with the FMP (agreement)
- I was satisfied with the FMP (agreement)
- I was consistently "in character" during the scenario (agreement)
- The FMP will be an effective natural resource management tool (agreement)
- Describe, in your own words, your group's FMP (Open essay response)
- How much of a role did you character play in writing the FMP? My character contributed _____ of the FMP. As a reference, in a group of five if everyone contributed equally, you would have contributed 20%. (6 = More than 40%, 5 = 40%, 4 = 20%, 3 = 10%, 2 = 5%, 1 = 0%)
- Group members contributed to the role-playing discussion _____. (5 = Equally, 4 = Somewhat equally, but everyone participated consistently, 3 = Somewhat equally, one or two players didn't participate consistently, 2 = Not equally, over half of the players didn't participate consistently, 1 = Not equally, discussion was consistently dominated by one person)
- Reflect on, critique and evaluate your group's FMP. Does it seem realistic? Would your character but into it? (2 – 3 paragraphs; Open essay response)
- What was the hardest part of writing the FMP? (Open essay response)
- Reflect on World of Watershed Management as a learning tool in the lab. Should we include it as a lab next year? (Yes/No) Why or Why not? (Open essay response)
- For the Water Clarity Scenario Group: Explain what factors influence water clarity and why water clarity might be important for a lake ecosystem
- For the Invasive Species Scenario Group: Explain how invasive species impact ecysystems and why it might be important to control invasive species and mitigate their impacts.

Appendix G – Selected Short Answer Quotes from Students

What did you like most about the activity?

- "I really liked how there was an emphasis placed upon having stakeholders that were very different from one another. This enabled our group to consider multiple perspectives and work together to come up with a plan that benefited everyone rathdelter than unconsciously formulating a plan that benefited some groups much more than others."
- "I thought the activity was a fun, engaging, and new way to learn. I liked how the activity made us see that there is so much more to conservation efforts and management. There are many factors to look at in conservation and science doesn't always win out. The activity showed that there isn't always an easy or right solution to a conservation problem."
- "Being in character and watching my classmates try to act, especially when their role forced them to have a stance or opinion they do not personally hold."
- "I enjoyed being forced into a position on the subject whether you personally agreed with it or not it still managed to make you think about the problem in a whole new way and perspective."
- "I liked how in the beginning we got to draw out characters. It helped us get in the part we were playing. I was skeptical of the activity but it turned out to be a great way to learn."
- "I liked how everyone needed to work together in order to properly solve the problem. It was an eye opener to understanding how these problems are solved in the real world and the importance of having someone with scientific knowledge (the scientist) to look out for the ecological aspects/safety in some of the solutions."
- "I enjoyed the light-hearted nature of the activity. Everybody was comfortable with the role-playing which made it a fun and relaxing environment for learning."

What did you like least about the activity?

- "Not everyone knew the roles and what their character would do in reality. In our group it ended mostly being 2 or 3 people talking."
- "Also, we should have been assigned characters in lab the week before so we could come to class prepared or maybe dressed as our character."
- "Two people in my group didn't really participate and one was a big role. I feel that since the person who had an important role & didn't participate we missed out on some good ideas and discussion."
- "When people didn't stay in character."

Which elements of the activity helped you feel most comfortable with role-playing?

- "The part where we made up a name and got to draw a picture, some of them were hilarious."
- "The character creating sheets I thought really helped structure the character and helped me get into character, which was fun."
- "Reminders that this is just a game and that roles don't reflect personal beliefs (or attacking other's beliefs) were helpful."

- "We were not required to pick characters that had the same opinions as ourselves on the issue."
- "That our class is small and we've worked with the same small number of students. We're gone on a field trip together, presented a project in front of each other, it makes it easy to talk openly."

Why should we include WOWM as a lab next year?

- "While I already had an idea that public decisions are tugged at from all sides before they finally settle, this lab did a good job of illustrating that. Plus, classes are often too focused on teaching students to become researchers. Not every student wants to be a researcher. If someone wants to deal with management or public affairs, for example, this lab might be more applicable to their career goals than anything else we've done thus far."

VI. Delta Internship Reflection

My Delta internship project was a great pathway in which to immerse myself in the application of the three Delta Pillars to my teaching. Here I reflect on several of the main points born from my experience developing, executing, and evaluating the World of Watershed Management activity.

Learning-Through-Diversity

The Delta internship revealed two new elements regarding diversity that I hadn't considered prior to the internship. First, and most obvious, was that students were remarkably in tune with the diversity goals of the "World of Watershed Management" role-playing activity. Without prompting, they were able to identify the benefit of considering stakeholder diversity in solving real world ecosystem management problems. They felt that the activity helped them have a deeper understanding of this diversity that traditional lectures or lab activities hadn't help them achieve to that point. Also, the role-playing activity adds an additional layer of differing perspectives, values and backgrounds to learning communities by forcing students (with their own backgrounds) to play out a role that didn't match their own perspectives in group discussion, collaboration and debate. Developing more activities that explicitly address diversity is something that I plan to do in the future. Nesting those activities within real world examples of ecology-related concepts seems to be an easy way to perpetually include diversity in my teaching since diversity is so tightly intermingled with so many of these ecological concepts. In particular, this activity highlighted the potential for discussion regarding the socio-economic factors that affect decision-making on natural resource isues at both local and global scales.

Second, addressing ethnic diversity in the course reinforced some of the thoughts I've had regarding the scarcity of minority PhD candidates in limnology. A former director of the UW Center for Limnology, John Magnuson, described in a talk that he can count on one hand the number of minority PhDs he has advised. The vast majority of students (90.6%) in the role-playing activity identified as white compared to 76% of undergraduates across UW – Madison campus (the city of Madison is 79% white and the state of Wisconsin is 86% white). This comes after thinking that more minority students were participating in the lab than in previous years. As someone who identifies as both a minority (Ojibwe) and white, I have limited experience addressing these issues and *all but one* of the 12 undergraduates I have mentored or even interviewed for a research position have been white. However, this internship helped me further commit to making this problem a cornerstone of my education and research program as I continue my career. Right now, I believe the best way to do this is to integrate more closely with the communities surrounding the university. Here in Madison, this approach has been championed by Rev. Alex Gee, who has been an inspiration to me outside of my academic and professional career as a key faith leader in Madison. Recently, Alex spoke with the Delta program about his "Justified Anger" movement in Madison and outlined how we, as a University, can better address the glaring racial disparities in Madison. Though my time here in Madison is limited, Rev. Gee all but ensured that I will engage with a community like his wherever I end up next.

Teaching-As-Research

Going into the internship, I felt very confident in my ability as a researcher – in my scientific research field. Needless to say, teaching-as-research is probably where I needed the most development, where I developed the most and where I still have the most work to do. The Delta internship helped me scratch the surface of human subjects research, qualitative data analysis and the current state of educational research. Though I still need work in identifying teaching-as-research questions that align with both my own teaching goals and my interests in furthering educational research, I felt like this internship helped to point me in the right direction of where I need to further develop skills and how I can develop them. I plan to continue to develop theses skills as I develop courses, course materials and continue research in undergraduate education. In particular, I'd like to see my ability to ask teaching-as-research questions that can be answered efficiently improve. My goal would be to be able to apply teaching-as-research to the vast majority of the decisions I make in my teaching and, to do this, I need to be more pointed about the questions I ask and the methods I use to answer them.

In my internship I attempted to address higher order learning domains (like application, analysis, synthesis and evaluation) in upper level ecology education and I predicted that the WOWM role-playing activity would help student's further develop these. I learned a lot about student confidence and perception of their own higher order learning skills and the students felt that the role-playing activity helped them further develop these skills. Using the information I collected this semester, I am confident that I can design a more mechanistic TAR question to address the direct impact of the role-playing activity on student learning and I have the internship to thank for that. With an improved activity, particularly in pre-activity instruction preparing students for the roles they will play and the scenarios they will plan them in, I could successfully address these questions. I also feel that this skill will be an essential tool as I move forward as an instructor.

Learning Communities

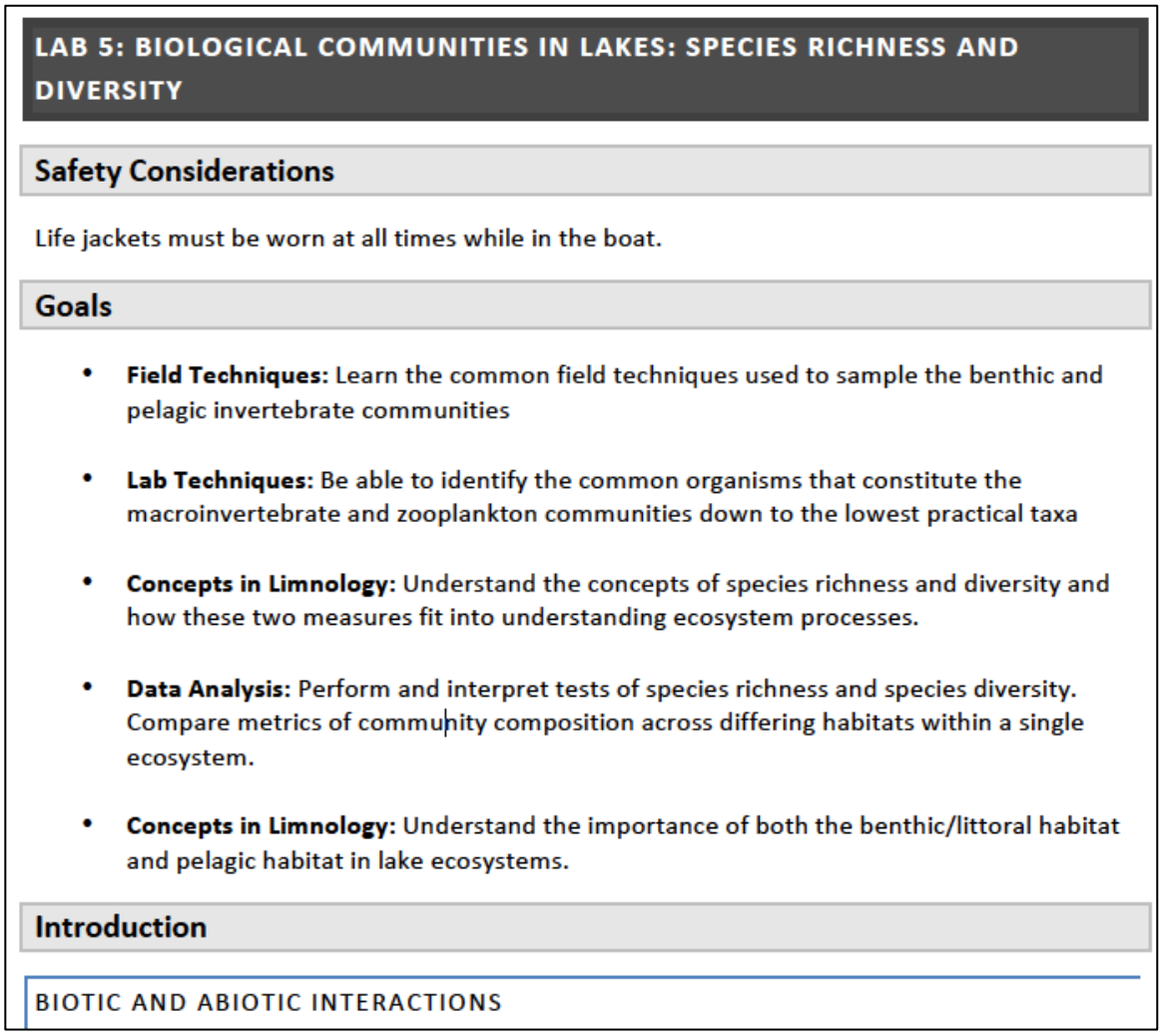
The limnology lab where I conducted the role-playing activity already facilitates very strong learning communities from weekly group work, multiple whole-class field trips and outside of class group field studies. Students frequently reported the already shared bonds they held with their classmates as one of the reasons they were comfortable role-playing. Students frequently reported that the activity was laid back and informal and it was a fun way to interact with other classmates.

The learning community I developed with my peers who were conducting their own teaching-as-research projects reflects the kind of community I'd like to be a part of in my career. Wherever I end up, it is likely that I will be teaching in some way and having a community of peers going through the same struggles (and maybe value teaching successes as I do) who are open to discussion of failures, successes and potential solutions to problems is immensely valuable. A learning community of instructors with different and shared perspectives and teaching backgrounds can act as a safety net in this regard.

My faculty partners were very interested in the broader context of the role-playing activity and the activity draws on some of their own efforts in teaching on the complexity of socio-ecological systems and the diverse range of fields that must be drawn on to solve

problems in these systems. In the day-to-day details and administration, the faculty partners entrusted the TAs (the limnology lab is developed and taught by graduate students). TAs were incredibly enthusiastic, saw the same potential challenges going into the activity that I did (plus some others) and willingly helped me develop ways to address those challenges. In particular, I think the TAs were the primary reason that the lab atmosphere so readily facilitated good role-playing through their enthusiasm and understanding of how role-playing could help their students learn. Having the TAs readily support my ideas and help me refine them was an incredible benefit of our learning community.

Appendix – Biological Communities Lab (From IV. Teaching and Learning Through the Scientific Process)



LAB 5: BIOLOGICAL COMMUNITIES IN LAKES: SPECIES RICHNESS AND DIVERSITY

Safety Considerations

Life jackets must be worn at all times while in the boat.

Goals

- **Field Techniques:** Learn the common field techniques used to sample the benthic and pelagic invertebrate communities
- **Lab Techniques:** Be able to identify the common organisms that constitute the macroinvertebrate and zooplankton communities down to the lowest practical taxa
- **Concepts in Limnology:** Understand the concepts of species richness and diversity and how these two measures fit into understanding ecosystem processes.
- **Data Analysis:** Perform and interpret tests of species richness and species diversity. Compare metrics of community composition across differing habitats within a single ecosystem.
- **Concepts in Limnology:** Understand the importance of both the benthic/littoral habitat and pelagic habitat in lake ecosystems.

Introduction

BIOTIC AND ABIOTIC INTERACTIONS

Figure 1. Goals of the Biological Communities lab section from the Introduction to Limnology Laboratory course.

Methods

In today's lab you will be investigating the invertebrate communities of two *very* different habitats within Lake Mendota: the open-water, pelagic habitat and the near-shore littoral and benthic habitat (Figure 2). There are even interesting sub-habitats within these two habitats, so consider how the pelagic and littoral zones of lakes can be further divided by variation in physical, chemical and biological factors. You will gather zooplankton from the pelagic zone using a Schindler trap. A javelin rake and a kick net (also known as a D-net) will be used to sample macrophytes and macroinvertebrates from the littoral zone.

During the course of the lab, you will identify these invertebrates to the lowest practicable taxonomic level using the keys provided in the lab and lab manual. Taxonomy can be very difficult as genus and species level identifications often require the ability to see small and subtle differences in the anatomies of similar taxa. So, patience and attention to these details is a necessity for this lab – maybe take a few minutes before your microscope work and calm your mind, listen for flies' heartbeats and stuff like that.

Figure 2. Methods section for the field experiment I designed where students are asked to compare the benthic and pelagic invertebrate communities in Lake Mendota.

7. **Beyond Limnology Skills (see reading at end of section).** For each of the following hypothetical datasets 1) state the hypothesis you would like to test, 2) the statistical tool you would use to test it and 3) a quick description of why you would use that tool. There may be more than one right answer to each case or, more accurately, more than one question to ask with each dataset (obviously, you only have to design one study).

Figure 3. Example of the exercise students were asked to complete for three case studies of ecological datasets after completing the "Beyond Limnology Skills" reading I developed for the lab section.

BEYOND LIMNOLOGY SKILLS: COMMON STATISTICAL TOOLS AND THE TYPES OF QUESTIONS THEY HELP ANSWER

Before we get into the specifics of *how* we apply statistical analyses to our data, it is worth discussing the *when* and *why* of statistical analysis. As mentioned in previous sections, we use statistics to help support and verify the claims we make about the research we have completed. Statistics are also a means for us to communicate and have meaningful conversations about our data and findings.

COMPARISONS: THE T-TEST

Big Picture. We learned about the t-test in last week's section (pH, ANC and conductivity), it helps us compare two means of two **distributions** of numbers and primarily answer whether they are significantly different from one another. Specifically, we are testing whether we are able to reject the H_o that the magnitude of the difference between two distributions is zero. So our H_a can be "there is a significant difference between these two distributions" or "one distribution is greater than or less the other".

RELATIONSHIPS: THE LINEAR REGRESSION

Big Picture. Though we haven't learned about linear regression yet, it is likely that you are familiar with the term **correlation**. Correlation refers to the statistical relationship between two random variables. The linear regression gives us a means to describe that statistical relationship. Of course, great care must be taken when using correlation to describe a relationship hypothesized to be causational (e.g. proper controls and experimental design).

MULTIPLE COMPARISONS AND CATEGORICAL DATA: THE ANOVA

Big Picture. ANOVA stands for "analysis of variance" and it allows us to look for sources of variability in complex (but carefully designed) studies or experiments. We saw the ANOVA applied to the linear regression in order to compare the slope and the intercept of the regression line to the "null" line (m_o=0, b_o=0) simultaneously. If we were only comparing the slopes (m to m_o) or the intercepts (b to b_o), we would simply use a t-test (Excel will actually provide output on these t-tests). If we're comparing multiple groups of data (like multiple t-tests), the ANOVA tests whether the variation among groups is larger than the variation within groups. If we find that the variation among groups is larger than the variation within groups ($p<0.05$), then we can start applying multiple t-tests comparing our groups to one another through a Tukey's HSD (Honestly significant difference).

Figure 4. Headers from the "Beyond Limnology" reading. Each statistical analysis section comes with a "Big Picture", "Details", "Application", and "In Excel" section. This gives students the opportunity to get a general understanding of the use of the tool, the actual statistical meaning of the tool, an example of how the tool can be applied to datasets they are familiar with from class readings, and a step-by-step tutorial for how to complete the analysis for their own projects.