

Interdisciplinary Evaluation Techniques Using System Dynamics

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ABSTRACT

Most educators recognize the value and importance of teaching and learning with an interdisciplinary approach. This paper discusses how the use of computer models by STELLA in a high school Ecology and Environmental Studies class demands skills and content that is interdisciplinary in nature. I use a food chain model and curriculum that I

created to describe how I was destined to discover an evaluation technique which nicely parallels the important, valuable, and fun teaching and learning that STELLA models demand.

STUDENT QUOTES

"STELLA is an incredible program. It brings modern technology and food chains together and simplifies them to a high school educational level."

"STELLA allows us to test what would happen in various ecosystems if we were to change a factor. In STELLA, we can remove a species, without destroying the actual ecosystem, and watch the consequences."

"Scientists can use STELLA models to help determine how businesses, and populations behave."

"Maybe scientists might discover ways to replenish forests or save endangered species. These discoveries might take years when using conventional research methods, but with STELLA, they can take just seconds to discover."

"It is important for students and adults to be educated through this program. STELLA can teach people how our misdoings cause tragic and even fatal effects to the rest of our natural world. People as a whole must realize that many extinct animals died off due to nothing more than human ignorance. If we do not learn soon how important our water supply is, our ozone layer, and our rain forests are, we may cause ourselves to become extinct, which may be for the better because it would give our natural world an opportunity to heal itself."

"Maybe STELLA can help us find ways to avoid starvation and overpopulation. Hopefully, one day we will be able to use STELLA for the betterment of mankind, but for now, STELLA is a great learning experience that all high schools should get a shot at."

"STELLA is a wonderful tool to be used in the schools and taught to the students. It has given me a chance to be God and create a whole little world of my own where whatever I want to happen can happen. I feel very fortunate to have learned it. I must say, I wasn't crazy about it at first, but now it has given me an appreciation for living things and it will make me think twice about anything that can effect poor helpless creatures."

INTERDISCIPLINARY LEARNING

The question students have been asking for decades now, "What does this have to do with my life? When am I ever going to use this stuff?" has for too long been interpreted as a student's excuse for his laziness, lack of motivation, and apathy toward learning. It is instead a justified plea to redirect the focus of our teaching from delivering compartmentalized knowledge to delivering a way of thinking that requires students to consider and employ various disciplines and skills.

Interdisciplinary learning includes application of concepts learned in various subjects to everyday lives of the students. Students want and need more application to give value to education. When this happens, they become intrinsically motivated to continue asking questions and teaching themselves well after formal education has ended.

Science For All Americans¹ says, "Science, energetically pursued, can provide humanity with the knowledge of the biophysical environment and of the social behavior that it needs to develop effective solutions to its global and local problems..." This statement automatically implies that science learning in American schools must change from compartmentalized separated learning of subjects to integrated, interdisciplinary approaches that more accurately reflect the complexity of local and global problems that we face today.

Interdisciplinary teaching and learning more closely parallels students' everyday experiences. An interdisciplinary approach requires a synthesis of skills and knowledge with a critical way of thinking to accurately and sensitively identify and resolve a problem.

THE FOOD CHAIN MODEL

I have been trying to use an interdisciplinary approach in my science teaching. I teach a high school course called Ecology and Environmental Studies which integrates science, math, technology, social studies, history, politics, and ethics. I introduce the course as an interdisciplinary experience and inform my students that it is not at all like any other science course they have taken before. In the course I like to use case studies that invite debates, writing and personal reflection.

The course starts out with a focus on science because an understanding of basic ecological concepts is necessary before all other disciplines get woven into the fabric of the course. I had been looking for a way to have students manipulate and experiment with a food chain to reinforce basic ecological concepts they had learned. The most popular way to monitor ecosystem dynamics is by population assessments over a given period of time. My school schedule and funds make it impossible for me to take my students to a given area of land and perform experiments to monitor populations of interacting organisms.

I discovered computer models using a software called STELLA and immediately recognized they could provide the solution to my food chain experimenting problem. I elicited help of some System Dynamics people to build a model of a food web for my Ecology and Environmental Studies class. The model that was built featured four populations of organisms; grass, mice snakes and hawks. Data was collected from area field researchers and experts for each population, and a model was created which monitors interrelationships between four populations as they are subjected to environmental changes over a simulated twenty-four year period. The environmental changes, both natural and human- induced, included DDT spraying, area encroachment, and general yearly weather.

The model represented a new and exciting way for students to investigate and experiment by computer simulation. Unlike real field research, they could yield results

¹ Rutherford, James F. and Andrew Ahlgren. Science For All Americans. Oxford University Press, 1990.

from experiments they performed in seconds. The computer model allowed my students to investigate interrelationships within an ecosystem in a time-effective and cost-effective way. However, students would be gaining data in a very different way. They would not be tagging and counting living things over a long period of time. Instead, they would be gathering data from graphical displays that STELLA models offer. I was certain that all of my students were not prepared to effectively analyze data from a graph, so I decided to create a curriculum that started from basic skills of graph interpretation. I also wanted my students to recognize that STELLA models can be created for any system and so I created lessons which explored generic models generating exponential growth, overshoot and collapse, s-shaped growth, and sustained oscillation behaviors².

WHAT STELLA MODELS DO TO YOUR TEACHING

During the two month curriculum which culminated with the food web model, I discovered how teaching with STELLA models demands a different type of teaching and learning which were more valuable to me and my students. The use of STELLA models requires teachers to give students more control of their learning. STELLA models change traditional teacher and student roles in the learning process. STELLA models forced me to change the way I teach and the way my students learn—but all for the better!

Science for All Americans³ says:

"The collaborative nature of scientific and technological work should be strongly reinforced by frequent group activity in the classroom. Scientists and engineers work mostly in groups and less often as isolated investigators. Similarly, students should gain experience sharing responsibility for learning with each other. In the process of coming to common understandings, students in a group must frequently inform each other about procedures and meanings, argue over findings, and assess how the task is progressing. In the context of team responsibility, feedback and communication become more realistic and of a character very different from the usual individualistic textbook-homework-recitation approach."

This type of learning environment that Science for All Americans describes is just what STELLA models can bring to a classroom. A STELLA model, with an appropriate curriculum, can transform teaching and learning in a classroom from a textbook-homework-recitation approach to learner-centered learning. Students working closely together creating their own procedure for tackling a problem and then arguing over the findings and interpretations, are important elements of learner-centered learning.

The use of STELLA models offers another way other than laboratory experiments to have your students become more involved, responsible, and in control of their learning. Most high school laboratory texts stifle student creativity and take control away from students by prescribing a step by step procedure reminiscent of a cookbook recipe. Therefore, a STELLA model with appropriate curriculum can often be more successful at empowering and engaging your students than traditional science labs.

² "Evolution of a Food Web." Chris Prince MIT of the MIT System Dynamics in Education Project, D-4301. Available from Creative Learning Exchange, 1 Keefe Rd. Acton, MA 01720.

³ Rutherford, James F. and Andrew Ahlgren. Science For All Americans. Oxford University Press, 1990.

I do stress that only appropriate types of STELLA curricula are successful in giving students some control of learning. What does appropriate mean? An appropriate curriculum is one that fosters creativity and gives the student initiative for problem solving and self-directed discoveries. It is very easy for a teacher first using STELLA models to fall into the trap of creating worksheets that have too many directives on how to manipulate the model.

Chris Prince, a member of the System Dynamics in Education Project at MIT and developer of the food chain curriculum with me, agrees that there were some aspects of the model's curriculum that students did not respond well to. Chris Prince and I created some computer lab guided worksheets which were not one hundred percent successful and dampened student enthusiasm.

In the food web model, students would manipulate environmental factors and generate a graphical output with four populations going up and down in response to each other and environmental changes. Some of the first worksheets created for this model, would ask students to plug in certain prescribed values and then run the model. This type of worksheet takes all the fun out of learning with the model, and students do not feel empowered. Instead, students should be asked to change certain values to achieve a specific type of population curve, and then explain why that change caused the population to change the way it did. When creating worksheets for students to use as they experiment with the system, a teacher must be very careful to supply just enough directives to catalyze student enthusiasm and desire to take control, without replicating what American laboratory textbooks have already done so effectively-- squelch creativity.

After discovering the need to let go of control, I discovered still another problem with the way I had developed worksheets. The worksheets would ask students to hypothesize, in writing, what graphical outputs would look like before they ran the model. Students did not respond well to this request because it was often laborious and difficult to write down intricacies of four populations' simultaneous effects on each other over time. Industrious students toiled with long paragraphs of run-on sentences that were hard for me to decipher, while most students simply ignored the requests for written hypotheses and conclusions. These behaviors pointed out to me that I was not understanding an important aspect about teaching and learning with computer models.

One of the most important aspects of learner-centered learning is student dialogue. With learner-centered learning, it is absolutely necessary that students work in pairs or in groups of three because ideal experimentation involves dialogue and criticism between scientists. Guided worksheets with requests for time consuming written hypotheses were squelching the value of, and time for, dialogue. Students greatly preferred and enjoyed telling each other and me their hypotheses for a run and interpretations of a run while pointing to graph displays.

DIFFICULTIES IN EVALUATING STUDENT PROGRESS

Just as STELLA models forced me to change the way I teach, they also demanded some creativity when trying to evaluate student progress with model experimentation. It took me a while to discover that my evaluations were not assessing skills I wanted my students to develop. My first quiz on modeling was primarily asking my students to recall knowledge about STELLA models that they had been taught. This type of quiz is counterproductive because it tells students who are engaged in a new type of learning that their science teacher is still stuck on old fashioned evaluations that do not focus on How's, Why's and learning process itself.

Science For All Americans⁴ says, "Scientists, mathematicians, and engineers prize the creative use of imagination. The science classroom ought to be a place where creativity and imagination...are recognized and encouraged. Indeed, teachers can express their own creativity by inventing activities in which students' creativity and imagination will pay off."

Recognizing the important role of dialogue in learner-centered activities that STELLA models demand, I employed some creativity and imagination to change the way I would evaluate progress my ecology students had made.

THE SOLUTION: AN INTERDISCIPLINARY ASSESSMENT

When students learn by use of STELLA models, constant communication between students within groups and the teacher is necessary. The model my students were experimenting with asked them to see how a combination of three different types of environmental changes affected interrelationships of four populations within a small food web. They spent a few class periods trying different combinations of effects and trying to explain why populations behaved the way they did over the twenty-four year simulation. Students were asked to share their interpretations of graphs with their partners and then when they felt they had a sound understanding of the dynamics, they were asked to explain them to me. Having spent some class periods immersed within conversations, I decided that my evaluation of my students' progress with the model must involve both oral and written communication.

I created three assignments for the students. Two assignments were written assignments and one was an oral presentation. I have included all three assignments that I gave the students. These assignments are preceded by a sample run of the model with graphs describing environmental change inputs that created that sample run. After each assignment I will describe the rationale for the assignment, it's importance to student learning, and its importance in an interdisciplinary classroom. I will also provide student responses to each assignment.

⁴ Ibid.

A. CREATIVE WRITING

Ecology and Environmental Studies
Food Web Evaluation assignments

Name _____
Date _____

Assignment #1 YOUR STORY

This will be a written paper of one to three pages in length which should read like a storybook. You may even want to start your story with "Once upon a time....." Tell about four types of organisms existing within the community. State the size of the community (100 square kilometers) and it's location (anywhere you want in New England).

The name for the hawks is the red tailed hawk, the name for the mice is the New England white-footed mouse, the snake is a garter snake and the biomass is the plant life that the mice feed on. Think of a creative name for your community, and for the evil villains (living or non living) that might disrupt their equilibrium. You must write in full sentences and you and your partner are responsible for turning in a story. The story should start in the year 1990 and end in the year 2014.

All you are really doing in this story is talking about environmental changes in your community such as weather changes, DDT introduction, and area infringement. There is no need in your story to explain what caused a certain population to go up or down. In other words, you do not have to say that the "... building of the highway by the terrible Waqwaqs in 1998 caused massive biomass destruction which then caused the mouse population to go up drastically which then caused the hawk population to go up drastically, which then caused the mouse....." That would be altogether too wordy and wouldn't flow nicely. What you should do is experiment for a while with a couple changes here and there, get the most exciting and interesting run output for the class to see, and THEN start writing your story around your favorite changes. Your story will be graded on creativity and good writing in full sentences!

You certainly can say in your story that some of the changes you made caused the hawk community to nearly die out in the year 2008, but the point is that you do not have to state WHAT exactly caused it in terms of the populations of the other organisms. You will save detailed explanations for your oral presentation to the class, which leads me to the second evaluation you will experience.

•RATIONALE

Too many students graduate high school, not having learned how to clearly express their thoughts. Reading and writing skills, therefore, must constantly be developed. The big mistake high school educators make is that they assume that students have enough writing practice in their humanities classes. Not stressing writing skills in a math and science education is a disservice to students and a terrible error. It is essential that scientists be able to express their thoughts clearly- both orally and in writing- otherwise the progress of science becomes severely retarded and lots of research time and money is lost.

It makes sense that in any interdisciplinary classroom, writing has to be a priority and time must be invested to teach writing skills. I have invited English teachers from my school and others to come into my class and help my students gather ideas by free writing and then condensing, molding, and ordering ideas into coherent written expression that flows. I could have done this myself, after meeting with English teachers and sharing ideas. But by having the English teacher in my classroom, the students get the obvious message that what they learn in one classroom must be shared in the next classroom. Science and math teachers must understand that the most important skills students need to develop are communicative skills and that they have not taught their subject well if their students cannot effectively communicate what they have learned.

The student response to this assignment was very positive. Some students who had not had the opportunity to shine in class, let their creativity and imagination go wild and created very entertaining stories that the whole class enjoyed hearing. Here is a part of one group's story:

Harry the hawk was ruler of the air, soaring above the trees and feasting on mice and snakes. Nothing could be better for him. One day in 1994, while soaring on a lift of warm air, Harry heard an unfamiliar rumbling. Looking down he saw large yellow monsters tearing trees down and clearing out the land. Day after day, puzzled Harry watched on until a huge contraption had replaced half the land on which he lived. Then it happened. Humans in mass quantity surrounded this contraption, coming and going, day in and day out. Harry was worried at first, but then he realized that Marty Mouse and his family had to move in with relatives in smaller areas. Harry began to drool at the sight of these plump mice all stuck in one area. Little did he know that Sammy Snake and his relatives were also drooling at this sight. For about two years, Harry feasted on Marty and Sam's families, until he had realized that he had eaten almost all of Marty's family. Harry then could not find enough members of Marty and Sammy's families to feed his own family. Soon thereafter, members of Harry's family began to die...

Harry was having an average day in the year 2000 when, out of nowhere, a larger human-made bird flew overhead, dumping large quantities of a fog-like substance. Harry could have cared less, until he realized that this substance killed his babies before they were born. Harry cried and wept for years as his family decreased in number close to zero. Marty's family became very happy because Barry (biomass) continued to grow and Marty did not have to worry about Harry's family harassing his family as much...

B. ORAL PRESENTATION

Assignment #2 YOUR ORAL PRESENTATION TO THE CLASS

You and your partner(s) will give a 12 minute presentation in our classroom using the MAC overhead and an additional overhead. The additional overhead on the other side of the blackboard will have blank table functions for weather severity, DDT, and area going from 1990 to the year 2014. Before you actually run your program for the class, one of you will begin to read the story that your group read out loud to the class. While one of you is reading the story, the other person is depicting the environmental changes on the three graphs on the overheads with an overhead marker. That way the class will know, and be able to remember the changes you decided to put into your food web in order to get the incredibly interesting run graph that you get.

After you finish telling your story (this will take about 4 minutes) like a good story teller would, you will leave the environmental changes overhead up on the screen to the right of the blackboard and will run your great program for all to see with the MAC overhead (on the left side of the blackboard)! After the run comes the important part. You will then take a flashcard and/or pointer and move along year by year explaining in detail how the populations went up and down and what caused them to go up and down. One of you might say, "Remember class that in the year 1993 there was a terrible blizzard (as you are saying that, your partner points out the blizzard on the table function graphs which are on the other overhead) and this caused the hawk population to immediately go down which then caused the mice to....." Each time in the explanation of the run (which is displayed on the left side of the classroom on the MAC overhead) when you talk about a new environmental change, your partner will point it out on the table function overhead on the right side of the blackboard. It's like a duet performance! After you finish explaining the run, your partner will be asked a couple specific questions about various points in the run to check his comprehension.

You will be graded on how clear and correct your explanation is of the dips, climbs, and plunges in your population graphs. Hint: you don't want your graph run to be too complex and wild because then it will make it harder for you to explain it and the explanation is a major part of your grade. However, if you created a situation in which 3 of the populations all died off by 1999, then there's not much to explain for the next fifteen years, your report is not very creative, is rather unexciting for the class to see = bad grade for the oral presentation. Get it? Bonus points will be awarded for the most entertaining, ingenious, and creative presentations! Each group's oral presentation will be videotaped and you can view it upon your discretion.

- RATIONALE

Science For All Americans⁵ says,

"Effective oral and written communication is so important in every facet of life that teachers of every subject and at every level should place a high priority on it for all students." Students need to be able to present ideas in front of people with clarity and coherence. Public speaking is a skill that takes a lot of work to develop and many high school's do not recognize it's importance and, therefore, do not stress it in their curriculum. I do not need to go in to detail to describe the importance of public speaking in the working world. This skill is an important determinant to people's successes in many professions. Why don't we prepare our students for this fact of life? Also, do not forget the question often asked by math and science students, "When am I going to use this in my life?"

In a classroom which uses STELLA models and learner-centered learning, dialogue is paramount. It makes perfect sense that any evaluation done on a student's progress with STELLA models includes an oral presentation. The typical student response to any oral presentation assignment is fear. It was interesting to see that few of my students dreaded the idea of presenting before the class. There were several reasons for this. First, students were excited about the oral presentation because it began with a reading of their short stories which they were very proud of. Secondly, learner-centered learning had involved them in a lot of class dialogue before the presentation so they were accustomed to this educational process. Finally, they had the chance to share another creative endeavor other than their short story. They had spent hours creating what they considered to be a very interesting and dynamic scenario. They had rehearsed their oral defenses of the run of their scenario with each other and felt confident and excited about giving their presentation.

My job as a teacher was to reward and foster the development of creativity. I provided students with an overhead Mac and another overhead to display their environmental influences over the twenty four year long scenario. Each member of the group was given a pointer for the overhead screens. Such things sound trivial, but were important in creating an atmosphere of importance. This was probably the first time any of these students were asked to give such a high technology performance- and in front of a video camera too! The student response was very positive, each student giving the presenters their undivided attention. The presenters wanted to be heard because they were proud of their product, and they understood that everyone else felt the same way.

Any course which is interdisciplinary in its approach should include a lot of dialogue, debate and discussion. When trying to evaluate your student's progress in this type of learning environment, it makes sense to make use of oral presentations as well.

⁵ Ibid.

C. EXPOSITORY WRITING

Assignment #3 WRITTEN ESSAY ON STELLA 'S FOOD WEB AND YOU

This will be a paper of at least two pages in length (single spaced) done by you only. A good paper will have its thoughts well organized and will answer these questions. Remember, this is an essay in which the writing must flow together! It will not be a list of answers!

Try to include discussion about these questions and points:

Why was it important and valuable to study how animals and plants relate in a food chain and food web and how are the food chain and food web different? How can the use of STELLA models make it easy for us to take a look at how a food chain and a food web work? In other words, what neat aspects does the STELLA model have that allow you to be educated about food chains and food webs?

What is the definition of ECOLOGY and how exactly were we studying ecology on the computers? Which environmental factors seemed to be most important in determining the fate of the different species of living things in our simple community?

Is the STELLA model a good tool for scientists to learn from since it can simulate real life ecosystems? Was our simulation very realistic? What was unrealistic about it? Could scientists make it more realistic? What must a scientist do before she can input a new critter into our model, to make it even more realistic? How can scientists use STELLA models of ecosystems for the benefit of mankind?

Why can't STELLA models be perfect simulators of real world living communities? So why is it still worth it to make models of certain systems?

If you address all of these interesting questions and write your essay neatly and in full sentences, you are sure to do quite well! Any questions or concerns? Just stop by after school and I will be glad to help you compose your essay!

Essay due _____

- RATIONALE

Unlike the previous creative writing assignment, this writing assignment was more of an analytical essay. I provided students with some questions to encourage them to free-write responses and then consolidate, clarify, and organize ideas into a coherent essay. The essay assignment had many other purposes besides helping students develop their writing. This paper was also a student evaluation of STELLA model usage in a science classroom. It also asked students to recognize the versatility and power as well as the shortcomings of STELLA modeling in all fields .

This writing assignment asked students to consider how STELLA helped them understand delicate balances within a small food web, but also asked them to consider other ways in which STELLA models could be powerful tools for investigation.

CONCLUSION: THE STUDENTS MAKE CONNECTIONS

The beginning of this paper started with students' quotes from the analytical writing assignment. The purpose of including them is not only to share student impressions but to underline the important fact that student-centered learning with STELLA models can invite the student to discover that a valuable and meaningful education is one which teaches us to take what we have learned and apply it to other experiences, ideas, and disciplines. When we can do this in our classrooms we accurately reflect the complexities and wonder of the social-scientific-political-mathematical-ethical-historical world we live in.