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An account of a system dynamics course for high school students and teachers, and community sustainability activists

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Abstract

Over the 1999-2000 academic year, an introductory evening and weekend course in system dynamics was held at the high school in Sturgeon Bay, Wisconsin, USA. The students consisted of high school students, high school teachers, and community members. This paper documents some of the attributes of this experience, in the hope that our story may benefit others interested in attempting something similar.

The belief that system dynamics modeling capacity could help support community sustainability projects in Sturgeon Bay and Door County, Wisconsin drove the course. Our hope is that, with proper education, some community members, especially from the ranks of high school students and retirees, will be interested in serving their communities by providing system dynamics consulting to community business, government and charitable organizations. To achieve this vision, K-12 teachers must learn to use system dynamics in their teaching. And community organizations must be aware of the potential of system dynamics to address organization and community problems. This class was a first effort at bringing these groups together to develop community system dynamics modeling awareness and capacity.

This paper discusses several aspects of our experience, including:

- *How the course got started…illustrating how community sustainability can be a mechanism for introducing system dynamics in a community.*
- *Curriculum and process*
- *Inexpensive distance education techniques used*
- *Some initiatives undertaken by the students on their own volition*
- *Some reflections on our experience*

1.0 How the course got started… illustrating how community sustainability can be a mechanism for introducing system dynamics in a community

The course came about primarily because of the accidental coming-together of two independent multi-faceted initiatives. In one initiative, Larry Smith, Susan Gullion, and Roy Aiken had been taking several paths toward developing public and government awareness of, and action on, sustainability/stewardship in Door County and its communities, and the larger region of Northeastern Wisconsin. The other initiative had been Paul Newton's efforts at promoting system dynamics in K-12 education in nearby Green Bay, WI. Larry, Susan, and Roy had, independently of Paul, decided that the tools that they would promote toward their community sustainability agenda were 1) sustainability principles, 2) system dynamics, and 3) dialogue. Simultaneously, one of Paul's initiatives had been the formation of a system dynamics study group for educators, which, somehow, Susan became aware of and joined. Learning of one another's initiatives through Susan, Larry, Susan, and Roy saw Paul as a system dynamics knowledge resource, and Paul saw community sustainability as a mechanism for introducing system dynamics in K-12 education. Thus, the two initiatives were joined…

Some months later, while Paul was home in Wisconsin for the Christmas holidays from his system dynamics studies at Norway, he and Roy met with the Sturgeon Bay Superintendent, High School Principal, and District Curriculum Director, and proposed a high school/community system dynamics course. The idea was to find a high school teacher who would be interested in learning and teaching system dynamics. The teacher would get started learning system dynamics at Trinity College during the summer, and Paul and the teacher would then teach the first course together in the fall. The course would be funded by local business, government, and charitable organizations, which, in return for their funding, would also be offered seats in the course along with the high school students. Further, the course would be advertised to other K-12 teachers who might be interested and would be held either the first or last period of the day to facilitate participation by the adult students.

Despite some communication snafus it all came together. After playing a bit with Stella® on the computer in his basement, Don Ziegelbauer, a high school social studies teacher, became very interested in co-teaching the class with Paul. In July, he and Paul attended Course 1 of the Waters' Center's 5 course sequence for teachers at Trinity College in Burlington, Vermont. Don recruited three other teachers (1 biology, 1 economics, and 1 social studies) to take the course, as well as five high school sophomores. Four adults enrolled in the course, including Roy Aiken (director of the Door Property Owners Association, Larry Smith (a social sciences professor at the University of Wisconsin - Green Bay), Pat Miller (a retiree who is very active in Door County community issues), and John Jessup (a business process modeling consultant). The high school students would receive normal elective credit for the course, with Don being responsible for grading their work. The class decided to meet each week for two hours on Monday evenings and three hours on Saturday mornings, for a total of five hours per week.

2.0 Curriculum and Process

The class had several types of students, differing in their objectives, aptitudes, ages, and backgrounds:

a) The four high school teachers and one university professor were interested in adding systems thinking and dynamic modeling to their teaching toolkits across several curricular areas. To attract their interest, Don had personally demonstrated Stella ® to, and discussed Waters Course 1 with, each of the high school teachers. In addition, Don was interested in teaching a system dynamics class to students beginning the following school year (2001-2002)

b) The five high school students had a lot of faith in their social studies teacher, and believed they would enjoy system dynamics, especially the computer simulation aspects.

c) The four community members were interested in learning to apply system dynamics to address sustainability issues in Door County.

d) The consultant and the authors of this paper were interested in learning how to help people learn to use system dynamics to address problems.

Clearly the course's curriculum needed to meet a diversity of needs in context of an extraordinary range of student preparation.

2.1 1st semester curriculum and process

2.1.1 1st semester curriculum and process for the teachers and 3 of the 4 community members

First, Don and Paul decided that the teachers' needs would probably be best served by, in general, following the Waters' Center curriculum. Trinity College and Waters' Center professors John Heinbokel and Jeff Potash have developed a five-course curriculum addressed at helping K-12 teachers learn to use systems thinking and dynamic modeling in their classrooms. Don had taken, (and Paul had audited) the first course during the summer at Trinity College (1 week), and decided to use this course, with extensions, as the curriculum for the teachers and the community members. The Waters' Center approved our application to enable the teachers to obtain graduate credits through Trinity College for the course.

Waters' Center's first course is entitled, "Introduction to Systems Thinking and Systems Tools". You may read a description of it, and the other four Waters' Center courses in the series, at the following page of The Waters' Center web site:

http://www.trinityvt.edu/waters/Services/GradCert/GradCert.htm

The first course focuses on behavior-over-time graphs, and stock-flow and causal loop diagrams. Students use pre-built simulations but do not build any simulations of their own. Curricular examples and exercises are extensively employed in the course. The course concludes with students applying the tools in the development of their own application, usually a curricular unit, and by critiquing others' applications.

Earlier we mentioned that Paul had decided to add extensions to Waters' Course 1. The major extensions consisted of portions of several chapters from an early draft of Sterman (2000). We read portions of the chapters aloud in a circle in class, and also executed many of the challenges in those chapters, either individually followed by class discussion, or together as a class. The chapters we partially read together were:

"Chapter 4. **Structure and Behavior of Dynamic Systems**"

"Chapter 5. **Tools for systems thinking: Causal Loop Diagrams**"

"Chapter 6. **Tools for systems thinking: Stocks and Flows**"

"Chapter 7. **Tools for systems thinking: Dynamics of Stocks and Flows**"

"Chapter 8. **Closing the Loop: Dynamics of Simple Structures**"

Also, Paul made his system dynamics books and papers available as a class library for independent study by the students. Finally, many system dynamics web sites were referenced and used in the class, particularly as part of Waters' Center's Course 1.

2.1.2 1st semester curriculum and process for the high school students and the remaining community member (the business consultant)

Paul believed (from reading and conversations with others), that if we didn't engage the sophomores in computer modeling rather quickly, we risked losing their interest. Because Waters' Center's Course 1 does not focus on computer modeling, he decided to use a different curriculum for the sophomores (and the business consultant, who was also interested in modeling). We started with Diana Fisher's (1999) curriculum. However, after several weeks with that curriculum, the sophomores began vociferously grumbling about the step-by-step modeling instructions; they indicated a preference for building their own models. Paul doubts that this was the real problem. Rather, he believes the problem may have been that, because he had to divide his time between the two classes, he was unable to give enough time and encouragement to the students.

At any rate, the dissatisfaction of the students got to the point where Don and Paul felt a change was essential to keep their interest. So, about halfway through the semester, we started modeling our way through sections of Forrester's (1968) *Principles of Systems*, but using Stella and Vensim PLE as our modeling tools. Also, we changed the class schedules in such a way that Paul could spend more time with the students. The students

seemed to enjoy the class more, but it is difficult to say whether this was due to the curriculum or the schedule change.

Late in the first semester it once again became difficult to keep their interest, perhaps somewhat because of the curriculum, but also because of the class' being held on Monday evenings and Saturday mornings, causing inevitable conflicts with other (and more interesting!) extra-curricular activities. Toward the end of the semester, after they helped Don get the School Board's permission to teach a system dynamics course the next school year, four of the five students decided that they didn't want to continue in the spring semester. As a final exam for the first semester, Don had them use system dynamics in a class project for one of their other courses. The remaining student, Rob Watson, is still in the course and continues to study system dynamics. More about what he is doing when we discuss the second semester curriculum.

The whole time the business consultant was asking a lot of questions, and learning a lot, from both Diana Fishers' and the *Principles of Systems* curricula.

2.1.3 1st semester curriculum and process - weekly reading and discussion for both classes together

Because the students (sophomore, teacher, & community students) had very little time to devote to system dynamics outside of class, we decided that they would do all their exercises during class, and that the only homework would be approximately 1-2 hours of reading per week. Also, to break up the Saturday mornings, the adult class met from 9-12 and the sophomores (and business consultant) from 10-1. This enabled the two classes to spend one hour together discussing the homework reading for the previous week. This proved extremely beneficial to the adults; however, we often had to work really hard, changing our approach to these discussions several times, to engage the sophomores in these discussions. We tried unstructured discussions around questions that people had about the readings, focused discussions around pre-defined questions, and even having a student, rather than an instructor, develop these questions. All approaches had their pros and cons. All in all, however, this was successful, especially for the adults, including the teachers. The homework readings we used were topical, as follows:

a) Why systems thinking?

Richmond, Barry. (1997) "Systems Thinking and *ithink*: Tools for meeting the needs of an ever more complex, ever more rapidly changing business environment" from Richmond, Barry et al. *An Introduction to Systems Thinking*. High Performance Systems, Inc. 1997. 12 pages.

Chapter 2 from the book, *Introduction to systems thinking* that comes with Stella. High Performance Systems, Inc. (1997), Hanover, N.H.

Also read box entitled "Systems Theory" from Donella Meadows' "Places to Intervene in a System", *The Whole Earth Catalog*. Winter, 1997.

b) What is system dynamics?

Kim, Daniel H. (1999) *Introduction to Systems Thinking*. Pegasus Communications, Inc. Waltham, MA. 19 pages

Chapter 1, entitled "The System Dynamics Approach", from
Richardson & Pugh (1981).

c) What does system dynamics have to do with learning?

Chapter 1 entitled "Learning in and about Complex Systems" from Sterman (2000) (50 pages - 2 week assignment)

d) How do I use system dynamics?

Goodman, Michael, Richard Karash, Colleen Lannon, Kellie Wardman O'Reilly, & Don Seville. (1997) *Designing a Systems Thinking Intervention* Pegasus Communications, Inc. Waltham, MA. 16 pages

Chapter 3 entitled, "The Modeling Process" from Sterman (2000). (23 pages)

e) How do I get started?

Randers, Jorgen, (1980) "Guidelines for Model Conceptualization" in Randers, Jorgen (ed.) *Elements of the System Dynamics Method*. 1980. Pegasus Communications, Waltham, MA. 21 pages

Chapter 2, entitled, "Problem Identification and System Conceptualization", from Richardson & Pugh (1981). Pages 18 to top of page 38 = 19 pages

f) Why are model purpose and boundaries so important?

Forrester, Jay W. (1967) "Market Growth as Influenced by Capital Investment" in Forrester (1975) Pages 111 to top of 114 = 3 pages.

Forrester, Jay W. (1968) "Industrial Dynamics - After the First Decade" in Forrester, (1975) Pages 141 to top of 147 = 6 pages.

Chapter 2, entitled, *Problem Identification and System Conceptualization*, from Richardson and Pugh (1981) Pages 38 thru 1st half of page 45 = 7 pages & 2nd half of page 61 thru top of page 66 = 5 pages, for a total of 13 pages.

g) Looking for leverage in a system:

Meadows, Donella. (1997) "Places to Intervene in a System (in increasing order of effectiveness). *Whole Earth Catalog*. Winter, 1997.

h) System dynamics' value to people and society.

Forrester, Jay W. (1994) "Learning through System Dynamics as Preparation for the 21st Century". In *Road Maps*, Chapter 8, downloadable from http://sysdyn.mit.edu/

i) System dynamics' value to education.

Forrester, Jay W. (1992) "System Dynamics and Learner-Centered-Learning in Kindergarten through Twelfth Grade Education" in *Road Maps*, Chapter 1, downloadable from http://sysdyn.mit.edu/

Paul had also selected readings on the following topics, but we didn't get to them in the first semester, and then Paul decided to focus the second semester entirely on modeling, so the class never read them:

j) System dynamics' value to business
k) System dynamics' value to government
l) System dynamics' value to sustainability
m) History of system dynamics
n) Modeling soft variables
o) What is dialogue
p) System dynamics and dialogue working together

2.2 Second semester curriculum and process

All four teachers, all four community members, and one of the five sophomores, wished to continue their study of system dynamics.

2.2.1 Second semester teachers' curriculum and process

As planned the teachers moved on to Course 2 of the Waters' Center's 5-course curriculum. Course 2 is described at the Waters Center website (url above). The course focuses on developing system dynamics modeling skills. It is self-taught and contains approximately 18 units, each of which is a self-contained Stella model. The student downloads and completes the units in a sequential fashion. An assignment is due to the Waters' Center after every four or five units, which assignment is reviewed by Waters' Center staff to ensure that the student is absorbing the material. Upon successful completion of an assignment, the student is given a password that enables them to download the next four to five units.

The four teachers are working together, meeting after school, and on Monday nights and Saturday mornings, to do the units. They also occasionally share their work with the other class. As we write this, they have completed 8 units and two assignments, and are moving on to the third set of assignments.

2.2.2 Second semester curriculum and process for the community class

As mentioned earlier, the community members were interested in applying system dynamics to community sustainability issues. The concept of sustainability is often discussed in terms of three parts, environmental sustainability, social equity, and economic sustainability. There were two texts that seemed appropriate, Ford's (1999)

Modeling the Environment, and Alfeld & Graham's (1976) *Introduction to Urban Dynamics*. Ford addresses environmental sustainability issues, and Alfeld & Graham address social equity and economic sustainability issues.

Comparing the two books, Ford has the student study many different environmental issues in the process of learning system dynamics modeling, whereas Alfeld and Graham develop one model of a generic urban area, with the model starting simply in Chapter 1, and gradually increasing in complexity as one moves through the book. Also, Alfeld and Graham do a marvelous job of illustrating the modeling process. Each chapter moves from a detailed verbal description of the problem that the particular chapter will address, to a causal loop diagram, to model formulation, to a study of model behavior, and to policy recommendations resulting from study of the model. Both books discuss modeling methodology, Alfeld and Graham in separate sections in each chapter, and Ford mostly in individual chapters. Ford is more modern, of course, in that he uses iconic software, whereas Alfeld and Graham use Dynamo equations (iconic software wasn't available in 1976).

The issues at the top of our particular students' agendas seemed to be more in line with those discussed in Alfeld & Graham. Also, our students had limited available time for the course each week, and we had planned to finish the course by the end of the school year, suggesting that we should use but one text. For these reasons, we chose to use Alfeld & Graham. However, both texts could be used together to cover application of system dynamics to community economic, social, and environmental sustainability in a one-year long community system dynamics course in which the students commit to say, 10-15 hours of course-work each week, or in a course in which the students agree to take whatever time is required to work through both texts.

Our process was one of reading outside of class, followed by doing selected exercises in class that Alfeld & Graham provide at the end of each section. I assigned many modeling extensions to the exercises, in order to require more modeling than the book's exercises entailed. Students compared their exercise solutions to my solutions. Often, we would have group discussions about the reading or exercises; these discussions often evolved into discussions of applications of system dynamics to local Door County issues. To do the reading, the students had to learn to read Dynamo equations, which was not difficult with the excellent introduction that Alfeld & Graham provide. The students used Stella or Vensim, rather than Dynamo, for the exercises. Introduction to the Dynamo language, in conjunction with iterative mathematical integration exercises provided an excellent context for understanding how the iterative computations of system dynamics work.

As we delved more deeply into the book, two of the four students wanted to take a more qualitative approach. One of the students was having difficulty with the algebra involved in modeling, and the other was wondering how one would do what we were doing with community groups who would be unfamiliar with system dynamics.

Now for an aside… Roy, Larry, and Paul envision two types of systems practitioners supporting the study of community issues with community activist groups, systems

facilitators, and system dynamics modelers. Our thoughts are that the systems facilitators would be adults who are well versed in group process and qualitative systems thinking, with the ability to capture the systems stories underlying community problems using diagrams (stock/flow & causal loop) and behavior-over-time graphs. The systems facilitators would appreciate system dynamics and would know when to invite system dynamics modelers into the group's process. The system dynamics modelers would probably be mostly high school students and retirees who had had the time to study system dynamics in community system dynamics courses. Of course, there may also be working adults whose interest had led them to take the time to learn system dynamics. These system dynamics modelers would be brought in by the system facilitators to apply system dynamics to problems for which the systems facilitators feel it would be beneficial.

Now, back to the class… It seemed that the two students who wanted to take a more qualitative approach might be good candidates to become systems facilitators as described in the previous paragraph. So, Paul decided to have them continue reading with the rest of the class to promote continued development of an appreciation for the power of system dynamics, but to develop different exercises for them intended to develop skills required of a systems facilitator. Those exercises focused on documenting systems stories through writing, drawing stock-flow and causal loop diagrams, and graphing behaviors-over-time. Many of their assignments were based on the readings from Alfeld, and some were based on local issues. Yet to be completed are exercises and readings (Richardson, 1986 and 1997) intended to convey the limitations of causal loop diagrams, so that they will be able to use them most effectively and correctly.

3.0 Inexpensive distance education techniques used

From early February in the second semester Paul was doing research at Cornell University in New York for his Master's thesis for the University of Bergen. Therefore, he could no longer physically meet with the class in Wisconsin. So, we decided to use the Internet.

We used the free facilities provided at two websites: www.blackboard.com and www.webex.com, hereafter referred to as blackboard and webex, respectively.

Blackboard provided asynchronous posting and downloading of reading assignments, exercise assignments, solutions to exercises, reviews of reading assignments, instructor's presentations, notices to students, etc.

Webex, along with a voice telephone call, enabled synchronous communication between the class and the instructor during class time. Webex provides many functions, but the ones we mostly used were the "presentation sharing" and "whiteboard" functions. Using the "presentation sharing" function, the instructor could share a Word document or PowerPoint presentation running on his computer in New York with up to four computers in the class in Wisconsin, or vice versa. Using the "whiteboard" function, the instructor could make sketches on his computer display in New York (just as though he were writing on a blackboard or whiteboard, and his sketches would show up on up to four

computers in the classroom in Wisconsin, or vice versa. Webex also provides "application sharing", for a fee, which would have enabled the instructor and class to share running Stella or Vensim simulations. This would have been very useful, but we could not afford Webex' $2,000 to $3,000 setup fees for this service.

Webex also provides features, for a fee, that could have allowed communication with all the computers in the class. But we chose instead to have communication only to one computer in the class. We hooked that computer up to a VGA projector so that everyone in the class could see the instructor's PowerPoint or whiteboard presentation. All of this was done in parallel with a voice telephone call to a speakerphone in the classroom.
Note that we could not see each other, but this was not a problem since we already knew each other very well from having spent the fall semester together.

Webex and the speakerphone were mostly used to kick-off each class session with a discussion on the homework reading assignment, a review of student's solutions to exercises, and a discussion of any questions on upcoming exercises. It was also occasionally used to answer individual student's questions while they were working on exercises later in the class period. Students submitted their solutions to exercises either electronically or via fax.

The instructor also made himself available for discussions with students outside of class time, either via voice or email.

This approach, which can be characterized as synchronous [same-time, same-place (for students) and different place (for students vs. instructor)], has the following primary advantages over asynchronous (different-time, different-place) distance learning approaches:

a) Because all the students are physically meeting with one another during class time (and outside of class time, if they desire), they can encourage one another, and help each other with questions. Also, group work is less difficult.

b) The students, as a group, using the webex functions that work both ways, have regular verbal and written discussions with the instructor. This enables all students to participate and learn from each other's discussions with the instructor.

Most of the time when people think of this type of synchronous communication for education purposes, they believe it essential that the technology allow the students and the instructor to see one another. Admittedly this is best. However, in circumstances where the students and the instructor are familiar with one another, as we were, having spent an entire semester together, we found that seeing one another on the display was not necessary.

Finally, there are several software packages (CuCme®, Microsoft NetMeeting®, etc.) available that will allow teleconferencing, with presentation, whiteboard, and application-sharing features, which is essentially what our class did. However, Paul's understands

that most of these software packages require each computer to have its own IP (internet protocol) address. In our case, and this may be the case in many schools with a Novell network like ours, individual computers in the computer lab where we were holding the class could not have individual IP addresses. However, since Webex is operated totally off a web site, it does not require that the computers that access it have individual IP addresses, thus making what we were doing possible using Webex, whereas it would not have been possible using standard teleconferencing software.

4.0 Initiatives undertaken by the students on their own volition

4.1 Teaching a system dynamics course next school year

Don Ziegelbauer was so enthralled by his introduction to systems that he not only wanted to use it as a tool in his social studies classes, but he also wanted to teach a course in system dynamics as a high school elective. In early December he and several of the high school students taking the first semester's course presented system dynamics to the Sturgeon Bay School Board, and requested and received approval for Don to teach a 9 week course beginning in the 2000-2001 school year. Don anticipates that one or more of the sophomores (or perhaps even the adult) students in our class this year will be interested in assisting him in teaching the new system dynamics course.

4.2 Continuing their own systems education

Nine of the thirteen students who studied systems the first semester elected to continue with their studies in the second semester. Also, some of the students have been exploring other literature. An example is one of the community members who purchased and is occasionally referring to Andrew Ford's book, "Modeling the Environment." Finally, Don believes that some of the sophomores, who did not continue the second semester, will enroll in his course.

4.3 Using systems thinking in their current teaching, or thinking about using it in their future teaching

4.3.1 Steve Schmelzer

Steve Schmelzer, the high school economics teacher in the class, has used systems tools in several contexts in his class, including:

- Demand-side fiscal policy: Steve used causal loop and stock-flow diagrams as communication tools. As an aside, he indicates that his students more readily understood stock-flow than causal loop diagrams.

- Financial planning: Steve showed his students how to build a simple, first order financial planning model where inflow was income, outflow was

spending, with budget items feeding expenditures. The students built the model in a lab and used it to test budgets they had developed prior to the lab.

- Understanding savings and credit: On the board, Steve showed his students a savings account stock-flow diagram, then modified the variable names on the diagram to create a credit stock-flow diagram, illustrating transferability of structure. He then had the students run experiments in the lab using the retirement/credit/inflation model from Waters Center's Demo Dozen.

- Steve had the students study exponential growth in the lab using the Lily Pad model from Waters Center's Demo Dozen.

- Steve is planning on attending the Systems Thinking and Modeling in K12 Education this summer in Oregon.

4.3.2 Don Ziegelbauer

Don Ziegelbauer teaches high school social studies, and has used systems tools in several contexts, both in and out of the classroom, including:

- Population studies: Don developed a Mexico to U.S. immigration model that he used both in class and with the School Board to sell the idea of teaching a systems class. Both with his classes, and with the School Board, he posited some system assumptions, then asked the students/School Board to predict population behaviors, followed by testing the behavior-over-time resulting from those assumptions.

- Population studies curriculum development: Don has developed a population model for local fish populations. He is improving his model in collaboration with local state DNR (Department of Natural Resources) personnel, and hopes to use the model as a discussion mechanism between DNR personnel and his students.

- Prison overcrowding: One of Don's students worked with Steve Schmelzer to develop some systems diagrams to illustrate her prison-crowding project for Don's class.

- Biology presentation: Don is working with three of the four sophomores who took our first semester course to help them develop a simple biology model to present to a biology class.

- Curriculum for his systems course: Don is choosing/developing a curriculum for his 9 week systems elective that he will be teaching this next academic year.

- Don is continually introducing other teachers and students to system dynamics applications in education. He is recruiting teachers throughout Door County to take Waters Center's Course 1 this summer, and he is also recruiting students for his upcoming system dynamics class.

4.3.3 Jim Adams

Jim Adams, a history and social studies teacher at Sevastopol High School (another Door County town, near Sturgeon Bay), responded to my request for initiatives he had undertaken with the following (taken from his email to me):

> " Not a lot so far but here goes:
>
> "Most of what I am doing is subtle rather than full-blown S/D [system dynamics] instruction. I have found myself introducing BOTGs [Behavior-over-time graphs] and some stock-flow diagrams in my instruction as we go through various units.
>
> "Last week one of my freshmen students did a report on Easter Island in our anthropology unit. After her report I began asking the students questions to get their responses re: what happened. After a brief discussion we went to the computer lab and I took them through the Easter Island model. Unfortunately, we didn't get very far with time constraints but I will be taking them back to the lab on Monday to continue our discussion.
>
> "In the American History class (juniors) I have used BOTGs for civil rights and immigration. I had the students draw BOTGs expressing what they thought has happened re: civil rights. They came up with BOTGs showing: an increase in black voting, changing levels of KKK activity, more black participation in athletics, etc. I was pleasantly surprised to see their reaction to using BOTGs. They took to it right away & it stimulated a lot of good discussion. They would ask why things happened and some of the students that participate the least in class came up with some rather perceptive explanations of behaviors.
>
> "I used BOTGs similarly in my unit on immigration.
>
> "I am not as comfortable with the use of CLDs yet. I have used some of the ones that we have used in class but I am not ready to create one 'on the fly' in the class.
>
> "I also have used the population model from the Demo Dozen in class.
>
> "Outside of the classroom I have been trying to 'infect' other teachers & my principal. I gave the 'Flying a Cell' CD [a learning environment demonstration from High Performance Systems, Inc.] to the science teacher & have tried recruiting him for the summer class. Dale Carlson (Ag teacher: animal science, forestry, etc.) plans on taking it, Ade Webber (Econ, World Hist, Geography) is a possible as is Roy Raynier (Earth Science). Mike Zittlow (Math) has not

committed & I plan on sharing some math models from the CLE with him. Hopefully he will get infected.

"We are just starting the Wars Unit that I submitted for Course 1 that you, Jeff, & John reviewed. I shared that with my principal, Randy Watermolen in my professional growth plan review. All teachers are required to prepare a PGP at the beginning of the year and I chose to incorporate my S/D class work in my wars unit. The teachers are also required to have a unit constructed by the end of the year that ties in their standards & benchmarks. So I killed several birds with one model!

"Next year I have a new assignment (Current Issues) so I plan on incorporating much of what I have learned in these courses. This will let me 'test drive' a possible course for the following school year. After using S/D in Current Issues first semester I plan on proposing a S/D course for the following school year (2001-2002). Hopefully Don Ziegelbauer and I can get together this summer to work on it. He is getting paid to do curriculum work and Randy wants me to put in time this summer for the Current Issues course so we should be able to dovetail our work."

4.3.4 Larry Smith

Larry Smith (co-author of this paper) is also selecting system dynamics curriculum to use in his undergraduate economics, global studies, and sustainability courses at the University of Wisconsin - Green Bay. He is currently looking at some sustainability curriculum produced by John Heinbokel and Jeff Potash at The Waters' Center. He will also look at Professor Khalid Saeed's sustainability and development economics work and software, as well as Decision Dynamics' RCM model, as potential resources. While choices about materials to use in these courses are not yet firm, available resources like those mentioned above could clearly enhance several of Larry’s courses in both the lower-level general education program and at the upper-level in both economics and in the interdisciplinary undergraduate degree program in social change which he chairs.

4.4 Introducing system dynamics at a seminar for other teachers

Every spring the teachers in all of the school districts in Door County gather for a day they call T3 ("Teach the Teachers"). Don Ziegelbauer and Jim Adams took it on themselves to offer a 1-hour introduction to system dynamics in education as part of this day. Fifteen teachers attended their session, and, as a result, several teachers have expressed interest in learning more about system dynamics.

4.5 Recruiting other teachers to take Waters' Center's Course 1 this summer

As you may have surmised from Section 4.3 above, Don Ziegelbauer and Roy Aiken are promoting the idea of having John Heinbokel and Jeff Potash of The Waters Center teach Course 1 this summer (2000) in Door County. Don believes that he can recruit 15

teachers (probably half of whom heard about system dynamics at the T3 discussed above) who would be very interested in taking this weeklong full-time course. This is seen as critical to continuing Door County's momentum into next year, because, the teachers who complete Course 1 in the summer will be able to take Course 2 over the internet in the fall, enabling Door County to have a group of ten to twenty teachers who are simultaneously learning to use system dynamics for learning.

4.6 Beginning to use systems thinking on community initiatives

Larry Smith (co-author of this paper) lives in the township of Nasewaupee which is adjacent to Sturgeon Bay in the heavily recreational and problematically attractive Door County, Wisconsin on the western shore of Lake Michigan. The Nasewaupee Land-Use Planning Committee, which Larry chairs, now works with a consulting firm to find creative approaches to land-use planning and management for the town. But the town can't manage its fate alone, and Larry hopes that tools like systems dynamics will help the committee and town develop meaningful partnerships with other entities in Door County and, perhaps the larger region, to find or create useful approaches to evolving problems of sprawl. Larry hopes to use system dynamics alongside the consulting teams' efforts for the purpose of better understanding and evaluating their policy recommendations and to provide visual models of likely outcomes of implementation of land use tools in the Town. He also hopes that use of system dynamics in conjunction with land use visualization tools as in the package offered by the Prescott College/NASA (Arizona) program described at http://www.prescott.edu/nasa/pnf_contents.htm will help further this effort.

4.7 Doing sessions on system dynamics at an annual Wisconsin-wide education conference

The GWETC (Governor's Wisconsin Educational Technology Conference) is held every year in a different location in Wisconsin. It will be held in October 2000 in Madison. Three members of the class have applied to present at this conference; we hope their applications will be approved. Here are their descriptions of the presentations they have submitted for approval to the conference organizers:

4.7.1 System Thinking and Computer Modeling as tools in 7-12 Classrooms, by Don Ziegelbauer

"This presentation will be an introduction to system dynamics. The central concept of system dynamics is understanding how all the parts in a system are interconnected and interacting. It gives us additional tools to better understand the phenomenon of change so that we can approach social and scientific problems from a new perspective.

"Participants in this session will become aware of systems thinking and the potential uses of computer modeling in their classrooms. They will learn some of the building blocks of system dynamics in the form of stock-and-flow diagrams and behavior-over-time graphs.

Examples of computer models designed and constructed by high school students using STELLA software will be showcased. Finally networking and personal contacts for those wanting to know more about system dynamics and its potential to enhance student learning will be available."

4.7.2 Computer Simulations: From Student Education to Learning Communities, by Roy Aiken

"In order for a community to understand and work with concept of a “Sustainable Community” skills in holistic systems thinking are required. The poster session will describe an effort that has been underway in Door County to establish systems thinking in the community. The effort to date has resulted in a full school year of course work for high school students, teachers, and community volunteers to achieve the skill of systems thinking and the capability to use computer simulation tools. The poster session will portray this effort using system dynamic causal loop diagrams. Examples of the models that were built by students will be shown using a portable computer. The audience of the poster session will come away with a general understanding of systems thinking and system dynamic technology tools as well as a model for incorporation of these techniques, methods, and tools into a community’s education system."

4.7.3 Sustainable Development and Global Studies Utilizing System Dynamics, by Larry Smith

"Global history provides outstanding examples of the behavior of systems that result in local or global stresses on economic, social, and ecological resources. Many of these examples, from the collapse of civilizations in isolated places like Easter Island and less isolated collapses like those in Mesoamerica to contemporary global concerns like climate change, atmospheric ozone depletion, or population pressure are easily illustrated with systems thinking skills and system dynamic models. Demonstrations will include using causal loop diagrams to tease out issues in the audience's awareness about high-visibility concerns like climate change or population pressure and presentations of models used to teach about sustainable development and global ecological history in lower-level university courses. The tools demonstrated can easily be adapted to audiences at other educational levels and especially to adults engaged in policy decision making."

4.8 Developing collaborations with other local organizations

Larry Smith and Roy Aiken are working down several avenues to collaborate with other organizations, including:

- The Education Department of the University of Wisconsin - Green Bay
- CESA 7 (Cooperative Educational Service Agency 7 - one of Wisconsin’s twelve regional districts created to oversee development and delivery of educational programs as well as provide cooperative support services for constituent K-12 public school districts)

- Other Northeast Wisconsin schools and school districts

- The Rotary Club

Most of the effort revolves around collaboration on research, grant-writing, and joint participation. Examples include:

- Collaboration with CESA7 in responding to a grant solicitation from the U.S. Department of Education, in which we proposed to provide system dynamics education for students, teachers and community members using CESA 7's distance learning classrooms and technology.

- Seeking teachers from other districts to participate in educational opportunities such as taking Waters Center courses.

- Identifying education professors who might be interested in researching various aspects of the use of system dynamics in K-12 education. We're also promoting the teaching of system dynamics for learning in undergraduate and graduate teacher education.

Last October, Roy presented the use of system dynamics for community sustainability to the local Rotary Club. They "asked a lot of questions and showed considerable interest" (email from Roy). Roy will be meeting with them again shortly with an update.

4.9 Raising funds to support the activity

Roy Aiken is devoting much time and effort to finding funds to support all of this activity. This is a very difficult task that, over time, we hope will become easier as the communities, businesses, and schools involved begin to see the benefit of system dynamics for education, community sustainability, and improving business performance. One avenue that we believe holds promise, at least in larger communities, is financial support from larger businesses and government, specifically aimed at providing system dynamics education for people from the supporting organization, alongside of support for K-12 students and teachers, and other community members.

5.0 Some reflections on our experience

Our reflections are structured as a discussion of the degree to which our experience supports the following three assertions.

5.1 Community sustainability is a viable mechanism for introducing systems thinking and dynamic modeling to communities and their K-12 schools

Without the 'moving and shaking' of Susan Gullion, Roy Aiken, and Larry Smith, all community sustainability activists, and in particular Roy Aiken, this class would not have come to be. The authors also have experience with other communities' sustainability

efforts. Our experience supports the notion that many people who are involved with sustainability movements are relatively more intuitive systems thinkers than are people at large. Not only are sustainability activists more likely to be intuitive systems thinkers, but because system dynamics is most often used to identify policies which have the best long term, rather than short term, consequences, it can easily be argued that system dynamics is fundamentally about sustainability. Therefore, it may be that people who are concerned about community sustainability will be more attracted to system dynamics than will people at large.

The very act of centering community system dynamics education efforts in a community's K-12 schools is itself an act driven by sustainability goals. Although community activists who become interested in using system dynamics to address community problems could simply focus its use on those problems, they are not thereby directly building the community's capacity to address other, and future, issues using system dynamics. Our thought is that focusing the education efforts in the K12 schools, and hopefully identifying K12 students who are interested in applying their system dynamics learning to current community problems, will develop in those students the desire and ability to use system dynamics throughout their lives, which is certainly a sustainability concept.

Given that many, if not most, communities today are, or will soon, have sustainability movements within them, we believe that many of the intuitive systems thinkers in these movements will readily be attracted to system dynamics, and will see the value of centering system dynamics education in their community's K-12 school systems. Therefore, both our specific experience, and our interaction with sustainability activists in other communities, supports the assertion that community sustainability is a viable mechanism for introducing systems thinking and dynamic modeling to communities and their K-12 schools.

5.2 Both a 'citizen-advocate' and a 'teacher-advocate' are very beneficial, if not necessary, to successfully launch a community system dynamics initiative

Gordon Brown (1992) introduced the term "citizen advocate", meaning someone in the community, outside of the K-12 education system, who can be very effective in facilitating development of system dynamics capacity in local schools. Roy Aiken was our primary citizen advocate. Roy set up the initial meetings, committed both to provide and raise funds, identified people in the community who would be interested in taking the course, and promoted the class across the county.

But we also had a teacher advocate in the person of Don Ziegelbauer; and a couple of the other teachers in our course seem to have caught the bug and are working with Don as teacher-advocates. The definition of a teacher-advocate is the same as for citizen-advocate, except that the teacher-advocate is within the community's K-12 education system. Don took time out of the gorgeous but short Door County summer to take Waters Center Course 1, promoted the class with high school students and their parents who he thought would be interested, presented systems to the school board, did an in-

service on systems for teachers throughout Door County, and is now signing teachers up to take Waters' Center's Course 1 this summer. Of course the other teachers in the course are now helping him.

Having both a citizen and teacher advocate created a class full of different perspectives - high school sophomores, teachers from two different districts and in different disciplines, and very thoughtful community members with different backgrounds. We think these differences, along with the differences in the curricula that were used for the two fall and two spring courses, and the different mixing of the fall and spring classes, created positive feedback loops that worked to maintain everyone's interest, as everyone saw others with different perspectives staying engaged in the process. In the absence of both a teacher and a community advocate to attract this diversity, we doubt we would have had such diversity, and therefore we doubt the students would have been able to sustain such levels of interest in the topic.

It seems very doubtful that we would have been as successful in the absence of either role. So our experience seems to support the assertion that both a 'citizen-advocate' and a 'teacher-advocate' are very beneficial, if not necessary, to successfully launch a community system dynamics initiative

5.3 We devised a curriculum that works for a mix of community members interested in sustainability, & K12 teachers interested in using systems for learning

In section 2.2.2 we made the statement, "both texts [Ford, and Alfeld & Graham] could be used together to cover application of system dynamics to community economic, social, and environmental sustainability in a one-year long community system dynamics course in which the students commit to, say, 10-15 hours of course-work each week, or in a course in which the students agree to take whatever time is required to work through both texts."

However, we think that it will be more the exception than the rule that working people will be able to commit to either 10-15 hours per week, or an indeterminate timeframe.

To address this problem, perhaps we need to set a long-term goal of developing a continuum of system dynamics skills in a community. At the most skilled end of the continuum are system dynamics computer simulation modelers who can also facilitate group model building process, both qualitatively and quantitatively. At the least skilled end of the continuum are people who have done no simulation, cannot facilitate group process, but who understand and appreciate the value of rigorous system dynamics for the design of social systems, and also enjoy and value the use of qualitative systems tools, e.g. CLDs, SFDs, BOTGs, and system stories, to study complex dynamic personal, work, and community problems.

One long-term objective of system dynamics in K12 education is that all students graduate at this least skilled end of the continuum. Another long-term objective of system dynamics in K12 education is that students who so desire are offered system dynamics learning opportunities that will enable them to learn to become very good

system dynamics computer simulation modelers. We do not anticipate these students becoming adequate group process facilitators. However, they could work in concert with a facilitator from the community who has less system dynamics skill than the student, but more group facilitation skill, to help community and business teams use system dynamics to address community and business problems. Thus some students might leave high school approaching the advanced end of the continuum.

Now, what about system dynamics education for businesses and community members? Our contention is that people who are working in a team that is using system dynamics to address a business or community problem should be enabled, "on the job", as they use the tools where they need them, to learn to be proficient at the afore-mentioned least skilled end of the continuum. This means that the adult team facilitators should be sufficiently skilled, not only in qualitative systems thinking and group process facilitation, but also in providing this "on the job" education for their team members. Finally, there will be some adult community and business members who become sufficiently interested in system dynamics that they wish to work toward learning system dynamics computer simulation modeling. These people may, or may not, wish to acquire group process facilitation skills. In any case, education in system dynamics computer simulation modeling should be available for them too, probably alongside the high school students who desire the same education.

Let's call the above a theory of community system dynamics education. Assuming a community adopts this theory, what sorts of system dynamics education should be available? We posit the following:

a. Education for all K-12 teachers sufficient to help them use systems thinking and dynamic modeling as another learning tool in their teaching toolkits.

b. Sufficient education for some K-12 teachers and community/business members to enable them to guide those students and community/business members who want to become system dynamics computer simulation modelers.

c. Education for group facilitators on group process facilitation, and on the use of systems thinking tools (BOTGs, CLDs, SFDs, & system stories), as part of that facilitation process. Include education on how to help team members learn the "low end of the continuum" skills "on the job."

d. Education on group process facilitation where both a facilitator and a system dynamics computer simulation modeler are involved. See Richardson, (1995), Vennix (1996), Morecroft and Sterman (1994) and the special issue of the System Dynamics Review devoted to group model building (Volume 13, Number 2, 1997).

In reflecting on our earlier statement that "both texts [Ford (1999), and Alfeld & Graham (1976)] could be used together to cover application of system dynamics to community economic, social, and environmental sustainability in a one-year long community system

dynamics course in which the students commit to say, 10-15 hours of course-work each week, or in a course in which the students agree to take whatever time is required to work through both texts," we now believe that this statement is true only for the education in (b) above. However, Ford may be useful for (a) and parts of (c). Also, in addition to Alfeld & Graham and Ford, Sterman (2000) would be useful for (b).

Waters' Center's Course 1, which was taken by both the teachers and three of the four community members, although still somewhat experimental, seems to provide a good beginning for (a) above; and is useful in (b) above, as a preamble to Alfeld & Graham (1976), but may not be needed if Ford (1999) is used in conjunction with Alfeld & Graham. However, in both Paul and Don's opinion, augmenting Water's Center's Course 1 with some readings in the classic system dynamics literature was a valuable addition to Course 1. (Recall that Paul and Don took the basic Course 1 at the Waters Center in the summer before teaching it in the fall).

At present (April/May 2000) the teachers have finished approximately half of Waters' Center's Course 2, which, although even more experimental, seems to be continuing the process of preparing the teachers to add systems thinking and dynamic modeling to their teaching toolkits.

Last week the community members were very impressed with the teachers modeling work completed for their second assignment. The teachers' demonstration graphically illustrated a shortcoming to our approach in the spring course for the community members. We have worked from Alfeld & Graham's exercises, and modifications thereto; we have not had any free-form modeling assignments in which the students model something from their own experience. This is partly an oversight, but also reflects our snail's pace through the book due to the limited amount of time the community members have had to spend on the course work. We were going so slowly, that the instructor hesitated to assign free-form modeling exercises until we had made more progress. Of course, our snail's pace may reflect not only time available, but also may reflect some lack of interest in the work, at least relative to other things the students had to do. Also, relative to free-form assignments, in contrast to the community members, the teachers were required to do some free form diagramming at the end of Course 1 in order to get graduate credit for the course. So, one shortcoming that we have allowed to occur to date in the community course curriculum is a lack of free-form exercises. At present, the community course students are planning to qualitatively use systems tools, and perhaps to build simulations, of some community issues discussed in community stewardship meetings that they attend once a week.

The fact that four of the five sophomores elected not to continue with the spring class may point to curriculum problems, or instructional process problems. Also, at present, Rob Watson, the remaining sophomore, although he wants to continue his system dynamics studies into the fall, has asked to start using materials other than Alfeld & Graham (1976). Obviously it has been difficult to retain the interest of the sophomores. Perhaps, in cases where an instructor who is not a K12 teacher teaches the first community course, it is best not to have high school students in the first course. On the

other hand, it is valuable to have students' perspective and background in the course, both for the K-12 teachers and the community members. This question remains unanswered.

In the end, we think our curriculum represents a step toward devising "a curriculum that works for a mix of community members interested in sustainability, & K12 teachers interested in using systems for learning." It seems to address education type (a) and (b) above. However, our curriculum does not address education types (c) and (d). Therefore our curriculum only partially supports the assertion.

Summary

We have:

1) Described the origins of the course (Section 1),

2) Described the curriculum and process used in the course (Section 2), including some notes on the distance education techniques we used (Section 3),

3) Described some preliminary results from the course, in the form of initiatives undertaken by students in the course (Section 4), and

4) Reflected on our experience by discussing the degree to which we believe our experience supports the following three assertions (Section 5):

    a. Community sustainability is a viable mechanism for introducing systems thinking and dynamic modeling to communities and their K-12 school (Section 5.1)

    b. Both a 'citizen-advocate' and a 'teacher-advocate' are very beneficial, if not necessary, to successfully launch a community system dynamics initiative (Section 5.2), and

    c. We devised a curriculum that works for a mix of community members interested in sustainability, & K12 teachers interested in using systems for learning (Section 5.3)

Perhaps because we know so little of others' experiences, we believe that our story may benefit others attempting something similar.

It remains to be seen whether our effort will be successful in the long run, but for now, we're still kicking.

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