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STREAM ECOLOGY: USING HANDS-ON ACTIVITIES AND FIELD RESEARCH TO TEACH ECOLOGICAL PRINCIPLES IN IB BIOLOGY

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ABSTRACT

STREAM ECOLOGY: USING HANDS-ON ACTIVITIES AND FIELD RESEARCH TO TEACH ECOLOGICAL CONCEPTS IN IB BIOLOGY

By

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Ecology is the study of relationships between living organisms and between organisms and their environment, and ecological content is often taught to secondary students in the life science classroom. In 2007, a stream ecology unit was developed to teach basic ecological concepts to Portage Northern High School International Baccalaureate Biology students. This unit included four components: background ecology content lessons, field sampling in a local creek, an interdisciplinary, inquiry-based research project, and student presentation of scholarly posters at a symposium. The hands-on activities were used to prepare students for field sampling and inquiry-based research projects, and the unit was completed over approximately three months. The unit was evaluated with student pre- and post-surveys to gauge student preferences of general learning practices, and pre-and post-assessments were used to gauge the effectiveness of the unit in teaching ecological concepts. The analysis of the survey data indicates no significant change in student preferences towards general learning practices after completion of the unit. The analysis of the assessment data indicates a significant statistical increase in student learning of ecological content after completion of the unit.

To Terry, for joining me on this wild ride we call life, and to Ashton. We are so blessed to have you join our family; we can not wait to meet you.

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Introduction

Teaching and Learning Ecology- Why does it matter?

People living in these first decades of the new millennia are experiencing a time of world wide ecological change. Though the extent and reach of the changes are hotly debated in the political world, scientists tend to agree that humans are influencing the environment now more than ever in history. At the same time, children are more and more disconnected with the natural world. Many children are totally unaware of the conditions of the natural world around them, do not spend any considerable amount of time outdoors, and consequently do not understand the implications of their actions on the world's ecosystems. In light of these conditions, it often becomes the responsibility of the science teacher to teach students about the natural world, to bring these students outside, to get them exploring and asking questions, in the hopes of fostering some awareness of the natural world.

Ecology is the study of relationships between living organisms and between organisms and their environment. The science of ecology has roots extending far back into history, including such famous naturalists as Aristotle, Buffon, Wallace, Darwin as well as many nameless agriculturalists worldwide who have observed and nurtured relationships between living and nonliving things for thousands of years. (McComas, 2002). At the end of the nineteenth century, the German biologist Ernst Haeckel developed the modern conception of ecology, as described in McComas:

> "By ecology we mean the body of knowledge concerning the economy of nature – the investigation of the total relations of the animal both to its inorganic and to its organic environment: including above all, its friendly and inimical relations with those animals and plants with which it comes directly or indirectly into contact – in a word, ecology is

> the study of all those complex interrelations referred to by Darwin as the conditions of the struggle for existence (Haeckel, 1866)".

These basic principles, including the interrelatedness of organisms, the influence of organisms on one another, and the conditions that drive evolution, continue to be the basis for ecological education today. In the late twentieth century, modern environmental education was shifting away from the natural study and conservation movement, being shaped by public awareness of the environment and potential environmental disasters, exemplified by books such as *Silent Spring* by Carson in 1962 (Ehrlich, 1986).

In present day secondary schools, environmental education often falls within the life science curriculum. Modell, et.al, (2005) assert that students learning life science face more complex challenges than those learning in the physical science disciplines. The life sciences study systems with much more complexity, therefore these students face additional conceptual and reasoning difficulties. For example, biology students must understand basic physics and chemistry concepts and apply them to levels of organization ranging from the molecular level to the ecosystem level. For these reasons, ecology can often be found as the capstone unit of a biology or life science class. "Ecology education provides students the opportunity to apply and synthesize much of what they have learned throughout a typical year of biology instruction…ecology is a more sophisticated, higher level, and synthetic pursuit that involves almost all other domains in the life sciences" (McComas, 2002).

Ideally, ecological education also provides students with the opportunities to use a variety of laboratory techniques, to work in the field, to work with living organisms, to discuss interspecies relationships, and to consider energy flow through ecosystems.

Combining the content material and investigatory aspects of ecology should provide students the opportunity to develop the practical tools and acquire the background knowledge needed to gauge human impact on the environment and then provide solutions to these problems. The hope is that exposure to these concepts will affect student understanding of the interaction between science and society, allowing students to see how they fit into and affect the ecosystem (McComas, 2002).

It appears that exposure to the content material in the classroom alone, however, is not enough. In the article titled "Are High School Students Oblivious to The World Around Them?", Sheldon Margulies (2004) argues that "the experienced-based approach is better able to capture a child's attention." According to Bowen, et al. (2007), providing students with the opportunity to complete inquiry-based investigations in the ecology classroom teaches authentic science practices. This type of investigation is gaining importance in this age when humans are interacting and interfering with the natural ecosystems to the extent that human living conditions are changing on a global scale. For example, "in the production of greenhouse gases and their effect on global climates, in the effect of fishing some species on marine ecology in general…the destructive potential of introducing foreign species to new ecosystems" (Bowen, 185).

Rationale: Why was this specific unit/topic chosen?

Teaching Biology within the International Baccalaureate Organization (IBO) Diploma Program provides a unique opportunity for educators to address the above mentioned problems. The IB curriculum requires a minimum of twelve lecture hours devoted to ecological concepts, including discussion of human impact, the increased greenhouse effect, and global warming. Teachers are given the opportunity to use traditional classroom methods such as lectures and presentations to deliver core content, but then have the opportunity to engage students outside of the classroom with field investigations including quadrat studies and capture-mark-recapture techniques. Additionally, students in the IB Biology courses must complete a fifteen hour student research project. This project is called the "Group IV Project", because it includes students from all of the IBO Group IV sciences- namely Biology, Chemistry, and Physics. The Group IV Project is described by IB as follows:

> "The group 4 project allows students to appreciate the environmental, social, and ethical implications of science. It may also allow them to understand the limitations of scientific study, for example, the shortage of appropriate data and/or the lack of resources. The emphasis is on interdisciplinary cooperation and the processes involved in scientific investigation, rather than the produces of such investigation. The exercise should be a collaborative experience where concepts and perceptions from across the group 4 disciplines are shared. The intention is that students analyze a topic or problem which can be investigated in each of the science disciplines offered by a school. The topic can be set in a local, nation, or international context."
>
> (IBO,2001)

Beginning in the 2005 school year, the IB Science teachers at Portage Northern High School chose the topic of watershed ecology as the focus of the Group IV project. Watershed ecology presents the opportunity for biology, chemistry, and physics students to work together on projects collaboratively, and it allows for authentic field research. The Portage Creek watershed runs right through the city of Portage, and is part of the larger Kalamazoo River watershed. Due to the ongoing nature of the IB curriculum within Portage Public Schools, the IB Science teachers wanted to further develop and refine the watershed ecology projects, which is why this particular research was conducted.

Ecological Misconceptions

Even with an established environmental ecology curriculum beginning in elementary school, it is interesting to note that students often bring with them a number of misconceptions when learning ecological concepts. It appears that people hold a number of fundamental misconceptions with regard to ecological issues, including the ideas that including the idea that plants and animals are independent and have no impact on one another, that communities consist only of similar organisms, that imbalance of species in an environment is always bad, and that damaged ecosystems will forever remain so. There is also concern regarding the current political agenda of environmentalism, and a false link with true ecological scientific concepts, as many people are unable to separate the two. It is a concern if educators are continuing to teach ecological concepts, yet are producing "members of the public [who] base their environmental views and action on too little science and technology but consider it ecology nonetheless" (McComas, 2002).

Specifically, students seem to harbor many misconceptions regarding food chains and webs. Students tend to believe that food webs are less complex than they actually are, that eating relationships are directional in one way only, and students often do not identify the cyclic nature of energy flow in an ecosystem. Students also do not realize that chemical pollutants flow through the food chains, and that the chemicals change form and accumulate in higher-order organisms. When examining whole ecosystems and populations, the idea that each organism [species] is an essential component of the ecosystem is missing for many students. For example, many students believe that organisms are impacted only by the organisms they rely directly upon as prey, and fail to consider the interactions in which they are prey for other organisms (McComas, 2002).

These misconceptions must be identified and overcome in the course of learning ecological concepts, or the loftier goals of environmental awareness and impact may never be attained. Within the framework of this research project, identifying and correcting these student misconceptions is obviously important, and falls within the teaching of the background material and reinforcement of concepts through the field research.

Ecological Concepts- Stream Ecology

Ecology is the study of relationships- relationships between organisms, and relationships between organisms and the abiotic (non-living) aspects of the environment in which they live. Organisms that are able to interbreed and produce fertile offspring are of the same species, and many different species live together in one habitat to form a community. Scientists often study ecology at the level of the ecosystem, which includes examining the community of a particular area, as well as the abiotic environment. When considering the interactions between ecosystems, scientists often examine the level of the biosphere. The biosphere is considered to be the area of the planet that can support life, and therefore extends from the deepest reaches of the oceans to the highest levels of the atmosphere where organisms exist. The ecosystems found within the biosphere are both interdependent and interrelated. The ecosystems are interdependent because they often rely upon one another for existence. For example, a terrestrial ecosystem boarding an aquatic ecosystem may be dependent upon the aquatic ecosystem as a source of water for many of its organisms, and the aquatic ecosystem may depend upon the terrestrial ecosystem for nutrient input. The ecosystems in the biosphere are interrelated because many materials, nutrients and water, for example, cycle between the ecosystems on a regular basis.

The idea that ecosystems are linked to one another, and that subsequently the organisms found in those ecosystems are intricately linked, is central to ecology. In stream ecology, organisms often rely upon the environment outside of the stream as an input of food and building materials. For example, in a small stream, sometimes called the headwaters, the stream itself will be fairly narrow and shallow. Alongside the stream, the terrestrial ecosystem may include many trees which shade the stream, limiting light to the water and providing much organic material in the form of leaves and branches. This type of environment will directly affect the types of aquatic macroinvertebrates found, because only certain organisms will live in this habitat. The macroinvertebrates found in these small order streams will be those that obtain nutrients by shredding organic material into smaller pieces, some that filter these shredded organic materials from the water, and others that are predators upon these organisms. As the stream network progresses downstream, the physical environment will change. The stream will become wider and deeper, and the banks will be farther apart. The terrestrial ecosystem on the banks will begin to have less of an influence on the stream, because there is less direct cover from the tree canopy. As more sunlight reaches the stream bottom, the conditions will be better suited for algal growth, and macroinvertebrates that feed upon algae will begin to be found. There will also be more organisms that filter the organic material from the water, and less organisms that are shredding the organic material. Predators will continue to be found, but because the species composition of the other organisms has changed, the profile of predators found may be different than upstream.

These changes continue as one moves down a stream network to larger and larger streams. The stream ecosystem, as found under the surface of the water, is interrelated and interdependent upon the terrestrial ecosystem which it borders. If changes occur in the terrestrial ecosystem, then one would expect to also find changes in the stream ecosystem. Streams are also unique in that the water within the ecosystem is moving, sometimes at high velocity. This physical characteristic of a stream directly influences the organisms found in the streams, as these organisms must have distinct adaptations that allow them to survive in this habitat. In this way, stream ecosystems are wonderful examples of how organisms and their adaptations are influenced by the environment in which they live, which is a basic premise in ecology. In fact, scientists often study the aquatic macroinvertebrates found in a stream ecosystem, and use the presence or absence of these organisms as an indicator of stream health.

What is the best way to teach ecological concepts?

The American Association for the Advancement of Science (1990) has recommended that "…science should be taught as science is practiced" (Lawson, 2000). In an article titled "Field Investigations in School Science: Aligning Standards for Inquiry with the Practices of Contemporary Science", Mark Windschitl (2004) asserts that the current science education reform movement is working to move teachers "away from an exclusive pedagogical emphasis on content knowledge and to align instruction more with problem-solving and inquiry - activities which characterize the pursuits of scientists" (Windschitl, 2004). Documents such as *Science for all Americans* (1993) by the American Association for the Advancement of Science, *National Science Education Standards* (1996) and *Inquiry and the National Science Education Standards* (2000) by the National Research Council, and *Scope, sequence, and coordination of secondary* *school science* (1995) by the National Science Teachers Association have highlighted the need to include scientific practices such as hypothesis testing, problem-solving, modeling, researching, experimenting, and dialoguing in the secondary science curriculum (Windschitl, 2004). In short, science should be taught in a way that is both "hands-on" and "minds-on", through investigations that engage students in active inquiry (Lawson, 2000). Inquiry-based lessons have been found to develop better student attitudes regarding the science content being presented, as compared to lecture and worksheet style learning. Through the completion of inquiry-based activities, students have also been shown to develop better laboratory and graphing skills, as well as better developed data analysis and interpretation abilities (Jarrett, 1997). The process of working collaboratively on a problem with fellow students also allows students to practice articulating their own ideas while learning to respect the opinions and knowledge of others, which is an important science process skill (Jarrett, 1997).

What is inquiry?

It turns out that there are many different definitions of inquiry-based learning. Denise Jarrett (1997) asserts that inquiry strategies exist on a continuum, beginning with highly structured hands-on activities, to laboratory experiments that may be found in a standard "science kit", to investigations in which students are generating their own questions. Teachers should work to move students along the continuum towards the higher order thinking skills. In an inquiry-based curriculum, questions are used as a tool around which to organize concepts, and students may be simply answering the questions, or they may be asking the questions as well. Goodman (2000) believes that inquiry should be used to tap into students' natural curiosity, and teachers should then give students tools and information to fuel this wonder.

In the examination of what "inquiry" means for the scientific learner, Mark Windschitl (2004) asserts that science is about asking questions as well as finding answers and scientific inquiry is defined as "the way we frame questions, search for answers to them, and then connect the emerging knowledge to what we already know." Scientific inquiry should involve more than simply following the steps of a given experiment, and should include the following components:

1. Exploring events in nature until a meaningful question emerges
2. Probing the material world directly for an answer
3. Arguing the validity of that answer to an audience (ibid)

Windschitl & Buttemer (2000) propose an inquiry model with three phases: "developing a question, answering the question, and arguing the answer", which will be discussed here. In phase one, students should begin to use higher order thinking skills such as observing the natural world, inferring from observations to make predictions, developing significant questions based upon the observations, and finally forming testable hypotheses. These skills are necessary to formulate a significant question to research. This research question should be more than a description of events. It should have the potential for students to arrive at an answer that explains relationships. In this phase, teachers may use exploratory activities to provide experiences for students to practice forming acceptable questions. It is noted that at the secondary level, students need a solid background of knowledge and conceptual understanding before they can develop meaningful questions worthy of investigation.

In phase two, answering the question, students identify variables to determine what type of data to collect as evidence, decide upon the best methods to use, how deep to explore the variables, how best to manage time, and often times must refine the research question and start over. For this reason, inquiry-based investigations should be systematic in progression, yet must be flexible enough to allow for modification and revision. Teachers must realize that students will make mistakes, and these mistakes are valuable in the process of understanding science, both in content and process (Windschitl & Buttemer, 2000). This phase of inquiry is often most frustrating for students who simply want to "find the right answer" and who consider making mistakes to be a waste of time. It is important to expose students to the idea that much scientific research does not find "the right answer", and that finding "the wrong answer" is not necessarily a waste of time, but an important part of the scientific process.

Phase three requires students to argue their answers in front of their peers, a step that is often left out of the traditional laboratory method. This process requires students to defend their conclusions, review their procedures, organize their results, and find "links between observations, questions, procedures, interpretations, and conclusions" (Windschitl & Buttemer, 2000). Ideally students will learn to use graphs and other visual interpretations of data to communicate trends and patterns, and will begin to value the evidence necessary to defend their conclusions. Another useful tool to the inquiry learner is the use of a laboratory notebook. A lab notebook may be used for the student to journal thoughts, ideas, questions, and attempts at answering those questions, which will allow them to develop the habit of record keeping. It also serves as an opportunity to "think on paper"- "a concrete way for students to organize their thinking before engaging in a study and a way to reflect back on the recorded links between question, experiment, evidence, and interpretation" (Windschitl & Buttemer, 2000). Ideally, students will have multiple opportunities in their careers to engage in this scientific inquiry, which will help to further develop scientific habits of mind (Windschitl & Buttemer, 2000).

How to make inquiry work in the classroom?

As it has been explained above, an inquiry-based model seems to be the best way to teach students in a meaningful way. One may be left wondering, then, why all teachers do not implement inquiry-based experiences in the classroom. The reality is that inquiry-based teaching is difficult to do correctly. The process of inquiry-based teaching requires much more time, and as the number of standards and objectives included in the science curriculum grows as quickly as class size, resources for the inquiry classroom are often thin. According to Denise Jarrett (1997), when developing an inquiry-based activity, teachers must consider their own teaching skill strengths, the educational goals of the particular lesson, and student readiness and maturity levels. Inquiry-based activities should allow students to be both physically and mentally involved with learning the concept at hand, with materials that help students solve problems and investigate answers to questions. The teachers should be active with students in the classroom during the activity, using skillful questioning to focus student attention and learning, and probing for student misunderstanding. Teachers should also try to anticipate any content areas that might be stumbling blocks for student learning, and provide additional explanation or activities to reinforce that difficult content. Finally, upon conclusion of the inquiry-based activity, time needs to be spent reviewing main points of the activity, to make sure all students obtain the necessary content.

Anton Lawson (2000) provides teachers with sound practical guidelines to be used by teachers in the classroom to reduce or eliminate potential problems. Lawson suggests keeping groups of students as small as possible, so all students may be actively engaged. Secondly, teachers should determine how much time will be devoted to each phase of the activity ahead of time, and should inform students of these time restraints to keep them moving forward. Third, student progress should be monitored by actively walking among the students, interacting with them, watching and listening. Lawson believes teachers should be *enthusiastic* fellow investigators in the inquiry-process. Finally, students should have assignments that must be completed and handed in for credit throughout the course of the inquiry activity.

Students are often resistant to inquiry-based methods, because the "right" answer is not easily attainable. In the development of an inquiry-based investigation, students often construct research questions that are much too broad, causing the students to quickly become overwhelmed with the scope of the study. Students like inquiries that are challenging, but not overwhelming. In order for all students to be prepared to participate in the inquiry activity, lectures and activities prior to the inquiry should serve as background. In their previous learning experiences, many students have been praised and rewarded for simply recalling correct answers. Many students have not been taught how to think through complex situations nor how to derive the correct answers. When asked to do so in an inquiry investigation, students experience frustration. It should be made clear that the job of the teacher is not to dispense answers. The teacher should work to "raise interesting and challenging questions and to provide students with materials and suggestions of how to seek answers" (Lawson, 2000).

Different forms of scientific inquiry: Controlled Experiments vs Descriptive Research

The inclusion of scientific inquiry in a classroom may take on a variety of forms. Traditional scientific practices include testing of hypothesis using controlled experiments, with the identification of independent, dependent, and controlled variables. This practice of the "laboratory method" began with German chemists, eventually making its way into American universities and secondary schools, and many of the controlled experiments are still in use today. The systems being investigated with these experimental studies were relatively simple, with causative relationships between the variables (Windschitl, 2000).

While it has its place in scientific research, this type of experimentation does not apply equally well to all fields of science. Field biologists, for example, often complete observational studies. An observational study often examines a complex system, with variables that interact in probabilistic ways. While most observational studies are hypothesis driven, some studies are examining such new phenomena that not enough background exists to develop a sound hypothesis. Observational studies must be done in the field, because they cannot be reproduced in a traditional science laboratory, nor do these scientists maintain control and experimental groups or actively work to manipulate variables (Windschitl & Buttemer, 2000). In fact, "ecological systems resist the reduction to a small number of factors necessitated in experimental research" (Bowen & Roth, 2007). Instead ecologists conduct research by observing the natural world, selecting naturally occurring events, and examining these events for descriptive, correlative or causal trends. These field studies examine differences in sets of data for relationships, but they also do not assume cause and effect relationships between variables, as the relationship may be correlational, or may even be caused by influence of additional unknown or un-measurable variables (Windschitl, 2004). Therefore, "ecology is often more of an observational than an experimental science" (Bowen & Roth, 2007).

Ecologists also conduct investigations with the goal of developing a descriptive model of a natural phenomenon. This type of research is often conducted in newer fields of science where not enough is known to suggest sound hypotheses. An example of this descriptive research is "creating a profile of the presence of macro-invertebrates along the length of a river. These types of studies result in averages, medians, ranges, that 'tell a descriptive story' and often generate enough data to help pose a meaningful correlation or comparative questions as follow-ups" (Windschitl & Buttemer, 2000).

In addition to being a form of descriptive research, Bowen & Roth (2007) assert that field ecology has four basic differences from standard experimental sciences. First, ecological field research is highly emergent in character. Each study must be specifically designed for its particular setting, and this design often only occurs after the researcher has already spent a significant amount of time making observations in the field. Secondly, researchers have to be flexible enough to deal with the particulars of each setting, including changing weather and climate conditions that may change research plans on a seasonal or daily basis. The tools field researchers use are often modified or newly developed in the field, based upon the unexpected or unpredictable conditions in which researchers might find themselves. As data are collected and variables emerge, the researchers may need to modify the tools and methods used to collect data. In this way, Bowen & Roth (2007) argues that developing problem solving skills and "adaptation-to-context" skills is very beneficial to science students. Thirdly, ecology is unique in that the studies are often not replicable. Local environmental conditions are constantly changing, data are often collected from individual organisms to serve as a representation of the variation in the population, and the members of a population in a habitat may change from season to season. Therefore, even though the site and researcher may remain the same throughout a study, the actual "organism-environment units...studied [are] not the same at all" (Bowen & Roth, 2007). Finally, interactions among ecologists often foster a sense of community. Ecological science is often characterized by narratives and anecdotes allowing the researchers to share information, observations, insights and experiences with one another (Bowen & Roth, 2007)

As a discipline, ecology is quite different from the physical sciences to which students have been previously exposed. Ecology offers students the opportunity to apply creative solutions to problems, and allows individuality of each researcher to become evident. Field ecology allows teachers the flexibility to encourage students that might otherwise turn away from science in its more standard disciplines, which is increasingly important if educators are trying to reach all students. Bowen & Roth (2007) argue: "We simply cannot model all science teaching on a few laboratory sciences (especially physics) and continue to believe that we are offering a science for all".

Many secondary students have never been exposed to descriptive, comparative, or correlative research, in which there is no pre-determined correct answer, nor is there the immediate ability to determine cause and effect. More often, students complete traditional controlled experiments, in which a phenomenon is investigated for a pre-determined "correct" answer. Performing descriptive research may be frustrating for the student looking for the "right" answer, yet it is invaluable for developing scientific process skills and critical thinking ability through data analysis. In ecological research, students "need to rely on the knowledge of their peers and local persons as a resource for conducting their work" and "teachers could act more as facilitators of practices than as instructors" (Bowen & Roth, 2007).

Make inquiry meaningful by moving it outdoors

Even though inquiry-based methods have been identified as a strategy to meet the National Research Council goal of "Minds-on Learning", it has been argued that inquiry-based learning must also be connected to the larger world and issues that exist outside of the classroom in order to be meaningful for students. Donahue and colleagues (1998) propose making a meaningful link for students between the scientific concepts and the larger world through the use of community based watershed education. According to Donahue (1998), "placing inquiry in an authentic or real-world context, students move from passive organizers of detached data to active investigators of contemporary issues within their community". In an age in which students are increasingly disconnected from the natural world around them, it is more important than ever for educators to foster that link between students and the natural environments in their own communities. When students begin to work in the field, the learning becomes "constructivist by nature because students exercise greater control over their learning" (Donahue, 1998). At the same time, the students are discovering and accessing resources within their own communities, becoming members of a larger community of learners, and developing the ability to have a positive impact by sharing their discoveries with members of the community at large (Donahue, 1998).

Why community-based environmental research is important in the ecology curriculum

Though not included in most traditional ecology curricula, community-based environmental research is a valuable, inquiry-based tool that can be utilized to teach ecological concepts. SRI International has acknowledged that "students who conduct research generally develop a better understanding of science content and processes than do students whose exposure has been limited to traditional classroom science teaching (Gurwick & Krasny, 2001). Furthermore, Bowen & Roth (2007) believe that "field ecology may be the one science discipline with features that make it particularly attractive for enculturating a diverse student population currently not enrolling in science". With the implementation of the No Child Left Behind act, ensuring that all students are engaged in the sciences has become even more pressing. The use of field ecology research in the secondary classroom may better represent the broad range of scientific disciplines that are available for all students.

Students who have completed standard controlled experiments in research projects may still not recognize the fact that "science may be 'messy' or 'fussy', and involves creativity and making decisions; scientists often work collaboratively; and an experiment does not always give a definitive answer to the original research question (Gurwick & Krasny 2001). The use of inquiry-based research provides students with exposure to these situations. However, there are dangers in simply assigning a student an open-ended research project and then walking away. While they are learning, students require education in recording and interpreting observations, research question design, data analysis, and scientific presentation. Bowen & Roth (2007) recognize that students are often given very little time to observe natural phenomena before developing a research question, and that often times teachers directly assign the question to be researched. The use of semi-guided authentic investigations allows "students the freedom to make important decisions while also providing sufficient direction for them to complete the research successfully" (Gurwick & Krasny, 2001). Gurwick & Krasny (2001) recommend that instructors guiding students in inquiry-based investigations provide students with a sufficient amount of time to discuss ideas, research potential questions, and critically reflect upon the decisions made regarding how to conduct the research. They suggest providing students with the standard methods to use while gathering the field data, using field journals and class discussions as an opportunity to refine thoughts and ideas, and incorporating lessons of experimental design and data analysis into the research project (Gurwick & Krasny, 2001). When students are asked to defend their research methods and findings within their peer community, they often develop a deeper knowledge of the biological systems they are investigating, as well as the mathematical methods used to analyze and represent the data collected. This accountability for their actions then begins to serve as a self-regulating method for learning the scientific practices, and allows teachers to be a less central source of knowledge. Teaching students to design studies and to become aware of the world around them shifts the focus of environmental education away from memorizing rote facts towards investigating real-world phenomena, and the "task becomes one where they are attempting to develop a convincing answer, not find the authorized answer" (Bowen, et al., 2007).

In the last twenty years, many programs have been developed to involve students in ecological field research. Project GREEN (Global Rivers Environmental Education

Network) began with students from Huron High School in Ann Arbor, Michigan, and this watershed ecology initiative has grown to include educational programs in eighteen countries around the world (Donahue, et.al, 1998). In Washington State, students are able to earn a high school varsity letter in community service, and many students participate in the local "Stream Team" coalition through their biology classes (Pruett & Pruett, 2005). The Shell Creek Watershed Improvement Group in Newman Grove, Nebraska turned to the local public school system to involve students in monitoring the local watershed, along with educating the general public about local water quality and environmental concerns (Seier & Goedeken, 2005). Students in Aurora, Indiana also use the local watershed to complete community-based projects, monitoring local watershed conditions and reporting back to the city parks commission and local neighborhood associations (Hanes & Sadler, 2005). These are just a few examples of programs running across the nation using authentic, community-based research to teach students ecological concepts while making connections with the local community.

The current study: Where does it fit in the curriculum?

Knowing that inquiry and authentic, field based, "hands-on, minds-on" learning was the best way to reach the goals of the Group IV Watershed Ecology project, students investigated conditions within the local Portage Creek watershed. This study was conducted in the fall of 2007, as the ecology unit is the first taught in the IB Biology course. Teaching the background lessons developed in the ecology unit required approximately two weeks of class time. The additional field research (Group IV project) requirements were completed over an additional fifteen to twenty hours in the months of September and October.

What do students gain in the new unit?

This study allowed students the opportunity to spend time outside in a local yet unfamiliar environment, gaining knowledge of the biological, chemical, and physical structure of the local watershed. Students worked in interdisciplinary teams to conduct authentic field research implementing standardized field protocol. Students then began the inquiry process of discussing field experiences and developing an appropriate independent research question, analyzing the appropriate data, drawing conclusions, creating professional scientific posters, and presenting their findings at a community symposium. Completing authentic field research allowed students to better develop their understanding of the process and limitations of scientific study.

Why did this unit need improvement/change?

Even though the Group IV project had been conducted using the Portage Creek watershed for the previous two school years, as it stood the Group 4 project required improvement at a number of levels. First, the students needed increased exposure to the science of watershed ecology before entering the field to gather data; therefore a number of background lessons required development. Secondly, the students had to be taught how to use standard protocol for data collection in the field. This protocol had to be identified, taught, and used properly in the field so the data could be analyzed and applied accurately. This would permit students to make comparisons between collection sites and identify correlations between variables in order to draw conclusions. The data also needed to be managed within a database, for easy student access. Development of a database also allowed for the collection and use of longitudinal data for projects in the years to come. Finally, the small group research project had need of improvement, including parameters of developing of an appropriate research question, conducting relevant data analysis, and drawing appropriate conclusions, including understanding the differences between causation and correlation.

Relating rationale to research work on campus

Time spent in research at Michigan State University during the Summer of 2007 included identifying the best practices used to teach ecology, the identification and modification of appropriate watershed ecology background lessons, the identification of current ecological field protocols, and the development of a database within which to organize student data. As shown above in the literature review, the current best practices in ecological education include using inquiry-based activities and field research to teach ecological concepts. To prepare students for field research, a number of background lessons in watershed ecology were developed and analyzed for effectiveness.

In addition, the actual field research project required development. Since the IB Group IV project is interdisciplinary, it includes biology, chemistry, and physics students. Ideally, stream monitoring protocols would be found and utilized that incorporated all three disciplines- including methods for the collection of aquatic macroinvertebrates for the biology students, chemical analysis of the water and sediment for the chemistry students, and physical habitat assessment for the physics students.

The most applicable protocols available for the biology and physics students came from the Michigan Clean Water Corps (http://www.micorps.net/). This organization created the MiCorps Volunteer Stream Monitoring Procedures (http://www.micorps.net/documents/MiCorps%20Stream%20Monitoring%20Procedures.pdf), which have been developed for use by volunteer stream monitoring organizations within Michigan watersheds. The MiCorps program includes specific instructions for the collection of biological and physical field data, including worksheets upon which to collect the appropriate information. For those organizations officially monitoring streams for the Michigan Clean Water Corps, there is also a database into which the data must be entered. This Michigan Clean Water Corps database served as a model for the database constructed to manage all of the data collected by students in this study and in future generations of students.

Research Setting

Portage, MI & Portage Public Schools

Portage, Michigan is a city in Southwest Michigan, with a population of 45,679 citizens (City of Portage, 2008). Portage is considered a very stable community based on the following categories: 36.8% of citizens have the educational attainment of a Bachelor of Arts or higher, the per capita income is $25,414, the poverty status is a low 4.8%, and the median home value is $120,800 (City of Portage, 2008).

The Portage Public School district serves students in grades kindergarten through twelve. There are eight elementary schools, three middle schools, two traditional high schools, and one alternative community education center that also serves high school age students (Portage Public Schools, 2008). Almost half of the residents of the Portage Public School (PPS) district were in the same house five years ago, and virtually all residents have lived within Kalamazoo County during the previous five years (Portage Public Schools, 2008, Portage Northern Profile). Approximately eighty three percent of Portage parents own their homes, while the remainder rent. Within Portage Public Schools, seventy seven percent of the students live in married couple families, while twenty three percent live in single parent families or with grandparents and nonrelatives (Portage Public Schools, 2008, Portage Northern Profile). The median income of married couples with children is $80,295, which is well above the state median of $65,238. Median incomes of families with a single father or a single mother are considerably lower, being $39,297 and $28,125 respectively. Approximately sixteen percent of students live in "fragile families", which are families with incomes 200% of the poverty line. English is the language spoken by the majority of Portage residents, with only one percent of parents not speaking English in the home. The educational attainment of Portage public school parents is much higher than the Michigan average, with forty six percent holding a college degree or higher, and only three percent of PPS parents report not being high school graduates.

Portage Northern High School

Portage Northern High School serves students living in the northern and north-western areas of the district. In the 2007-2008 school year, the Portage Northern High School student body was composed of 1334 students in grades nine through twelve. The racial composition of students at Portage Northern has remained fairly consistent since the 2002-2003 school year; the 2006-2007 student body was composed of eighty two percent White students, nine percent African American students, six percent Asian/Native Hawaiian students, two percent Hispanic students, and no students reporting to be Native American or Multiracial (Portage Public Schools, 2008, Portage Northern Profile).

International Baccalaureate Biology Standard Level

This study was conducted with two International Baccalaureate Biology Standard Level classes. The IB program utilizes a rigorous international curriculum, and the courses are considered the most difficult content level offered within Portage Public Schools. The standard level course is completed in one year, with one hundred fifty required total teaching hours divided between one hundred ten hours of theory and forty hours of practical investigations (IBO, 2001). The Group IV project requirement falls within the practical investigation requirement.

Thirty four students enrolled in two sections of IB Biology Standard Level. Twenty one students were female while thirteen were male; sixteen students were in eleventh grade while eighteen were in twelfth grade. Ethnically, thirty-three of the students were white and one was African-American; two students were also foreign exchange students using English as a second language. Student grade point averages ranged from 1.98 to 4.0.

Implementation

In order to conduct field research under favorable environmental conditions, this ecology unit was implemented in the fall of the 2007-2008 school year. The unit can be subdivided into four stages: background lessons, field protocols and sampling, small group research, and poster symposium. Students began with background reading and lessons designed to improve their understanding of basic ecological concepts. A number of newly developed lessons and activities were then used in the classroom to reinforce the concepts, and bridge the gap between book learning and application. After the background lessons, students learned how to use field protocols to collect aquatic macroinvertebrates from a stream ecosystem. Students worked in interdisciplinary teams in the field to collect samples from the local stream ecosystem. These samples were brought back to lab and analyzed, using a pollution tolerance index to obtain a stream water quality score. The biology, chemistry, and physics data were entered into the PNHS Stream Monitoring Database for future use. Students then formed smaller interdisciplinary teams to begin the inquiry based research project. Using the data collected from the field sampling, students developed research questions and analyzed data to draw conclusions. Finally, students constructed academic poster presentations and shared their findings at a poster symposium.

Figure 1 outlines the specific sequence used to implement this new unit:

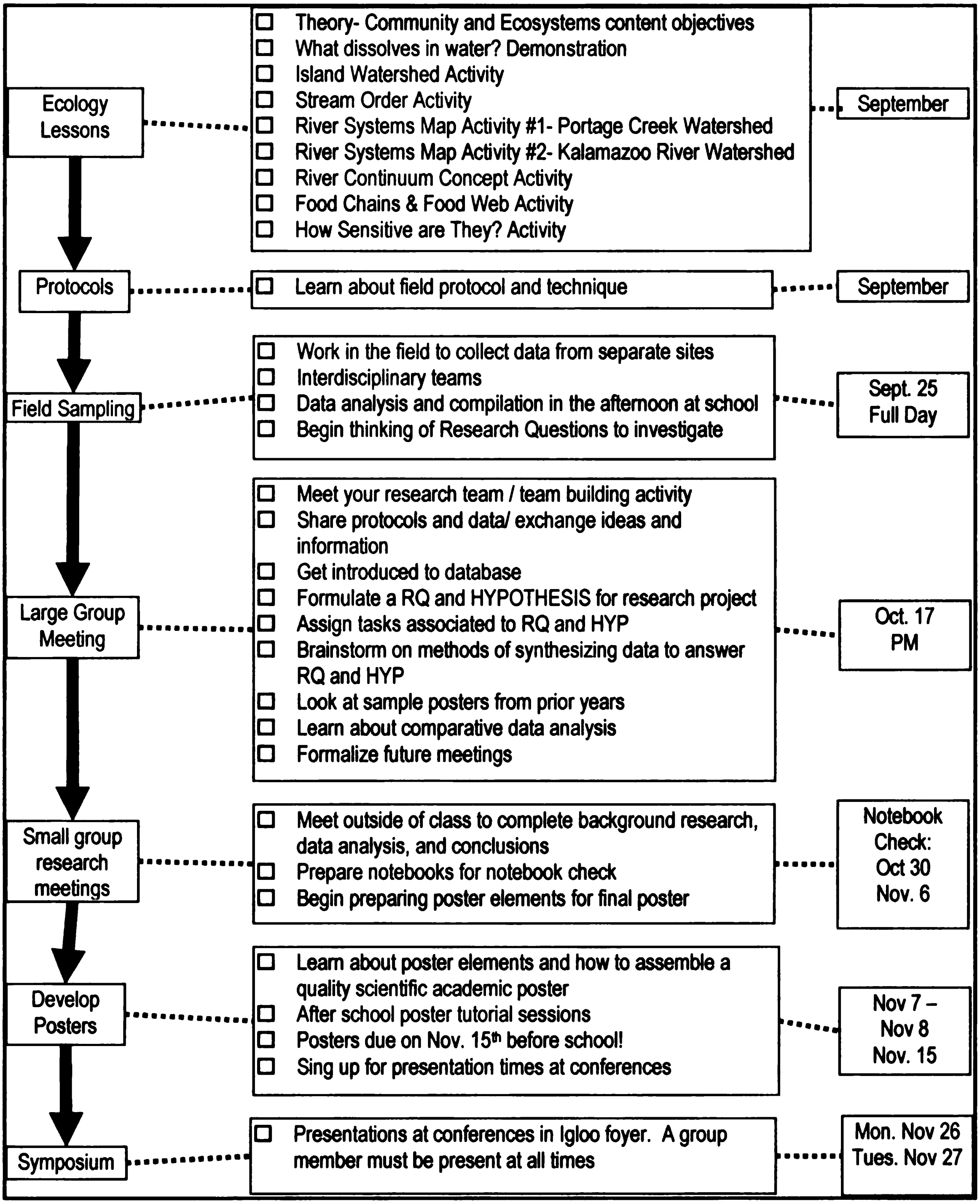

Figure 1: Flow Chart for Ecology Unit

Ecology Lessons

Before beginning field sampling and research, students needed a solid introduction to a variety of ecological concepts. A number of classroom and laboratory activities were developed and implemented prior to taking students into the field (Appendix I A-H). Students began the unit with a list of the ecology IB Biology assessment statements found below in Table 1. These assessment statements are intended to guide the learning in the classroom, and identify the material over which the students will be tested. Textbook reading and classroom discussion were used to introduce the ecology concepts.

Topic #	**Assessment Statement**
4.1.1	Define *ecology, population, community, species, and habitat*
4.1.2	Explain how the biosphere consists of interdependent and interrelated ecosystems
4.1.4	Describe what is meant by a food chain giving three examples, each with at least three linkages (four organisms)
4.1.5	Describe what is meant by a food web
4.1.6	Construct a food web containing up to 10 organisms
4.1.10	Explain the energy flow in a food chain
4.1.13	Explain that energy can enter and leave an ecosystem, but that nutrients must be recycled.

Table 1: IB Ecology Assessment Statements (IBO, 2001)

Allowing students the time to engage in background reading is an important first step in acquiring new knowledge. Classroom discussion and workbook practice of these concepts helped to introduce then reinforce these ideas before beginning hands-on activities.

Classroom & laboratory activities prior to field work

The first new activity, *What dissolves in water?* was a demonstration intended to get students thinking about water, runoff, and the local watershed. A clear container was filled with soil, sand, gravel, oil, acetic acid, and water. The contents of the container were labeled, and allowed to settle into various layers. Students were presented with the container and asked to propose answers to the question "What dissolves in water?" (Appendix I-A).

The container was shaken up, and students were asked to record observations. Students explained what dissolved and what didn't, what floated and why, and which particles settled out faster than others and why. Students were then asked to explain how this demonstration could serve as a model for our local ecosystem, which concluded with a discussion of runoff into the local watershed. This activity was an effective introduction to the concept water running off the land into the local stream system, carrying with it a variety of materials, as evidenced by the ideas brought forth in discussion with the students.

Students then began an activity building model islands and determining the watershed boundaries and major rivers on their islands. This *Island Watershed Activity* (Appendix I-B) introduced the idea that water is drained from land masses through stream networks that eventually lead to larger bodies of water. Each island required a minimum of four distinct drainage basins, with one basin being at least two times the size of the others, and prohibited lakes and unrealistic landforms. While there were distinct guidelines and pictures in the instructions to guide students in building their models, this was a very challenging activity for most students. It required construction of the model and then incorporation of the knowledge of land drainage to sketch in the major rivers and tributaries, as well as delineation of the watershed boundaries, and mapping of the island once fully constructed.

Having built model watersheds, students began an activity examining the local Portage landscape. *River Systems Map Activity #1* (Appendix I-C) required students to interpret data using a laminated topographical map. Erasable overhead projector markers were used to draw directly on the map. Students identified local landmarks, land elevation along and nearby Portage Creek, as well as land elevation along another creek system that is nearby, yet separate from the Portage Creek watershed. Through the identification of the creek system and watershed boundaries, this activity allowed students to visualize on the map how the local landscape drains into the local Portage Creek watershed. It was surprising to find that many students did not have prior knowledge of any streams in the sub-urban Portage area. This activity served as an effective link between the island watershed model activity and the students' own neighborhoods.

The concept of stream order was then introduced to help students understand the relative size of streams within a stream network. The *Stream Order* (Appendix I-D) activity introduced the concept of head-water streams feeding into larger streams, and explained the diagramming system used to identify stream order. Students examined and diagrammed the stream order in a given stream network, then drew and diagrammed their own stream networks. The concept of stream order is important when determining study sites within a stream network, as well as being an important aspect of understanding the local watershed and the River Continuum Concept. Students found this activity easy to understand and applied their knowledge well in the following map activity.

River Systems Map Activity #2 (Appendix I-E) expanded to a map of Southwest

Michigan, and students examined much larger watersheds, including the Kalamazoo River and Black River watersheds. Again using a laminated map and overhead markers, students worked through a guided activity identifying local counties, landmarks, and the Portage Creek watershed, which was familiar from *River Systems Map Activity #1*. Students then diagrammed and determined the stream order of the Portage Creek stream network, examined how the Portage Creek watershed fits within the larger Kalamazoo River watershed, and marked the stream network and boundaries of the entire Kalamazoo River watershed. Students were challenged in this activity to identify the boundaries of the Portage Creek watershed within the Kalamazoo River watershed, because this map was so much larger than in *Map Activity #1*. Students often expressed surprise at how much land was drained by the Kalamazoo River Watershed, and also expressed surprise that the Kalamazoo River actually runs in a northwest direction from Portage, draining into Lake Michigan at South Haven. Many students possess a misconception that all rivers run in a southerly direction; this activity was useful in demonstrating that Michigan is drained out to the Great Lakes much in the same fashion as the model islands the students constructed.

Once students became familiar with the geography of the Portage Creek and Kalamazoo River watersheds, it became important to introduce the aquatic organisms with which they would be working. The *River Continuum Concept* (Appendix I-F) activity was a web-based activity that used photographs of aquatic macroinvertebrates to introduce students to the organisms they would be collecting and identifying in the field. Students were also introduced to the idea that organisms are used as water quality indicators in stream ecology, and organisms have specific roles in the environments in which they live. Using a portion of the Wheeling Creek Watershed site (www.cotf.edu/ete/modules/waterq/wqcontinuum.html), students were guided through the identification of organisms that function as shredders, predators, collectors, and grazers in stream ecosystems. Through the examination of different order streams, students recognized that as the habitat of each order stream changed, the organisms found in those streams changed as well. Since most students were completely unfamiliar with organisms found in stream ecosystems, this provided a very good introduction to the many types of aquatic macroinvertebrates. Classroom discussions included the ideas that the life cycle of many insects includes a larval or nymph stage that is aquatic, that these organisms have many unique adaptations to life within stream ecosystems, that the conditions of the stream directly influence the presence or absence of these organisms in the ecosystem, and allowed for continued discussion of runoff from the land and potential impacts to the stream ecosystem.

Once students had seen the variety of aquatic macroinvertebrates found in stream ecosystems, they began to construct stream ecosystem food chains and food webs. Requiring these food chains to be built using local aquatic macroinvertebrates forced students to use research and apply the knowledge gained in the *River Continuum Concept* activity, becoming more familiar with the names and roles of the aquatic macroinvertebrates. Students then worked to link the food chains together into a food web representative of an aquatic stream ecosystem.

The final laboratory activity, *How Sensitive Are They?* (Appendix I-G) was a culminating activity, bringing together many of the previously mentioned concepts before taking students out into the field. This activity introduced the idea that organisms are used as indicators of stream health, and a pollution tolerance index may be used to quantify stream health. In the activity, the students function as biologists called to assess the health of a fictitious stream network. The students were presented with preserved specimens collected from six different sites of this fictitious stream network. They had to identify the organisms using dichotomous keys and Insect Fact Sheets compiled from the Creek Connections Project of Allegheny College http://creekconnections.allegheny.edu/. After the organisms were identified, students used a pollution tolerance index to determine the relative health of the stream at each site, finally compiling data from all sites to calculate an overall stream quality score for the entire stream network. This activity provided students the opportunity to work with the actual preserved specimens of the aquatic macroinvertebrates, versus the photographs and pictures they had previously seen. It allowed students to practice using dichotomous keys, as well as gave them the opportunity to model the identification and data analysis they would be conducting after collecting samples from Portage Creek.

Teaching Field Sampling Protocols

Once these background lessons and activities were complete, students were introduced to the Michigan Clean Water Corps- MiCorps Volunteer Stream Monitoring Procedures (http://www.micorps.net/documents/MiCorps%20Stream%20Monitoring%20Procedures.pdf). After reading the procedures and examining the data sheets that would be used in the field, students were given demonstrations on how to properly use the field equipment. Teachers and students together modeled the correct way to enter the stream, how to use the D-nets to collect specimens from a variety of substrates, how to sort the organisms on shore, and how to preserve the collected organisms.

Field Sampling

Prior to taking students out into the field to collect samples from the Portage Creek, the collection sites were identified and numbered for continuity in future collections. Students were divided into teams spread out along six collection sites along a two mile stretch of Portage Creek. This stretch of Portage Creek runs parallel to a nature preserve, through a neighborhood, over a dam, underneath Interstate-94, and through a public park. Each collection site had a team of students in biology, chemistry, and physics. Each discipline had specific collection protocol to follow, and students were required to work together in order to complete all of the collections successfully.

During the time in the field, the biology, chemistry, and physics instructors traveled from site to site, providing support answering questions and demonstrating techniques. Once students overcame the initial shock and fear of entering the stream and actually getting dirty, most enjoyed the field sampling experience. Students functioned as collectors and sorters, and rotated through the roles to gain experience in each. All students were encouraged to enter the water and spend some time collecting. The biology students were often surprised at the number and variety of organisms they were able to collect, once they learned how to recognize the organisms camouflaged within the detritus. It was also important for the instructors to stress the idea of randomized sampling, as many students became fascinated with the larger organisms such as the fish and crayfish, and were tempted to chase these organisms through the stream trying to collect them.

Students were in the field for approximately three hours, after which they returned to lab to analyze their collected samples. The biology students returned to the high school laboratory to sort and identify the organisms collected from each site, completing the pollution tolerance index worksheet for each site, then sharing and entering the data into the database. Chemistry and physics students spent the afternoon in their respective laboratories, completing the analysis of their samples and inputting the necessary data into the database. As they were working on the analysis of the field samples, students were encouraged to begin thinking of interesting parameters to investigate that would fall within the overarching Group 4 Project question "What are the factors that affect the health of an aquatic ecosystem?"

Small Group Inquiry-based Research Projects

After the initial field sampling was complete, students were divided into smaller, interdisciplinary teams of four to six students and each student was given a 2007 Group IV Project Guide (Appendix II-A). Each team was charged with the task of developing an inquiry-based research project, with a specific research question falling within the overarching Group IV project question: "What are the factors that affect the health of an aquatic ecosystem?" The only limitation placed upon the small group research projects pertained to data analysis: the research question needed to be investigated and data analyzed from the sites and protocol already used in field sampling. Students were not required to go back into the field to conduct additional sampling. It is also important to note that these small group research teams were allowed to develop research questions and use data from any of the Portage Creek sites sampled, regardless of which site they were assigned to conduct the initial field sampling. Students had access to the biology, chemistry and physics data collected from each site through the PNHS Stream

Monitoring Database, which was housed on a server to which all students had access.

At this point in the project, students were each required to maintain a Mead composition notebook. In an effort to teach authentic scientific practices, students were instructed to record all meetings, thoughts, ideas, reflections, raw data, data analysis, computations, graphs, and conclusions. Notebooks were periodically checked throughout the course of the project, and feedback was given to guide student progress.

During the introductory research meeting, students were released from classes for one-half day. During this time, students met with new group mates, became acquainted with one another, and shared existing knowledge of the factors that affect the health of aquatic ecosystems. Students in each discipline also explained the field sampling techniques and initial data collected from the Portage Creek field sampling. As a result of spending time in the field collecting samples, and spending time in the laboratories analyzing the samples, students had sufficient background knowledge to have intelligent discussions regarding variables that may affect the health of aquatic ecosystems, which is important at this phase of an inquiry-based research project.

Students were then asked to brainstorm potential research questions and propose answers to those questions, as well as to examine how variables may influence one another. As they worked, the instructors circulated among the groups posing reflective questions, helping students identify appropriate research questions. Some teams attempted to ask questions much too broad for a project of this scope, in which case they would not be able to draw conclusions based on the information available. Other questions were too narrow in scope to incorporate all three disciplines in the analysis of data. Once an appropriate research question was developed, each team was required to obtain approval from the instructors before proceeding.

Students then worked on constructing hypotheses that incorporated each of the disciplines. At this point, many teams conducted additional background literature research to obtain more information, which they were required to record in their lab notebooks. Before adjourning this meeting, groups determined future meeting dates and locations, assigned research or analysis tasks for each group member, and developed a general plan of attack to complete the project by the deadline, approximately five weeks later.

Over the next few weeks, classroom time was provided to answer student questions regarding the project. Discussions of the differences between correlation and causation were stressed, and a number of ad-hoc mini-lessons were used along the way to practice analyzing variables for correlations. Time was spent constructing graphs, and analyzing those graphs for lines of best fit to identify trends in the data. After school sessions were also held to teach students how to use publishing software to make scientific posters, as well as tutorial sessions to discuss what should be included in the scientific poster, and to provide time to construct the posters. While none of these activities were developed as a part of this study, the need to address these aspects of scientific research became apparent as students worked on their projects.

Finally, students submitted their Group IV posters to the instructors for evaluation. These posters were assessed by the biology, chemistry, and physics teachers for each student's specific contribution to the project through their discipline of study. The rubric used to assess these posters can be found in Appendix II-B. These posters were then displayed in a Symposium, held during the nights of parent-teacher conferences. Students were required to present brief explanations of their research projects to any of the parents, teachers, or administrators that were circulating through the symposium. Students were also required to answer questions regarding their research question, hypothesis, data, or conclusions to the instructors, as a final informal measure of student performance.

Assessments

In order to obtain baseline data of student knowledge and interest before beginning the Ecology unit, a pre-unit survey (Appendix II-C) and pre-unit assessment (Appendix II-D) were administered. These surveys and assessments allowed for the collection of both objective and subjective data. The pre-unit survey consisted of eleven statements pertaining to student learning styles and scientific investigation preferences, with responses measured on a five tier Likert scale. The survey also included three short response questions, one probing student prior knowledge regarding biological, chemical, and physical factors of watershed ecology (#12), and two opinion questions regarding the importance of watershed ecology and conservation education (#13&14).

The pre-unit assessment administered, prior to beginning the Ecology unit, was used to gauge prior knowledge of Ecological concepts. Questions included describing a watershed (#1), naming the local watershed and its physical characteristics (#2), sketching a stream network diagram (#3), and sketching a stream ecosystem food web (#4). Students were also asked to describe how energy flows through an ecosystem (5), how organisms are used as indicators of stream health (#7,8), and questions regarding specific stream ecology field protocol (#9,10). Finally, students described how humans impact stream ecosystems (#11), including predicting the biological, chemical, and physical changes of a stream as a result of fertilizer runoff (#12), and proposals to remediate such changes (#13).

Approximately half-way through the unit, students completed an Ecology test assessing the material included in the Ecology assessment statements from the IB curriculum. This test was also the final assessment for the post-unit assessment questions (Appendix II-D) regarding general watershed information, stream diagramming, stream food web construction, and energy flow in the ecosystem, as those activities were completed by this time. The remainder of the unit was assessed using a separate post-unit assessment (Appendix II-D), administered after the conclusion of the student symposium. This post-unit assessment addressed the remainder of the questions posed in the pre-unit assessment. The post-unit survey (Appendix II-E) was also administered at this time.

The post-unit survey included all Likert scale questions from the pre-unit survey, as well as a number of new questions regarding completion of field work (#5, 7, 14), use of teamwork skills (#9), and development of a poster presentations (#11, 12, 13). Students were also asked to describe how the use of field work helped integrate their knowledge of biological, chemical, and physical science concepts (#17), as well as to explain if they found the knowledge gained to be personally valuable (#20).

Results and Analysis

Pre-Unit & Post-Unit Survey Data Analysis

Though the IB Biology classes initially consisted of thirty-four students, full data analysis was conducted with data from twenty-six students. Eight students were eliminated from inclusion in the study as follows: two students opted out of being included in this study, three students were incorrectly scheduled and changed schedules prior to completion of the study, and three students had incomplete paperwork.

The pre-unit and post-unit surveys included a number of statements students rated on a five tiered Likert scale. The Likert scale responses were: 5- Always, 4-Often, 3-Sometimes, 2-Seldom, 1-Never. Data analyzed from these survey question answers are shown below in Table 1. According to the Pre-unit survey data (Table 2), students reported that taking notes (4.3) and completing hands-on activities (4.4) helped them learn biological concepts, yet they were less confident that lab activities (3.8) and lab work (3.6) aided in their understanding. Students responded that field work helped them apply concepts presented in class (4.1), yet many had never conducted authentic scientific field investigations. Students also reported that conducting research as a member of a team helped to develop teamwork skills (4.2), and having a local problem to investigate was sometimes more interesting to investigate (3.5). Finally, students reported sometimes finding creation of a poster as a useful means of understanding concepts (3.0), while they seldom preferred developing their own questions to investigate (2.8) or working independently on investigations (2.9).

	Mean Values & Standard Deviation				
Likert Scale Statement	**Pre-unit Survey**	***St. Dev.***	**Post-unit survey**	***St. Dev.***	**p-value**
Q1. Taking notes in class helps me to learn biological concepts.	4.3	0.7	4.4	0.6	0.183
Q2. Completing a hands-on activity helps me learn biological concepts.	4.4	0.8	4.2	0.7	0.476
Q3. I find it easier to remember concepts that have been presented through lab activities.	3.8	0.6	3.7	0.7	0.404
Q4. Discussing lab work with other science students helps me learn the biological concepts.	3.6	0.6	3.7	0.8	0.713
Q5. Doing field work helps me to apply the concepts presented in class.	4.2	0.6	4.2	0.8	0.703
Q6. I prefer developing my own question to investigate rather than answering a question given to me by someone else.	2.8	0.8	3.0	0.9	0.313
Q7. I find value in working with other students in a team to solve a problem.	3.9	0.9	3.9	0.9	0.764
Q8. Conducting field research as a member of a team helps me develop teamwork skills.	4.2	0.7	4.0	0.9	0.557
Q9. I prefer to work independently on investigations.	2.9	0.8	2.6	1.2	0.185
Q10. Creating a poster presentation helps me fully understand the biological concepts.	3.1	0.7	3.7	0.8	0.023
Q11. I am more interested in scientific work when a local problem is being investigated.	3.5	0.8	3.7	0.9	0.395

Table 2: Pre-unit and Post-unit Survey Student Data (n=26)

The Post-unit Survey was used to obtain student feedback after completion of the Ecology unit. The data found in Table 2 include the statements, averages and paired t-test results for each statement included in both the pre-unit and post-unit surveys. A t-test analysis was performed to determine that only one of the statements (Q10) had a significant change as a result of the unit. Otherwise, students appear to have not changed their preferences in these general learning statements.

Students continued to report that taking notes (4.4), completing hands-on activities (4.2), and conducting field research (4.2) were effective means of learning biological concepts. Students reported that creating poster presentations (3.7), using lab activities (3.7) and investigating local problems (3.7) were somewhat effective in learning biological concepts. Students also reported sometimes preferring to develop their own questions to research (3.0), and still seldom preferred working independently on investigations (2.6).

The Pre-unit and Post-unit Surveys also included three short answer response questions. One question (pre #12/post#16) required students to explain the basic biological, chemical, and physical concepts involved in stream ecology. One point was assigned for one correct answer in each discipline, as illustrated in the rubric (Appendix II-F), with a maximum of three points possible. Data in Table 3 demonstrate that the majority of students were able to use prior knowledge of general biological, chemical, and physical science concepts to adequately answer the question on the pre-unit survey. Student responses included explanations such as "pH levels, wildlife, and velocity" (Student 1), "turbidity"(Student 4), "size/shape/speed/length" (Student 5), and "observing animal and plant life" (Student 9).

	Pre-Unit Survey		**Post-Unit Survey**	
Question	**Number of Points Earned**	**Number of Students**	**Number of Points Earned**	**Number of Students**
What are the basic biological, chemical, and physical concepts involved in stream ecology?	3	17	3	25
	2	4	2	0
	1	3	1	0
	0	2	0	1

Table 3: Pre-Unit Survey Question #12/Post-Unit Survey Question #16

Upon completion of the unit, twenty five students were able to provide specific details to correctly answer this question on the post-unit survey. While seventeen students were able to provide three correct answers in the pre-unit survey, it was noted that the post-unit survey answers became much more specific, including the "pollution tolerance of organisms" (Student 1), "phosphate levels and buffering capacity" (Student 3), "velocity, width, depth, gradient, and discharge" (Student 7), and "dissolved oxygen, turbidity, phosphates, and pH" (Student 13).

Two additional questions asked students for their opinions regarding the importance of watershed ecology education. As seen in the data in Table 4, even before beginning the ecology unit, students overwhelmingly responded that learning about watershed ecology is important, both at the high school student and community level. Student responses included comments such as: "Knowledge is the only way to solve problems" (Student 24), "each new generation is responsible for keeping these areas healthy" (Student 24), and "it is important...to have a basic understanding of watersheds and stream ecology in order to keep our environment from being completely destroyed from pollution" (Student 13).

	Number of Student Responses			
	Pre-unit Survey		**Post-unit Survey**	
Question	**Yes**	**No**	**Yes**	**No**
P18. Is learning about watershed and stream ecology important for high school students?	24	2	26	0
P19. Is watershed ecology and conservation important at the community level?	26	0	26	0

Table 4: Pre-Unit Survey Questions #13 & 14/Post-Unit Survey Questions #18&19

Upon conclusion of the unit, all twenty six students reported that learning watershed and stream ecology was important, compared to twenty four students reporting so in the pre-unit survey. In explanation of why it was important for high school students to learn, responses included "we as high school students are the future people who may be in charge of taking care of the streams" (Student 16), "students should learn about the world around them and how streams work, and what effects it can have on the surrounding community" (Student 22), and "it is something we could be directly involved with (i.e.: we could actually go to the stream and do research). Often what is studied in high school is inaccessible material" (Student 23).

All twenty six students also continued to report that watershed ecology and conservation are important at the community level. When asked to explain, students responded that "Everything anyone does in the community in some way affects the watershed" (Student 26), "without it people are ignorant to the area around them" (Student 3), and "it is our own responsibility to take care of our watershed, yet so many people don't because they are uneducated about the issue (Student 4).

Post-Unit Survey-Additional Questions Data Analysis

Additional Likert scale statements were included in the Post-unit survey specific to conducting field research, creating and presenting academic posters, and using the scientific method to answer questions. The data in Table 5 include the additional statements, averages and standard deviations for each statement. The data indicate that students often felt these methods were effective in learning ecological concepts.

Likert Scale Statement	Mean Values & Standard Deviation	
	Post-unit survey	***St. Dev.***
P7. Conducting field research with students of other science disciplines helped me develop a more thorough understanding of stream ecology.	4.1	1
P12. Creating a poster presentation helped me understand how the science concepts are integrated in stream ecology.	3.9	0.8
P13. Developing and presenting an academic poster is a valuable tool for a high school student.	4.2	0.7
P14. Completing a field ecology investigation helped me understand how the scientific method is used to create and answer questions.	4.2	0.6

Table 5: Additional Post-unit Survey Question Student Response Data

Students were also asked to explain how completing the stream ecology field investigation helped them to integrate their knowledge of biological, chemical, and physical science concepts (post-unit survey question 17). Students provided a variety of responses, including "while putting this presentation together, talking with other science students helped me understand their part of investigating the creek" (Student 2), "we were able to see how our knowledge of one subject helped complete an idea in another subject" (Student 5), and "I learned more about biological concepts by putting them into practice to determine stream health...learn (sic) more about chemical and physical concepts by working with students of these sciences" (Student 10). One student (13) responded "We used all three sciences to develop a conclusion on an issue involving all three. Although I had no idea what turbidity, dissolved oxygen or even discharge were before this project, I now have a greater understanding as to what they are and how they affect biology". Another student (16) said "In order to be able to conduct a good investigation, we had to know about all of the other factors so that we could know how those would impact our part of the investigation. This knowledge made our overall poster/project a lot better". One student (17) added that "completing the stream ecology field investigation helped to put biological, chemical, and physical concepts into a real world situation, and being in our home town had a huge impact for understanding".

Finally, students were asked to explain if they found the knowledge gained in this unit to be personally valuable (post-unit survey question 20). Twenty four students did find the knowledge gained to be valuable, while two did not. One student responded "I learned more about different biological concepts by incorporating them, but I also learned more about teamwork by working with others through a massive lab" (Student 10). Another remarked "I know what is going on in my local watershed, FROM MY OWN RESULTS! I would never ever think I would have information like this, and now I do" (Student 11). Others responded "it has given me a greater understanding to how my actions can affect my environment" (Student 13) and "everyone should know about stream ecology to be able to understand the importance of clean water (Student 12).

The two students who did not report finding personal value in the knowledge gained in the stream ecology unit cited very different reasons. One responded "Going into musical theatre, I don't know if I would call it personally valuable. However, it was an interesting topic to study and I am glad I had the chance" (Student 23). The second student (15) obviously missed the major take-home message of watershed conservation, responding: "No, because I am not really interested in Ecology and it doesn't matter if I changed my ways, I wouldn't make a difference in the ecology of the stream. You would have to get more than one person to help change and continue to support that idea to make a difference".

Pre-Unit & Post-Unit Assessment Data Analysis

The pre-unit and post-unit assessments (Appendix II-D) were used to measure student learning, indicating the effectiveness of the activities in this unit to teach the ecology content. These assessments were graded using the Assessment Question Rubric (Appendix II-F). The pre-unit assessment was used to identify student knowledge of ecological concepts before beginning the unit. As show in the data in Table 6, very few students were able to correctly answer specific questions regarding watershed and stream ecology, as evidenced in the pre-unit mean values. This may be explained by the lack of student exposure to watershed or stream ecology concepts prior to this unit.

Question #4 required students to construct a food web of a stream ecosystem. Since most students had very little exposure to stream ecosystems prior to this unit, it is not surprising that students did not earn full credit. However, very few students earned any credit at all for this question, with an average of only 0.1 points out of 14 points possible. This identified an interesting gap in prior knowledge, as most students did not even use arrows to show the direction of energy flow. Students did exhibit possessing prior knowledge of general ecological information regarding humans negatively impacting the environment (#11) and remediating damage done to an ecosystem (#13).

Table 6: Pre-unit and Post-unit Assessment Data

Assessment Question	Possible Point Value	Mean Values & Standard Deviation: Pre-unit Mean	*St. Dev.*	Post-unit Mean	*St. Dev.*	p-value
1. What is a watershed?	2	1	0.7	1.7	0.5	2.25E-05
2. Name the local watershed and describe its physical characteristics.	4	1.2	1	2.8	1.6	4.62E-05
3. Sketch a stream network diagram. Include 1st – 4th order streams. Label each stream in the diagram with its stream order.	4	0	0	3.7	1	8.74E-17
4. Sketch a food web of a stream ecosystem. Include at least 10 named organisms, with four different trophic levels. A. Annotate the diagram to name the trophic level of each organism.	14	0.2	0.8	10.7	4	7.58E-13
5. Explain how energy enters a biological community, flows through it, and is eventually lost.	5	2.0	1	4.6	0.8	6.50E-10
6. Name a specific stream macroinvertebrate and describe how it is adapted for life in its environment.	2	0.1	0.4			
7. How are aquatic macroinvertebrates used as an indicator of stream health?	2	0.7	0.5	1.8	0.4	7.21E-10
8. Why do scientists use aquatic macroinvertebrates as a measure of stream health?	2	0.3	0.5	1.2	0.7	2.81E-06
9. Describe a field protocol that can be used to quantitatively analyze stream macroinvertebrates.	5	0	0	2.3	1.5	2.34E-08
10. Why is it important to complete a habitat assessment of the area when monitoring the health of a stream ecosystem?	1	0.3	0.5	0.7	0.5	0.001
11. In what ways do humans negatively impact the health of stream ecosystems?	2	1.5	0.6	1.7	0.6	0.161

Table 6: Continued

12. In a local watershed, a neighborhood is developed along a number of stream tributaries. The neighborhood inhabitants love their green lawns, and use excessive amounts of lawn fertilizer. Describe what effects one may see downstream from the neighborhood at the end of five growing seasons: biological, chemical, & physical.	3	1.1	0.8	2.5	0.6	4.11E -09
13. How might the above mentioned human impact on the stream be remediated?	1	0.7	0.5	1.0	0.2	0.008

Table 6 shows the assessment questions, possible point values, pre-unit and post-unit averages and standard deviations for each question. The data in Table 6 were analyzed comparing the pre-unit and post-unit averages via a paired t-test analysis (two-tailed, df=25) for each item. The t-test showed significant differences in student responses after completion of the unit, indicated by p-values less than 0.05. Students appear to have increased their understanding of ecological concepts presented throughout the unit.

Compared to the pre-unit assessment answers, many of which were left completely blank, students provided well developed answers in the post-unit assessment. Students were able to provide more complete definitions of a watershed (1), as well as correctly identify the local watershed (2). Some did not explain three different physical characteristics of the local watershed, which accounts for why the average student response is only 2.8 points out of 4 points possible. The majority of students were able to accurately diagram a stream network (3) after completion of the unit, with an average of

3.7 points earned out of four points possible, while none were able to do so in the pre-unit assessment. Sketching a food web (4) still posed difficulty for some students, with a mean of 10.7 points out of 14 points possible. Some students did not read the question carefully enough, and did not sketch the food web for a stream ecosystem. Others did sketch a stream ecosystem web, yet did not accurately identify the trophic levels of the organisms. However, compared to the pre-unit assessment, students still made significant gains in their understanding of food web construction ($p<0.05$). Students also improved their understanding of how energy flows through an ecosystem (5), with a post-unit average of 4.6 points earned out of 5 points possible.

Students demonstrated much better understanding of material pertaining specifically to stream ecology, macroinvertebrates, and the use of protocol in the post-unit assessment. Students were able to explain how aquatic macroinvertebrates are used as an indicator of stream health (7), often citing the pollution tolerance of organisms, earning a post-unit average of 1.8 points out of two points possible. Students exhibited more difficulty in explanation of why scientists use these macroinvertebrates as a measure of stream health (8), earning only an average of 1.2 points out of two points possible. Many did not explain the idea that the presence of these organisms provides more than a single moment snapshot of water quality, because they live major portions of their life cycles in these ecosystems. Instead students often repeated only the pollution sensitivity ideas used in the previous question.

In explanation of the field protocol used to analyze stream macroinvertebrates (9), most student answers were correct, yet lacking in the level of detail required to earn full credit, resulting in an average 2.3 points earned out of five possible points. Many students were also able to discuss the importance of completing a habitat assessment when monitoring stream health (10), with an average of 0.7 points earned out of one point possible.

Students provided more complete predictions to the question regarding the biological, chemical, and physical effects of fertilizer on a stream ecosystem (12). In the pre-unit assessment, students were able to provide an answer for one of the disciplines, with an average of 1.0 points earned. Upon completion of the unit, students earned an average of 2.5 points, increasing the level of detail provided regarding the other scientific disciplines.

Though students demonstrated an adequate grasp of the ways humans negatively the health of stream ecosystems (11) in the pre-unit assessment, with an average of 1.5 points out of two points possible, students retained that knowledge through the unit, earning a post-unit average of 1.7 points. Students also retained their understanding of how to remediate human impact on stream ecosystems, earning an average of 1 point on the post-unit assessment out of 1 point possible.

Small Group Inquiry-based Research Projects

Students worked in interdisciplinary groups to develop inquiry-based watershed ecology research projects. After having spent time in field collecting samples, students had adequate background knowledge and skills to ask questions regarding the health of the stream ecosystem. Projects were developed to answer research questions such as:

Conclusion

These data indicate that this newly developed unit did serve to increase student understanding of ecological concepts, as well as introducing students to ecological field sampling and authentic research projects. The background lessons used prior to field sampling fulfilled the number of lecture hours required by International Baccalaureate to teach Ecology, and the remainder of the unit more than fulfilled the fifteen hour Group 4 student research project.

Background Ecology Lessons

In general, the background lessons and activities used were effective, as indicated in the pre-unit and post-unit assessment analysis, in increasing student knowledge of ecological concepts. Students also acquired sufficient background knowledge to approach the field sampling and inquiry-based research projects with the information and tools necessary for success. As stated in the literature review, inquiry often fails as a method of instruction when students do not have sufficient knowledge to approach the problem at hand appropriately. That is to say, when students to not know enough about the problem or have the tools necessary to complete the activity correctly, they experience frustration which may interfere with learning.

The first activities used to introduce the unit, *What dissolves in water?, Island Watershed Activity*, and *Stream Order* were written at the appropriate level for discussion and completion by the students. These activities will continue to be used in their present form with future groups of students. The *River Systems Map Activities 1&2* were both valuable in introducing students to the geographical region in which they would be working, as well as reinforcing the idea that stream networks are parts of watersheds draining the land. However, a few changes will be made with these activities. Upon completion of *Map Activity 1*, the instructor will make an overhead of the map and walk students through the topography of the landscape. Discussion will be centered upon the idea that elevation is a factor in determining watershed boundaries, as well as the idea that the local watershed does not include all of the nearby streams. There are actually two separate watersheds in the city of Portage, and students often failed to comprehend that distinction. Upon completion of *River Systems Map Activity 2*, student groups will trade maps and check one another for accuracy and completeness. It seemed that some students did not make the connection between Map Activity 1 & 2, failing to truly identify the boundaries of the Portage Creek watershed within the larger Kalamazoo River watershed, though they had just completed identifying the boundaries of the Portage Creek watershed in Map Activity #1. Finally, throughout these activities, it will be impressed upon students that these activities are being completed as preparation to go into the field and conduct authentic research, so it is vital that they understand and are able to discuss these concepts, as opposed to simply finishing the activity quickly to earn credit. Students will need to be able to apply this knowledge, so they should learn it the first time through the lesson.

The *River Continuum Concept* activity was a very nice introduction to the types of aquatic organisms the students would be working with in the field, as well as a good introduction to the role the organism plays in the environment. Again, as students work through this activity, it will be stressed that they need to retain the knowledge they are gaining to be able to complete the remainder of the unit, and this introduction is the first step to begin identifying and discussing these organisms in future activities. For example, in order to complete the *Food Chain/Food Web Activity*, students need to apply the knowledge of aquatic macroinvertebrates and their specific feeding relationships gained in the River Continuum Concept activity to accurately construct a food web for an aquatic ecosystem. While trying to construct the stream food web, many students had to spend considerable time reviewing information about the aquatic macroinvertebrates, because they did not retain the information from the previous activity. The need to retain their knowledge of stream ecosystem food webs for later application and assessment will also be impressed upon students, so they can work to assimilate the information into their long-term memories.

The *How Sensitive Are They* activity was a particularly useful capstone activity before taking students out into the field. This activity brought together all of the concepts introduced thus far in the ecology unit, and allowed students to work with preserved organisms and a given pollution tolerance index to determine stream quality. One change will be implemented for future use. The pollution tolerance index data sheet included in this activity is effective. However, it is different from the pollution tolerance index used in the MiCorps Volunteer Stream Monitoring Procedures (http://www.micorps.net/documents/MiCorps%20Stream%20Monitoring%20Procedures.pdf). In the future, the MiCorps pollution tolerance index will be used with this activity. This will expose students to the format and calculations they will be using to analyze data collected in the field, as well as giving them the opportunity to practice using the form accurately with a predetermined set of data. Instructors will then have the opportunity to answer student questions and correct any mistakes prior to using this index to analyze field data.

Field Sampling

The MiCorps Volunteer Stream Monitoring Procedures were a useful set of protocols to use in the study of the Portage Creek. These procedures were very detailed, easy to understand, and the data collection forms were easy for students to complete in the field and to use as a template to enter the collected field data into the database. During the time spent in the field collecting samples, students had fun working in a new environment with peers of different scientific disciplines. Many students who were nervous or unexcited by the prospect of climbing into the stream to collect samples quickly overcame these obstacles. As instructors rotated between the sites, students were eager to share their findings, often exclaiming how cool it was to find so many organisms in the creek. The time spent in the field definitely increased student exposure to the local watershed, and allowed students to make a personal connection with the stream ecosystems they had been learning about in the classroom.

It must be mentioned that the use of students to collect accurate stream quality data is difficult, because they are inexperienced and their exposure to field sampling is often limited to one or two collections. That being said, there is still value in exposing students to field ecology methods. However, a number of modifications will be implemented in this portion of the unit for future students to increase the accuracy of data collected. Before taking students into the field to sample, students were given the opportunity to read through the procedures and datasheet, and to ask questions for clarification. In the future, instructors will point out certain aspects of these procedures that were stumbling blocks during this field collection cycle. For example, the procedure outlined in the MiCorps Stream Monitoring Procedures for determining steam average water depth, siltation, and embeddedness will be highlighted.

The biology, chemistry, and physics instructors will travel between sites on bicycle instead of on foot, to allow for faster access to students at the various collection sites. Consideration will also be given to modify the parameter of one student collection team assigned to one collection site. It was found that students collecting at sites with known low biodiversity finished their collections very quickly. These sites offered little in the way of diverse substrates from which to sample, consisting mostly of deep silt. Therefore the number and variety of organisms collected from these sites was very low, and student collectors were not very challenged. Perhaps in the future, the student collection team assigned to such a site would have an additional site from which to sample, increasing student exposure to collection techniques and a variety of organisms.

Instructors need to consider creating a system of checks and balances to ensure the accuracy of student analysis of collected specimens. Upon returning to lab to analyze the collections from each site, some teams of students hurried through the process of sorting, identifying, and completing the pollution tolerance index data sheet. This led to a chaotic time when entering the data into the database, as it became evident that certain values were incorrect, requiring students to go back after the fact and revisit the data. In the future, once a team is finished analyzing their samples, they will trade samples with a team from another site. Each team then analyzes the samples from the second site, completing a second data sheet for the site. Samples and data sheets would then be returned to the original collection teams. Data sheets would be compared and inspected for accuracy; any values that did not match would be re-analyzed immediately in lab. This process will be good practice for students in the identification of organisms and analysis of field samples, and should serve to reduce student error in data analysis.

Research Projects

The Group IV stream ecology research project had been conducted since the 2005 school year, with moderately successful results. However, the instructors felt there was much room for improvement, and many modifications to be made to the entire process in order to increase student success. Many of these changes have been implemented in the unit as described above, which did serve to increase overall student success in completion of the Group IV project.

This final piece of the unit, the small group authentic research project, was perhaps the most frustrating for the students, yet offered the greatest opportunity for individual growth. Though the students were well equipped with background knowledge and field sampling experience, and though they had access to a database complete with biological, chemical, and physical data collected from a variety of sites along the Portage Creek, students still struggled through the requirements of completing authentic research.

It is important to remember the goals of the Group IV project as set forth by IB: "It may also allow them to understand the limitations of scientific study, for example, the shortage of appropriate data and/or the lack of resources. The emphasis is on interdisciplinary cooperation and the processes involved in scientific investigation, rather than the produces of such investigation. The exercise should be a collaborative experience where concepts and perceptions from across the group 4 disciplines are shared" (International Baccalaureate Organization, Diploma Programme- Biology).

In the future, instructors will continue to require students to maintain laboratory notebooks, stressing the importance of compiling not only their data, but also their thoughts and reflections as they progress through the research. Periodic checks of progress in the lab notebooks allowed instructors the opportunity to monitor individual student progress and contribution, as well the opportunity to ask meaningful questions of the student research. Some students made very good use of their notebooks, organizing data and ideas, completing data analysis, and reflecting upon their progress. Other students made less use of the notebooks, with a few students disregarding project guidelines and not keeping one at all. This range of effectiveness in the student use of the laboratory notebooks is frustrating for the science instructors. However, learning to maintain a lab notebook is a valuable skill in the scientific disciplines, and will continue to be used in future projects.

Instructors will also continue to teach the difference between correlation and causation in data analysis. Students often want to find and assign causative relationships between variables, as that is the type of traditional laboratory science with which they are most familiar. Simply identifying relationships between variables while not assigning causation is a foreign and often frustrating concept for students, and is one that students fail to assimilate easily. It is important, therefore, for instructors to revisit this concept often, redirecting and re-teaching students quickly.

Instructors will also continue to teach students to recognize that failing to identify a relationship between variables in authentic research is a valuable step in data analysis. Students often expect to find dramatic, causative relationships between variables. When they do not find such relationships in the data, they think they have somehow "failed" or that the data analyzed is not useful. Students must learn that not all data will dramatically point to a conclusion; rather it is the inclusion of certain variables and exclusion of others that lead to a conclusion.

In fact, the level of student frustration is perhaps the most interesting aspect to note at this stage of the project. Before spending time in the field, many students had the misconception that the local watershed would be very polluted and devoid of life. Even after spending time in the field collecting samples, gaining first-hand experience working in a fairly stable and healthy stream, and analyzing data which indicated a fairly healthy stream, many students still clung to their misconceptions, insisting poor health of the stream ecosystem. As the student groups progressed through the development of research questions and hypotheses, the hypotheses often reflected such misconceptions. When data analysis did not support many of the hypotheses predicting dramatic relationships and poor health of the stream, students resisted accepting the accuracy of the data. Some groups analyzed data time and time again, hoping to find the "horrible" variable that would support their hypothesis. When these groups were unable to find such a variable, many students felt that they had "failed" in their research. It was important for instructors to continually remind students that the data could not be "wrong", and that it was up to the students to simply analyze the data and explain the conditions of the local stream ecosystem by providing correlations between the variables investigated. Students needed to be reminded that the stream existed in its particular state, and it was up to the students to identify and explain that state. While the data might not have supported their individual hypotheses, the fact that the stream was in good health was not actually a bad thing!

Poster Creation & Symposium

Again, in the mindset that the process of completing and presenting the research was the focus, rather than focusing solely on the research project conclusions, the development of a scholarly poster and presentation of research at a symposium was a valuable experience for the students. Instructors will continue to offer after school data analysis sessions, teaching students how to analyze data for correlations and create comparative graphs to represent the data. After school sessions in the use of a publishing program to create the poster presentation will also continue to be offered. Instructors set an early due date for the completed posters, hoping to help students minimize procrastination prior to the symposium date.

The poster symposium was held in the lobby of the building during the evening sessions of parent-teacher conferences. Students were required to address questions regarding their research asked by parents, students, teachers or community members. This symposium was an effective means of holding students accountable for their research in front of their peers and the larger community. It provided the opportunity to highlight not only the research completed by the high school students in their own communities, but also to demonstrate how much hard work had gone into completing these projects. In the future, only a few changes will be made to this aspect of the Group IV project. Invitations will be sent by mail to students' families, in hopes of increasing parental attendance specifically to the symposium. The symposium will also be highlighted in the district newsletter the month before it is held, to increase awareness of students, parents, and community members. The instructors also need to consider implementing some type of formal assessment for each student in the symposium, as a way to increase student concern and ability to discuss research findings.

In review, the implementation of this new ecology unit was an effective means of teaching ecological concepts. During the previous two school years, the ecology content was taught without the hands-on activities or the focus on stream ecosystems, and the Group IV project requirements were met using a stream study. These former students did not have the continuity of learning the ecology content, completing the activities, and applying the knowledge and skills directly to their Group IV stream ecology research projects. In the past, the research projects were much more disjointed from the rest of the ecology content, and based on past student performance and attitudes regarding the research project, the learning was more difficult and less meaningful for the students. While there are still a number of aspects of this unit to be improved as discussed earlier, the activities developed and changes implemented for this study are a vast improvement for student learning and will continue to be modified and implemented for future generations of students.

APPENDICES

Appendix I:

Activities

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Images in this thesis are presented in color.

APPENDIX I-A:

Demo Activity: What dissolves in Water?

-Adapted from People and Water: Alverno Science Inquiry Activities on the Internet. www.depts.alverno.edu/nsmt/Water.html

Teacher Preparation Instructions:

- Obtain a large bottle or other sealable container.
- Add a variety of test substances into the bottle
    - Soil
    - Sand
    - Aquarium gravel
    - Oil
    - Acid (vinegar)
- Label the bottle with its contents

1. Students form a hypothesis complete with explanation to answer the question "What dissolves in water?"

Shake up the bottle in front of the students.

2. What dissolved & what didn't?
3. What floated? Why?
4. Are things settling out now? Why?
5. Which settled out faster, fine particles or coarse particles?

Pose question: How is this a model of our local ecosystem?

- Segway into discussion of runoff

Runoff

1. What is runoff?
2. What is carried by runoff? Why is this important?
3. What else would water pick up?
4. Where will these things end up?
5. What happens when a lot of rain falls in a short time?

APPENDIX I-B:

Island Watershed Activity

-Adapted from "Rodney's Earth Science Site"
http://formontana.net/watershed.html

Background

In this activity you will design an island, figure out the approximate location of its major rivers, and identify the boundaries of its major watersheds (drainage basins). You will also make a map of the island.

Materials

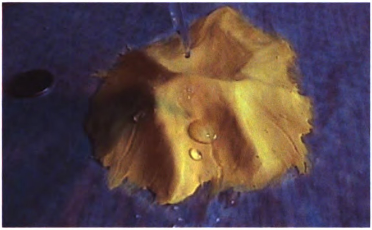
- Modeling clay
- Spray bottle
- Wax paper
- Metric ruler
- Graph paper
- Blue thread
- Red thread
- Colored pencils

Procedures

1. Lay the wax paper on the table, and use the clay to build an island. Be sure to follow the island specifications below:
   - Height less than 3 cm
   - Minimum 4 distinct drainage basins. Consider putting the highest point somewhere other than the middle of the island.

   - Shape/size of at least one basin should be at least two times the size of the others
   - Do not create lakes, cone-shaped peaks, or unrealistic landforms

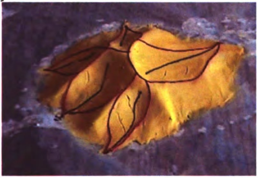
2. Find the approximate location of the islands 4 largest rivers. Hold the spray bottle 3-6 cm above the island and spray the water onto the island to simulate rain. Watch the path of the drops as they run off the island. If a drop gets "stuck, continue to spray to add more water to the drop. Eventually it should flow off the island.
   - You may reshape the island to get the rivers where you want them to be.



http://formontana.net/watershed.html

Images in this thesis are presented in color.

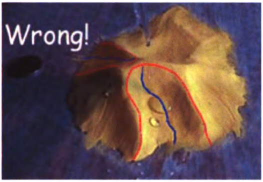
3. Once you are satisfied with the drainage of the island, use pieces of blue thread to mark the location of the major rivers. Press the thread gently into the clay to keep it in place. You will need scissors to cut the thread.
4. Next, use the red thread to mark the boundaries of the watersheds of each river that you have identified.

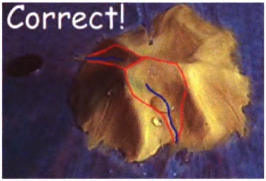


http://formontana.net/watershed.html

Avoid these common mistakes!

- Rivers do not typically originate at the highest point in a watershed. Usually the point of origin is some distance below the high point.
- The watershed boundaries should narrow as they near the coast. Do not include more land near the coast than necessary.
- Do not allow gaps between the watershed boundaries. Water at the top of a ridge will drain into one basin or the other, so the divide should be a single line.





http://formontana.net/watershed.html

Have the instructor check your island before proceeding!!!

5. Show the possible location of 2-5 tributaries for each river you identified. Use a dissection probe to lightly scratch these tributaries into the clay. You may wish to spray more water to find the location of realistic tributaries.

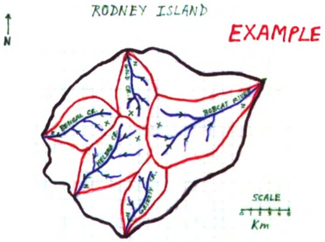
Mapping the Island

6. Dry the island using a piece of paper towel. Be careful not to damage the model.
7. Cut the island away from the wax paper.
8. Place the model onto a piece of graph paper. Trace the edge of the island onto the paper.
9. While the model is still on the graph paper, use a pencil to lightly mark the location of the end of each river on the graph paper.

http://formontana.net/watershed.html

10. Remove the model from the graph paper. Draw each of the following onto the map:
    - Major rivers (in blue)
    - Tributaries (in blue)
    - Boundaries of the drainage basins (in red)

11. Include the following information on your map (all in green):
    - Identify which direction will be North.
    - Name the Island and write the name at the top of the map.
    - Draw arrows on each river and tributary to show the direction of water flow.
    - Name each of the major rivers. Write the name along the river.
    - Put an X in the upper part of each drainage basin.
    - Put a Z in the lower part of each drainage basin.
    - Include a scale (km) for the map.



http://formontana.net/watershed.html

Analysis

1. Determine the length of the longest river channel on the map. (Be sure to include units)
2. Determine the area of the largest watershed on the map. (Show the calculation & units)

APPENDIX I-C:
River Systems Map Activity 1
- Adapted from "River Systems-Using a Kent County Map"- Jill Bouwers-Evers

Instructions: Use the laminated topographical map to complete the following activity. Make any necessary marks on the map with an overhed marker, and record your answers on a separate sheet of paper.

1. Find and color the following landmarks:
    - the building of Portage Northern High School
    - the building of Portage Central High School
    - the building of Loy Norrix High School
    - your house (if on this map)
2. Notice the topographical map has many lines on it not found on a traditional street map. These lines also have numbers associated with them. Some of these numbers have been highlighted for you in light green. What do these lines and numbers represent?
3. Record the number values found close to Portage Creek.
4. Now look to the west and east of Portage Creek. Record and color at least ten of these number values.
5. Find, color, and record the highest point you can find on this map.
6. Describe what these number values are telling you about the land and its relationship with Portage Creek.
7. Notice that West Lake and its surrounding wetlands and tributaries are not colored in blue. These waterways do not connect to the Portage Creek. Describe how this is possible, considering these waterways are found so close to each other...ie, why are they not connected?
8. Find, color, and record the locations of the following human uses of the land
    a. One golf course
    b. One athletic field
    c. One park
    d. Three gravel pits
    e. Two sewage disposal sites
    f. One water tank
    g. Two cemeteries
    h. Two gaging stations
9. In what other ways are humans using the land found on this map?

APPENDIX I-D:

Water Quality Assessment: Physical: Stream Order

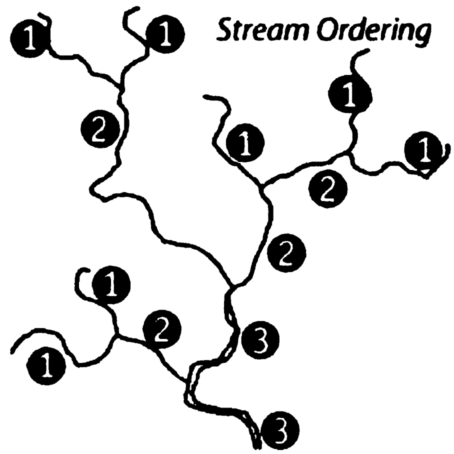
-Adapted from Exploring the Environment- Water Quality
http://www.cotf.edu/ete/modules/waterq3/WQassess4b.html

Water Quality Assessment: Physical: Stream Order

Stream order is a measure of the relative size of streams. The smallest tributaries are referred to as first-order streams, while the largest river in the world, the Amazon, is a twelfth-order waterway. First- through third-order streams are called headwater streams. Over 80% of the total length of Earth's waterways are headwater streams. Streams classified as fourth- through sixth-order are considered medium streams. A stream that is seventh-order or larger constitutes a river.

When diagramming stream order, scientists begin by identifying the first-order streams in a watershed. First-order streams are perennial streams--streams that carry water throughout the year--that have no permanently flowing tributaries. This means no other streams "feed" them.

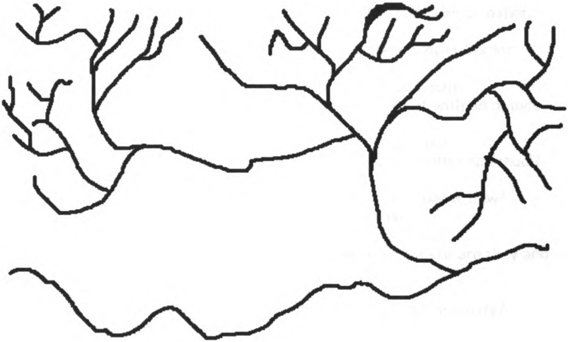
Once the first order streams are identified, scientists look for intersections between streams. When two first-order streams come together, they form a second-order stream. When two second-order streams come together, they form a third-order stream. And so on. However, if a first-order stream joins a second-order stream, the latter remains a second-order stream. It is not until one stream combines with another stream of the same order that the resulting stream increases by an order of magnitude. See the diagram to the right.



Examining the stream network is important in determining study sites. It is best to sample a stream above and below any point at which a tributary enters it, as well as in the tributary itself. The result is 3 sample sites at each intersection of two streams. This is done so that one can narrow down the location of any potential pollutants.

Stream order is also an important part of the River Continuum Concept. The River Continuum Concept is a model used to determine the biotic community expected in a stream based on the size of the stream itself. As water travels from headwater streams toward the mouths of mighty rivers, the width, depth, and velocity of the waterways gradually increase. The amount of water they discharge also increases. These physical characteristics dictate the types of aquatic organisms that can inhabit a stream.

Instructions: Examine the stream network below. Diagram the stream order, beginning with the first order streams and progressing downstream.



In the space below, draw a stream network. Diagram the stream order, including the numbers on the map.

APPENDIX I-E:
River Systems- Map Activity 2

- Adapted from "River Systems-Using a Kent County Map"- Jill Bouwers-Evers

Instructions: Using the map, complete the following activity. You will need to color on your map and record other answers on a separate sheet of paper.

1. Locate Kalamazoo County on the map. Identify what counties border Kalamazoo County, and their relative locations.
   Example: Huskie County is Northeast of Kalamazoo County.
2. Locate Portage Northern High School on the map. Mark it with an orange dot.
3. Locate your home on the map and mark it with a yellow dot.
4. How far is your home from PNHS, following the path you drive to school? (miles & kilometers)
5. Locate the Kalamazoo River. In what general direction does it flow?
6. Color the Kalamazoo River blue. Begin at Morrow Lake.
7. Through which major cities does the Kalamazoo River flow?
8. Are there any dams along the Kalamazoo River? If so, where are they and how do you know?

9. Locate the Portage Creek. Where does the Portage Creek originate?
10. Color the Portage Creek blue.
11. Locate the West Fork of the Portage Creek. Where does it originate?
12. Color the West Fork of the Portage Creek blue.

13. At Centre Avenue, what order stream is Portage Creek?
14. At I-94, what order stream is the West Fork of the Portage Creek?
15. In Milham Park, the West Fork and Portage Creek combine. What order stream does it become?
16. Where does the Portage Creek join the Kalamazoo River?
17. Mark the boundaries of the Portage Creek watershed. Does the Portage Creek watershed stay within Kalamazoo County?

18. The Black River empties into Lake Michigan at South Haven. Color the streams of the Black River watershed blue. Mark the boundaries of the watershed. Determine the stream order of the Black River where it enters Lake Michigan. Mark the stream orders on the map in red.

19. Within Kalamazoo County, find the first order streams that feed into the Kalamazoo River. Color all of these tributaries blue.
20. Mark the boundaries of the Kalamazoo River watershed. You will need to color the tributaries to help you define the outline of the watershed.
Does the Kalamazoo River watershed stay within Kalamazoo County? If not, what other counties are included?

APPENDIX I-F:

Aquatic Food Chain/Food Web Activity

Instructions: Use the information on the handout and the Creek Connections Aquatic Macroinvertebrate Key to create food chains and a food web. Remember that arrows are used in food chains to represent the transfer of energy, and should be read "is eaten by".

1. Create four realistic food chains below, each with at least 3 links. (4 organisms)

a)

b)

c)

d)

2. Using the food chains you created above, link them together to make a food web.

3. Deduce the tropic level of each organism in the web. Using a different color pencil, write the tropic level at which it is feeding next to the organism name. Note: an organism may feed at more than one tropic level, depending on its placement in the chain. Therefore, some organisms may have more than one tropic level designation.

APPENDIX I-G:
River Continuum Concept

Instructions: Use the address below to access the Wheeling Creek Watershed site. Read the background information provided, and examine the stream order map. Then begin to answer the questions below as you click on the types of consumers found in the different order streams. Be sure to read the information provided and examine the photos.

http://www.cotf.edu/ete/modules/waterq/wqcontinuum.html

Definitions- Describe the role each of the following consumers plays in the stream ecosystem.

Shredder-

Predator-

Collector-

Grazer-

1st - 3rd Order Streams

1. Why are these types of streams often referred to as "headwaters"?
2. Click on the Shredders.
    a. What type of organism is shown in this picture?
    b. What unique adaptation do these organisms use to survive in the environment?
    c. What role do these organisms play in the stream ecosystem that is important for other organisms?

3. Click on the Predators.
    a. What type of predator is common in the headwaters?
4. Click on the Grazers.
    a. Name a grazer in the headwaters.
    b. What do grazers eat, and how do they obtain their food?
    c. Notice the shape of the grazer. Explain how its physical structure may be an adaptation for survival in its environment.
5. Click on the Collectors.
    a. What type of collector might be found in the headwaters?
    b. What adaptation does this organism use to survive in its environment?
    c. What environmental material does the collector seem to rely upon?

4th Order Stream

6. Examine the distribution of types of consumers as one progresses into these 4th order streams. The collector and predator populations do not seem to have changed much. Described what happens to the populations of shredders and grazers.

7. Why do you think this change in population occurs?

8. Click on the Shredders.
    a. How are these caddisflies different than the other species?
9. Click on the Predators.
    a. Name this predator, and its food source.
10. Click on the Collectors.
    a. What adaptation does this mayfly use to survive in its environment?

11. Click on the Grazers.
    a. Notice the latin name of this caddisfly is *Helicopsyche*. How does the structure of this larval case relate to its latin name?
    b. What food source is this caddisfly relying upon?

6th order & Larger Streams

12. Click on the Predators.
    a. What type of organism is this predator?
    b. What is its food source?

13. Headwater streams are characterized by having a surrounding forest canopy. Why is this forest canopy important to the ecology of the stream?

14. Which type of stream has the highest population of shredders? Why is this?

15. Describe what happens to the grazer population as stream order increases. Explain why this occurs.

16. In high order streams the consumer population is dominated by collectors. Why does this occur?

APPENDIX I-H:
How Sensitive Are They?

Adapted from Creek Connections Aquatic Macroinvertebrates Module- How Sensitive Are They?
- http://creekconnections.allegheny.edu/Modules/Module-AquaticMacroinvertebrates.html#Activities

<u>BACKGROUND</u>:

Macroinvertebrates are organisms without internal skeletons that can be seen with the unaided eye (often considered larger than 0.5mm). Reference to the term "aquatic macroinvertebrates" can include arthropods (insects in all life cycle stages, nymph, larva, pupa, or adult or crustaceans or arachnids), mollusks, and worms. Examples of aquatic macroinvertebrates include mayfly nymphs, stonefly nymphs, dragonfly larvae, midge larvae, crayfish, leeches, aquatic worms, and water beetles. Some of these creatures are called **benthic** (bottom -dwelling) macroinvertebrates, which means that they live in, move along, or attach themselves to the waterway bottom or substrate. Not all aquatic macroinvertebrates remain on the bottom though - some swim through the water or live on the surface.

Indicator organisms are creatures that are sensitive to changes in water quality and will react to changes in their environment in predictable ways. Aquatic macroinvertebrates are one group of such organisms. Because different aquatic macroinvertebrates have different levels of tolerance to pollution, the amount of stress a stream is under can be measured by the organisms that live in that stream. Environmental degradation decreases the number of different types of organisms in a community by eliminating sensitive creatures while increasing the number of tolerant ones. This decreases the **biodiversity** (number of different forms of life) of the stream.

The **Pollution Tolerance Index** (PTI) is a means of measuring stream quality based on indicator organisms and their tolerance levels. **Tolerance levels** refer to the amount of pollution the organisms can handle before dying or moving to another habitat. By sampling a measured area of a waterway, usually a total of 3 square meters, and determining which aquatic macroinvertebrates are present and which are not, the pollution levels of a stream can be determined.

The indicator organisms are grouped into three categories based on their tolerance of pollution conditions. These categories are:

Sensitive (Group I)- The presence of sensitive organisms generally indicates GOOD WATER QUALITY because these aquatic macroinvertebrates cannot survive under polluted conditions.

Facultative (Group II)- These organisms can exist under a wider range of water quality conditions than sensitive organisms can. Therefore, they are found in MODERATE WATER QUALITY ***and*** good-quality water.

Tolerant (Group III)- The heartiest organisms, they are tolerant of pollution. In large numbers, they point to POOR WATER QUALITY conditions, but can also be present in good and fair water qualities.

Each of these indicator groups is assigned an index value, with the least tolerant group having the highest index value. The index score for a stream is based on the number of indicator organisms present per group.

In good-quality streams, each aquatic macroinvertebrate group should be represented, though there will probably be more sensitive organisms than tolerant or facultative organisms. Finding a worm or midge larva (both tolerant organisms) does not mean the stream is polluted, as long as the majority of the sample is from the sensitive range. However, a net full of worms and midges with no sensitive organisms will earn a poor stream survey rating.

A Pollution Tolerance Index is a common way for stream ecologists to assess the health of a waterway through biological methods. Chemical, bacterial, and land use monitoring exist as well to provide more information on the health of a stream. Although chemical tests are frequently used, they have limits that can be overcome with biological sampling.

For instance, chemical monitoring may miss a pollutant in the stream because the kit used may not include tests for that particular substance. Also, chemical testing is only a snapshot determination of stream health and pollution for that moment. Results may suggest a stream is clean even if it is polluted the other 364 days of the year. Aquatic macroinvertebrates are subjected to day-to-day and longer term changes in pollution, oxygen levels, and acidity levels. Most scientists believe that the PTI better reflects the overall condition of a stream.

Scenario

As a biologist, you have been called in to assess the health of a particular stretch of Huskie Creek. Community members are concerned about the health of the stream due to recent human activity. Your team will rotate through each of six stations.

Procedure

1. Examine the specimens using the magnifying glasses and/or microscopes.

2. Use the Creek Connections Organism Identification Pages to identify each organism and record each of the organisms found at the site.

2. Using the Taxa found on the Pollution Tolerance Index data sheet, predict the health of the stream at that collection site using the following categories:

- Good Quality
- Moderate Quality
- Poor Quality

3. Rotate through the stations, gathering data for each site. Record all of the data on the Student Data page

4. Answer the Analysis & Conclusion questions.

Student Data Worksheet: How Sensitive Are They?

Site #1

1. Macroinvertebrates: ______________________________
____
____
____

2. If you found many of each of these insects from this site in the entire stream, what type of health would you predict the stream to have?

____

Site #2

1. Macroinvertebrates: ______________________________
____
____
____

2. If you found many of each of these insects from this site in the entire stream, what type of health would you predict the stream to have?

____

Site #3

1. Macroinvertebrates: ______________________________
____
____
____

2. If you found many of each of these insects from this site in the entire stream, what type of health would you predict the stream to have?

____

Site #4

1. Macroinvertebrates: ______________________________
____
____
____

2. If you found many of each of these insects from this site in the entire stream, what type of health would you predict the stream to have?

____

Site #5

1. Macroinvertebrates: ______________________________
____
____
____

2. If you found many of each of these insects from this site in the entire stream, what type of health would you predict the stream to have?

____

Site #6

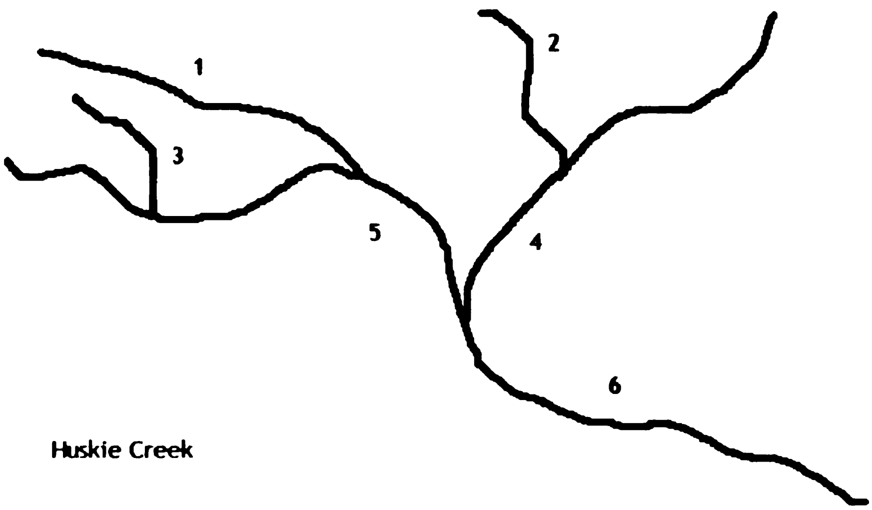
1. Macroinvertebrates: ______________________________
____
____
____

2. If you found many of each of these insects from this site in the entire stream, what type of health would you predict the stream to have?

____

Analysis

1. A map of Huskie Creek can be found below. Notice that the collection sites are marked. Label each site with the level of health you determined based on the organisms found.



2. Community members would like to know if there are any particular locations in the watershed that may be adversely affecting Huskie Creek. On the map, place a star where Huskie creek may be adversely affected.

3. How did you identify this location?

4. What order stream is Huskie Creek at site #6? ________________

5. Describe the health of Huskie Creek at site #6 compared to upstream.

6. Using the Pollution Tolerance Index Data Sheet, calculate the pollution tolerance index and identify the overall stream quality of Huskie Creek.

Conclusions

1. Why do scientists like to use aquatic macroinvertebrates to determine stream health?

2. How do you think stream ecologists decided on how to group aquatic insects into pollution tolerance categories?

3. What problems might be causing stream pollution that negatively affects aquatic life?

How Sensitive Are They? Teacher Materials

1. On different lab tables, place six stations of preserved aquatic macroinvertebrates from the reference collection using the chart below. You could use the labeled specimens or the unlabeled specimens (make them practice identification).

Huskie Creek Site 1	**Huskie Creek Site 2**	**Huskie Creek site 4**
Riffle beetle adult	Crane fly larva	Leech
Mayfly nymph	Fishfly larva	Blackfly larva
Case-building caddisfly larva	Damselfly nymph	Aquatic worm
Good quality	***Moderate quality***	***Poor quality***
Huskie Creek Site 6	**Huskie Creek site 3**	**Huskie Creek site 5**
Dragonfly larva	Stonefly nymph	Dobsonfly larva
Alderfly larva	Midge fly larva	Water penny beetle larva
Net-spinning caddisfly	Mayfly nymph	Aquatic sowbug
	Crayfish	Scud
Moderate quality	***Good quality***	***Good quality***

Good discussion questions

1. Why were sites 3 & 5 still considered to have "good quality" even though they had some group 3 "bad" creatures in them?

2. Why are some organisms not included in the pollution tolerance index?

APPENDIX II:

Evaluation Tools

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APPENDIX II-A:

IB GROUP IV

PHYSICAL & LIFE SCIENCES

2007 PROJECT GUIDE

PORTAGE NORTHERN HIGH SCHOOL

J. BAKER
D. HERTEL
M. HUBER
K. MIRAKOVITS

Abstract:

The group IV project is a culminating collaborative research project undertaken each year. The current project centers on aquatic ecosystems within the Portage creek watershed. The project is a requirement of IB sciences, and is required to use 15 lab hours. Literature research, development of a research question, hypothesis, and a collaborative lab research component all are involved in the project. At the project's completion you will submit a poster and present at parent-teacher conferences. The project is accomplished by an interdisciplinary team of students from IB Bio SL, IB Bio HL, IB Chem HL, and IB Phys HL.

Research Question:

What are the factors that affect the health of an aquatic ecosystem?

Project Flow Chart:

Ecology Lessons	☐ Theory- Community and Ecosystems content objectives ☐ What dissolves in water? Demonstration ☐ Island Watershed Activity ☐ Stream Order Activity ☐ River Systems Map Activity #1- Portage Creek Watershed ☐ River Systems Map Activity #2- Kalamazoo River Watershed ☐ River Continuum Concept Activity ☐ Food Chains & Food Web Activity ☐ How Sensitive are They? Activity	September
Protocols	☐ Learn about field protocol and technique	September
Field Sampling	☐ Work in the field to collect data from separate sites ☐ Interdisciplinary teams ☐ Data analysis and compilation in the afternoon at school ☐ Begin thinking of Research Questions to investigate	Sept. 25 Full Day
Large Group Meeting	☐ Meet your research team / team building activity ☐ Share protocols and data/ exchange ideas and information ☐ Get introduced to database ☐ Formulate a RQ and HYPOTHESIS for research project ☐ Assign tasks associated to RQ and HYP ☐ Brainstorm on methods of synthesizing data to answer RQ and HYP ☐ Look at sample posters from prior years ☐ Learn about comparative data analysis ☐ Formalize future meetings	Oct. 17 PM
Small group research meetings	☐ Meet outside of class to complete background research, data analysis, and conclusions ☐ Prepare notebooks for notebook check ☐ Begin preparing poster elements for final poster	Notebook Check: Oct 30 Nov. 6
Develop Posters	☐ Learn about poster elements and how to assemble a quality scientific academic poster ☐ After school poster tutorial sessions ☐ Posters due on Nov. 15th before school! ☐ Sing up for presentation times at conferences	Nov 7 – Nov 8 Nov. 15
Symposium	☐ Presentations at conferences in Igloo foyer. A group member must be present at all times	Mon. Nov 26 Tues. Nov 27

Assessment:

The Group IV project is assessed in three ways:

1. Lab Notebook -
   - ☐ The notebook is designed for you to keep all your research notes and documentation in one location. It will be checked in two methods. It will be checked for documentation of meetings, groups, etc. This is designed to give you points for doing the work. Don't neglect to record data! The second way is to evaluate the data that you have recorded. Are you collecting information appropriately? Are you collecting good data? Are you recording the right data?

2. Research Behavior -
   - ☐ You will be assessed in the team meetings based on professional behavior. This is also where the IB scores of Personal Skill (a), Personal Skill (b), Manipulative Skill will be assessed. The same criteria will also be applied to the research lab component.

3. Poster Presentation -
   - ☐ The poster will include individual as well as collective elements
   - ☐ RQ/ HYP and integration of project with DPP / CE are the collective elements
   - ☐ DC / DPP / individual discipline data are the individual elements.

Rubrics will be developed for each of these three criteria, and will be given to you by instructors at the appropriate time.

Other Details:

- ☐ Notebook check: you should have your subject data, and research. You should have your meeting notes. You should have data analysis and integration comments as well. These comprise your notebook grade.

- ☐ Stay in communication with teachers. Do not isolate yourself or your group and expect answers and solution to problems on the day work is due.

- ☐ Since this is a process, updates and details can change as the project progresses.

- ☐ PLEASE USE YOUR IB CRITERIA WHEN WRITING YOUR POSTER ELEMENTS

APPENDIX II-B: IB GROUP IV PROJECT RUBRIC

IB Group 4 Poster Project Rubric			
			Points Possible
Final Lab notebook check		• Credit for your individual work with the project.	10pts
Poster	**Research Question**	• Correct format, includes factors.	2
	Hypothesis	• Aligns with RQ • Directed research • Each discipline is included	2
	Background	• Literature review reflective of hypothesis & discipline	3
	Methods	• Describes collection methods to get data including sampling and processing • Uses correct vocabulary and terminology	3
	Data analysis	• Data were process correctly • Data were presented appropriately allowing for interpretation • Errors and limitations	10
	Results	• Discipline based, what did the data show you?	10
	Conclusion	• Answers the RQ and HYP • Brings together all of the disciplines • Discuss weaknesses / limitations • Provides realistic suggestions for future research	10
Presentation Points		Able to answer focused question(s) about research in your discipline. Every team member will equally participate. Minimum of 45 minutes per person – poster manned entire time. Professional dress, attitude, and approach. The conversations will happen on Tuesday – November 20, 2007 from 12:30 – 3:30 or 5:30-8:30, you must be in attendance at one of the above presentation times.	25
		Total Points Possible:	**75**

APPENDIX II-C:

Pre-Unit Survey Questions

Please answer the following questions using the scale found below.

1. Taking notes in class helps me to learn biological concepts.
   5-Always 4-Often 3-Sometimes 2-Seldom 1-Never

2. Completing a hands-on activity helps me learn biological concepts.
   5-Always 4-Often 3-Sometimes 2-Seldom 1-Never

3. I find it easier to remember concepts that have been presented through lab activities.
   5-Always 4-Often 3-Sometimes 2-Seldom 1-Never

4. Discussing lab work with other science students helps me learn the biological concepts.
   5-Always 4-Often 3-Sometimes 2-Seldom 1-Never

5. Doing field work helps me to apply the concepts presented in class.
   5-Always 4-Often 3-Sometimes 2-Seldom 1-Never

6. I prefer developing my own question to investigate rather than answering a question given to me by someone else.
   5-Always 4-Often 3-Sometimes 2-Seldom 1-Never

7. I find value in working with other students in a team to solve a problem.
   5-Always 4-Often 3-Sometimes 2-Seldom 1-Never

8. Conducting field research as a member of a team helps me develop teamwork skills.
   5-Always 4-Often 3-Sometimes 2-Seldom 1-Never

9. I prefer to work independently on investigations.
   5-Always 4-Often 3-Sometimes 2-Seldom 1-Never

10. Creating a poster presentation helps me fully understand the biological concepts.
    5-Always 4-Often 3-Sometimes 2-Seldom 1-Never

11. I am more interested in scientific work when a local problem is being investigated.
    5-Always 4-Often 3-Sometimes 2-Seldom 1-Never

Please answer the following questions using complete sentences.

12. What are the basic biological, chemical, and physical concepts involved in stream ecology?

13. Is learning about watershed and stream ecology important for high school students? Please explain your reasoning.

14. Is watershed education and conservation important at the community level? Please explain your reasoning.

APPENDIX II-D:

Post-Unit Survey Questions

Please answer the following questions using the scale found below.

1. Taking notes in class helped me learn biological concepts.
   5-Always 4-Often 3-Sometimes 2-Seldom 1-Never

2. Completing a hands-on activity helped me learn biological concepts.
   5-Always 4-Often 3-Sometimes 2-Seldom 1-Never

3. I find it easier to remember concepts that have been presented through lab activities.
   5-Always 4-Often 3-Sometimes 2-Seldom 1-Never

4. Discussing lab work with other science students helps me learn the biological concepts.
   5-Always 4-Often 3-Sometimes 2-Seldom 1-Never

5. Doing field work helped me to apply the concepts presented in class.
   5-Always 4-Often 3-Sometimes 2-Seldom 1-Never

6. I prefer developing my own question to investigate rather than answering a question given to me by someone else.
   5-Always 4-Often 3-Sometimes 2-Seldom 1-Never

7. Conducting field research with students of other science disciplines helped me develop a more thorough understanding of stream ecology.
   5-Always 4-Often 3-Sometimes 2-Seldom 1-Never

8. I find value in working with other students in a team to solve a problem.
   5-Always 4-Often 3-Sometimes 2-Seldom 1-Never

9. Conducting field research as a member of a team helped me develop teamwork skills.
   5-Always 4-Often 3-Sometimes 2-Seldom 1-Never

10. I would prefer to work independently on a field investigation.
    5-Always 4-Often 3-Sometimes 2-Seldom 1-Never

11. Creating a poster presentation helped me fully understand the biological concepts.
    5-Always 4-Often 3-Sometimes 2-Seldom 1-Never

12. Creating a poster presentation helped me understand how the science concepts are integrated in stream ecology.
5-Always 4-Often 3-Sometimes 2-Seldom 1-Never

13. Developing and presenting an academic poster is a valuable tool for a high school student.
5-Always 4-Often 3-Sometimes 2-Seldom 1-Never

14. Completing a field ecology investigation helped me understand how the scientific method is used to create and answer questions.
5-Always 4-Often 3-Sometimes 2-Seldom 1-Never

15. I am more interested in scientific work when a local problem is being investigated.
5-Always 4-Often 3-Sometimes 2-Seldom 1-Never

Please answer the following questions using complete sentences.

16. What are the basic biological, chemical, and physical concepts involved in stream ecology?

17. How did completing the stream ecology field investigation help to integrate your knowledge of biological, chemical, and physical concepts, even if you are a student of only one of those sciences?

18. Is learning about watershed and stream ecology important for high school students? Please explain your reasoning.

19. Is watershed education and conservation important at the community level? Please explain your reasoning.

20. Do you find the knowledge you gained in this unit to be personally valuable? Please explain your reasoning.

APPENDIX II-E:

Watershed & Stream Ecology
Pre-Unit & Post-Unit Assessment Questions

1. What is a watershed?

2. Name the local watershed and describe its physical characteristics.

3. Sketch a stream network diagram. Include 1^{st} - 4^{th} order streams. Label each stream in the diagram with its stream order.

4. Sketch a food web of a stream ecosystem. Include at least 10 named organisms, with four different trophic levels.
    a. Annotate the diagram to name the trophic level of each organism.

5. Explain how energy enters a biological community, flows through it, and is eventually lost.

6. Name a specific stream macroinvertebrate and describe how it is adapted for life in its environment.

7. How are aquatic macroinvertebrates used as an indicator of stream health?

8. Why do scientists use aquatic macroinvertebrates as a measure of stream health?

9. Describe a field protocol that can be used to quantitatively analyze stream macroinvertebrates.

10. Why is it important to complete a habitat assessment of the area when monitoring the health of a stream ecosystem?

11. In what ways do humans negatively impact the health of stream ecosystems?

12. In a local watershed, a neighborhood is developed along a number of stream tributaries. The neighborhood inhabitants love their green lawns, and use excessive amounts of lawn fertilizer. Describe what effects one may see downstream from the neighborhood at the end of five growing seasons.
    a. Biological-
    b. Chemical-
    c. Physical-

13. How might the above mentioned human impact on the stream be remediated?

APPENDIX II-F:

Assessment Questions Grading Rubric

Award marks for the following information included in student answers. Total marks possible for each question indicated by [ ].

1. Area of land/ drainage basin (1)
   Drained of water into stream network/drained into bodies of water (1) [2]

2. Portage Creek (1)
   part of Kalamazoo River watershed (1)
   low stream order (1)
   sub-urban (1)
   good overall health/clean (1) [4]

3. Sketch drawn correctly (1)
   Includes orders 4,3,2,1, (3) [4]

4. Includes ten organisms (10)
   Arrows drawn in correct orientation
   Includes four different trophic levels (4) [14]
   Deduct one point for each incorrect aspect of web
   Must be constructed for stream ecosystem to earn any credit*

5. sunlight (1)
   producers convert sunlight into organic compounds (1)
   photosynthesis (1)
   10% energy transfer between levels (1)
   Transfer from producers to consumers (1)
   Consumers to consumers/ detritivores/decomposers/feeding relationships (1)
   Energy lost to environment as heat (1) [5]

6. name of organism (1)
   correct adaptation for stream ecosystem (1) [2]

7. organisms able to withstand different levels of pollution/ pollution tolerance (1)
   pollution sensitive organisms will not be found in polluted areas (1) [2]

8. organisms have different levels of pollution tolerance (1)
   presence/absence of organisms indicates quality of water over long term (1)
   more comprehensive measure of stream health/ less of a snapshot
   easy to collect/analyze macroinvertebrates [2]

9. collect organisms properly using D-net (1)
   collect from variety of substrates/bottom substrate/plants/rocks (1)
   sort organisms collected (1)
   identify organisms collected/obtain count (1)
   use pollution tolerance index to obtain water quality score (1) [5]

10. physical environment directly affects stream ecosystem/
    types of organisms found (1) [1]

11. accept two correct answers [2]
    "pollution" is not specific enough

12. accept one correct answer for each a,b,c [3]

a- more algae (1)
   more grazers (1)
   less overall biodiversity (1)

b. increased nitrate/phosphate levels (1)
   lower oxygen levels (1)
   change in pH (1)

c. increased sediment levels (1)
   slower water velocity/change in water discharge values (1)
   less depth (1)
   increased turbidity (1)

13. educate residents about local watershed/runoff (1)
    decrease fertilizer use along stream (1)
    decrease runoff from neighborhoods into stream (1) [1]

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