Building Capacity for Effective Educational Change in Door County, Wisconsin

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For presentation at
Creative Learning Exchange
Systems Thinking and Dynamic Modeling Conference
Durham, NH June 28 - July 1, 2002
Conference CD Draft of 6/10/02

ABSTRACT

If the educational change implicitly demanded by the majority of communities imposing "accountability" measures in K-12 programs is to be effective it must be meaningfully grounded in community and ultimately global contexts. Effectiveness also requires that educational processes provide meaningful experiences from which schools can share and students can acquire higher-level thinking skills, not just rote facts. System dynamics, always a useful tool for grounding thinking in community and global context, has become accessible enough to serve this need. This paper reviews how the context of community response to existing problems spawned a project to bring system dynamics to the Door County Wisconsin educational system. After a brief overview of the early community context, the paper focuses primarily on the process and attempts at assessment of early efforts to integrate system dynamics into, so far, two Door County high schools. Instrumental in this process and its context are resource availability, including community and teacher enthusiasm, and constraints, which have, as things now stand, officially shelved the core of the process for the coming year, and the local variant of the nearly universal pressure for increased accountability within educational processes.

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1 INTRODUCTION

This paper continues and updates reports on system dynamics in the educational system of Door County, Wisconsin first as by-product, and increasingly as explicit part, of more general response to pressures responding to the community's extraordinary attractiveness. Attractive places, like attractive adolescents, suffer, and, often to their detriment, seek and celebrate attention and adulation neither can adequately prepare for. Extraordinary attention and resource abundance frequently distort personalities and growth patterns; this can happen both to people and to places. Especially when seasonal, abundance also distorts local politics including educational programming, finance and validation in ways similar to the painful distortions attractiveness sometimes visits on individuals, especially adolescents.

In context of such distortions a small group of concerned Door County citizens organized a project to vision a future for the community. The resulting 2-1/2 day, April 1977, "Future Search" identified eleven topics of agreement among the 78 participants from as many realms of the community as could be engaged (Weisbord and Jannoff 1995). One of those realms that seemed more feasible to influence than some others, affordable housing, was selected as the focus of a September 1998 Community Stewardship Academy. About 20 community members with specific ties, experience, or resources relevant to affordable housing gathered, with a comparable group focused on a different problem relevant to their, very different, community, for a day and a half at a distance from the distractions of home and family. The CSA program drew on the perspective of sustainability and expertise in sharing insights about dialogue and systems thinking to seed insightful response to the problem of focus in the two sponsoring communities.

As a by-product of the CSA one of its principal community organizers, Roy Aiken, and one of its systems resource people who shared local, but not explicitly Door County, residence and understanding, Paul Newton, began discussing the value of integrating system dynamics into community educational systems toward a long-term goal of encouraging students to apply SD to community, including local business, problems. As these discussions proceeded efforts were made to enlist business sponsors and mentors to join high-school students in studying SD and applying it to sponsoring businesses' issues of concern. More-or-less simultaneously, conversations with the Superintendent of Sturgeon Bay Schools and the Principal of Sturgeon Bay High School identified a teacher who was recruited to become interested in SD. Soon Don Ziegelbauer was "playing" with SD models of his fishing passion, bass populations, and was soon "hooked." Paul and Don attended, with some community financial support, the first Water's Center course in SD at Trinity College during the summer of 1999.

As the fall 1999 semester began Don was using some SD in one of his psychology courses and plans were moving ahead for Paul to teach an extracurricular course one weekday evening and Saturday morning. High-school students (who would get elective credit) high-school teachers (who would follow the Water's Center curriculum and receive graduate credit) and community members (whom it was hoped would include representatives of sponsoring businesses as mentors for real problems to be brought to the class) would share the class time and Paul's attention. (Newton 1998). While no explicit business sponsors were recruited, a community organization – the Door County

Land Use Forum – and several community leaders, the local office of the Wisconsin Department of Natural Resources, the school, and some business people, offered enough in kind and financial support to provide space and equipment and to cover Water's Center, travel, software and book costs and to otherwise barely keep the effort alive and provide minimal compensation to Paul as the, very hard working and, even today, not-yet-fully paid, instructor.

During the 1999-2000 academic year eight adult and five high school sophomores participated in the extracurricular SD course held one weekday evening and Saturday mornings each week. The eight adults consisted of four teachers representing two Door County high schools among them, and four community members. One of the sophomores continued the entire year, while the other four only completed the fall course.

During the fall semester, separate curriculum and courses were held for the high school students and the adults. During the spring, separate curriculum and courses were held for the high school teachers and the other adults; the remaining sophomore participated in the course with the community members. During both fall and spring semesters, all students read a paper as homework, and met during a shared reading circle between the two Saturday morning class sessions to discuss the reading. Teachers received graduate credit for both the fall and spring courses, and the high school sophomores received elective credit (Newton and Jessup 2002).

2.0 TEACHING THE TEACHERS

The evening and weekend course was tailored and, as tensions and conflicts evolved, re-tailored to meet the needs and expectations of the participants and the contingencies of resource and participant availability. For example, when initial readings and discussion became boring for the sophomores they moved to hands on model development with interactive help from Paul and Don while the more mature and less computer facile adults carried on their own, perhaps too long, with overview and discussion. Later in the course, when Paul found he had to leave the area to pursue his own work, Internet tools were found to allow him to continue as course leader and organizer, with assistance from the adults who were more comfortable with the material and SD as well as Internet software, from a distance. More detail on the curriculum and teaching process is available in Newton and Smith 2001.

The materials used, in approximate order of use were:

Introduction to Systems Thinking and Tools and ***Introduction to Dynamic Modeling***, Courses 1 (Fall) and 2 (Spring) respectively, from the Waters' Center for Systems Thinking and Dynamic Modeling in K-12 Education, described at http://www.trinityvt.edu/waters/Services/GradCert/GradCert.htm

Sterman, John (2000) Business Dynamics: Systems Thinking and Modeling for a Complex World, McGraw-Hill, Boston. Chapters 1, 3, and 4-8. For titles & description, see http://web.mit.edu/jsterman/www/BusDyn2.html

Fisher, Diana (1999) Lessons For a First Course in System Dynamics Modeling Using the STELLA Software, Summer Creek Press, Tigard, OR.

Forrester, Jay W. (1968) Principles of Systems, Pegasus Communications, Waltham, MA. Selected readings and exercises.

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

Richmond, Barry et al. An Introduction to Systems Thinking. High Performance Systems, Inc. 1997. (Stella software manual) Chapter 2.

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

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

Richardson, George and Alexander Pugh (1981) Introduction to System Dynamics Modeling, Pegasus Communications, Waltham, MA. "The System Dynamics Approach" and "Problem Identification and System Conceptualization," Chapters 1 and 2 respectively,

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

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

Forrester, Jay W. (1975) Collected Papers of Jay W. Forrester, Pegasus Communications, Waltham, MA "Market Growth as Influenced by Capital Investment" and "Industrial Dynamics - After the First Decade"

Forrester, Jay W. "Learning through System Dynamics as Preparation for the 21st Century" (1994) & "System Dynamics and Learner-Centered-Learning in Kindergarten through Twelfth Grade Education" (1992), Road Maps Chapters 8 & 1, downloadable from http://sysdyn.mit.edu/

Alfeld, Louis Edward and Alan K. Graham (1976) Introduction to Urban Dynamics, Pegasus Communications, Waltham, MA

Richardson, George (1986) Problems with causal loop diagrams, System Dynamics Review 2(2), 158-170.

Richardson, George (1997) Problems in causal loop diagrams revisited, System Dynamics Review 13(3), 247-252.

Shibley, John (1998) Some Notes on Door County. Unpublished. Available from Roy Aiken, Sturgeon Bay, WI.

A significant portion of the first semester curriculum consisted of readings from the above curriculum, for the purpose of studying the following questions and topics:

- Why systems thinking?
- What is system dynamics?
- What does system dynamics have to do with learning?
- How do I use system dynamics?
- How do I get started?
- Why are model purpose and boundaries so important?
- Looking for leverage in a system.
- System dynamics' value to people and society.
- System dynamics' value to education.

2. 1 Initiatives Undertaken By The Students On Their Own Volition

Following the course the teachers and the community member students pursued several initiatives that grew out of the course.

2.1.1 Teaching a system dynamics course the next two school years

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. At the close of the 2001-2002 school year Don has now taught three semester long introductory SD courses to approximately 30 students. He has also offered one second-level course. Students in his courses developed models in ecology, epidemics, local landfill issue, terrorism and drug trafficking among other topics. Unfortunately as of June 2002 budget cuts have eliminated the SD course from the curriculum for the coming school year, but plans are developing to continue the effort in an informal “club” context until budgetary constraints relax.

2.1.2 Using systems thinking in teaching existing courses and beyond

2.1.2.1 Steve Schmelzer

Steve Schmelzer, a 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, and one of the sophomores, attended the Systems Thinking and Modeling in K12 Education conference in Skamania, Washington in 2000.

2.1.2.2 Don Ziegelbauer

Don Ziegelbauer 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, and 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, with Steve Schmelzer's help, developed 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.

2.1.2.3 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):

"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."

2.1.2.4 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' "Rural Community Modeler" software (http://www.decisiondynamics.com) 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 and development in which he teaches.

Most recently Larry developed a course, Sustaining Educational Change: Systems Perspectives and Sustainable Development Applications in K-12 Education, to be offered for continuing education credit to regional teachers throughout the K-12 system. While current fiscal constraints and poor timing led to canceling of the course for offering during summer 2002 plans continue for offering of the course during the 2002-2003 academic year and beyond. We are also looking at making this course, the primary intent of which is to better market systems dynamics to K-12 decision makers, more accessible by constraining its calendar to a single semester and offering variable credit and non-credit options in addition to the standard three credit mode currently approved. (Seen Appendix C)

2.1.2.5 Tim Kaufman

Tim Kaufman (co-author of this paper) oversees the Master's of Science in Applied Leadership for Teaching and Learning at the University of Wisconsin-Green Bay, which is

partially grounded in the concept of systems theory. This program seeks to build the capacity for “teacher leaders” by helping them think critically about issues that impact their communities, students and lives.

2.1.3 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, with Steve Schmelzer's support, 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.

2.1.4 Recruiting other teachers to take Waters' Center's Course 1 summer 2000

Don and several of the other students invited The Waters' Center to teach their Course 1 during summer 2000 in Door County. John Heinbokel and Jeff Potash taught the course. It was hoped that some of the teachers who took the course would continue on to take Course 2 (the Waters’ Center’s internet course). While, this did not occur. This course resulted in a high school teacher beginning to use SD in his agribusiness courses and an elementary teacher in another school system expanded her use of ST in her classes. We do not know the degree to which the other teachers from this course are using SD in their teaching, but since we haven’t heard, we assume that it is being used little. Perhaps this points to the relative efficacy of the 1999-2000 approach with little or no follow-up work, as compared to simply taking a first course.

2.2 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, especially incentive as opposed to rule-based 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 in Smith, et.al. 2001 and at http://www.prescott.edu/nasa/pnf_contents.htm will help further this effort.

2.3 Presentations on systems dynamics at annual Wisconsin-wide education conferences

The Governor's Wisconsin Educational Technology Conference is held every year in a different location in Wisconsin. In October 2000 in Madison, members of the class made

three different presentations on their use of SD in grades 7-20. A fourth presentation on high school applications was made in 2001 when the conference was in Green Bay.

3.0 Summary and Further Information

We have briefly described three aspects of a continuing community system dynamics course: how the course got started, curriculum materials used, and some initiatives undertaken by the students on their own volition. A more comprehensive paper is available in Newton and Smith 2001 including more on the curriculum, educational process, use of distance education tools, and some reflections on our experience. Our reflections address three questions: the viability of community sustainability as a mechanism for introducing systems dynamics in a community; the roles and value to the effort of a 'citizen-advocate' and a 'teacher-advocate'; and the degree to which our curriculum meets its objectives. For an overview of the project in community context see Smith, et.al. 2001.

4.0 Assessing Student Impacts of Using System Dynamics in the Classroom

The following section overviews and summarizes a funded initiative to assess our efforts to implement systems dynamics in the classroom. We offer this general overview of the project to encourage further work in and assessment of applications of system dynamics in K-20 education. (Note: Much of what follows was written for the final report to the granting agency and assumes no, or very limited, exposure to systems dynamics. Hence much of the material or language here may seem superficial to the CLE conference audience. Since we did obtain funding for assessment, however, we think language like that used here is appropriate for reaching to audiences concerned about the effectiveness of technological applications in education but lacking familiarity with systems approaches.)

In fall 2000, our group secured funding through a collaborative University of Wisconsin System grant "Integrating Technology through Systems Thinking/System Dynamics Modeling" to research the impact of systems applications in the classroom. We proposed that the findings from this study would serve as a cornerstone to the greater educational community for the successful implementation of ***Wisconsin Wisconsin's Model Academic Standards***. Past research supports the potential effectiveness of Systems Dynamics (SD) on K-12 curricula, but we have found few discussions of efforts to assess the impact of SD on development of students' critical thinking and problem solving skills.

Our study was conducted during the 2000-2001 school year and explored the use of a systems approach in some of the applications discussed above, as a tool for integrating instructional technology in three high school classrooms, and investigated the technology's effects on student learning ***when combined with authentic use in the curriculum***. We explored technology's role in curricula relative to student learning; and explored student knowledge bases, especially in regard to complex domains. We also attempted to investigate the link between student performance and a System Dynamics approach in the classroom by seamlessly and appropriately infusing technology and SD theory with classroom activities. We explored how the use of System Dynamics computer models using STELLA II software demands technology skills and logic that requires

technology tools to be fully integrated with teaching and learning methods.

While SD using teachers realize that to understand technology through mastery of computer skills ***independent of other knowledge bases*** is to present a single-faceted awareness that only allows student and teacher to use the computer for stand-alone activities guided by traditional classroom practices, we feel that emphasis on this point was significant in obtaining funding for our assessment effort. Toward this point, our proposal also emphasized that, for example, computer applications can be used to type a paper, or organize information in a spreadsheet, or make a presentation. And that, in this mode, at the ***skills level***, instructional methodology remains unchanged, and students' uses of computers only replace traditional methods for accessing and reporting data.

4.1 Questions

Our study addressed the following broad questions in an attempt to advance knowledge on moving from stand-alone computer applications into the realm of using technology to reorder, assess, and propel information flow (Inatome, 1999).

- Can a computer-based Systems Thinking/System Dynamics modeling approach foster students' higher-level, critical thinking skills and foster effective uses of technology?

Learning the "Systems-Way" is a student-centered, inquiry approach that used technology to support insights into complex real life questions that allow for multiple points of view and multiple solutions. "Good modeling," means good communication and incorporates writing, dialogue and data summary as well as computer models. Our ST/SD approach, which cuts seamlessly across all discipline areas, fostered the development of students' skills in the application categories that ground all of ***Wisconsin's Model Academic Standards***—1) Ability to Think and Transfer; 2) Skill in Communication, 3) Production of Quality Work, and 4) Connections with Community.

- Can technology be used to expand learning boundaries, allowing and encouraging students and teachers to collaborate with both local (community) and global resources?

We implemented inquiry-based projects grounded in systems theory that required students to use various computer applications to gather data from multiple resources and formulate answers to generated questions.

4.2 Procedure

Our study on “Integrating Technology through Systems Thinking/System Dynamics Modeling” utilized a mixed methodological design (Creswell, 2001) in analyzing student gains in the areas of ST/SD. Both quantified student performance data using a developed rubric and qualitative teacher observations were gathered to create an accurate picture of student learning. This approach was utilized in response to the problem of prior research on measurement tools for technology-enhanced student learning having been inconclusive in showing student gains in learning.

Our group convened in late August of 2000 to develop a baseline rubric to measure student performances on problem solving scenarios of regional and contemporary concern. Using past research on ST/SD, it was decided that four specific skill areas would establish the best baseline criteria for gains. These areas included: 1) dynamic thinking, 2) systems-as-cause thinking, 3) operational thinking, 4) closed-loop thinking. In addition, four proficiencies ranging from advanced to minimal were established with several indicators at each level

- **Dynamic Thinking**: enables you to frame a problem or issue in terms of patterns of behavior over time. For example, sales in a company might rise for a while after every promotion, but then fall to a lower and lower point each time.
- **System-as-Cause Thinking**: enables a learner to "bound" a model by identifying which variables to leave in and which to leave out.
- **Operational Thinking**: enables a student to get at causality—how is a performance actually being generated?
- **Causal-Loop Thinking**: enables a student to see causality as an ongoing, interdependent process, rather than a one-time, one-directional event caused by independent factors.

In the fall semester of 2000, three groups of high school students and their teachers implemented ST/SD instruction. The following descriptions provide an overview for these groups and a brief analysis of their approaches.

Group #1: Ten 12th grade students enrolled in the course, ***Contemporary Social Issues***, at Sevastopol High School used ST/SD as a tool for understanding complex social issues. The students were introduced to ST/SD using behavior over time graphs (BOTG), causal loop diagrams (CLD), and stock flow diagrams (SFD). This group did not design, but ran pre-designed STELLA II software models on the Macintosh-platform lab computers networked through cascading hub configuration to the school's 10Base-T backbone. Students stored their computer work on the school's file server, and printed their diagrams on laser printers.

Group #2: Twelve 11th grade students enrolled in a required ***Economics and Government*** course at Sturgeon Bay High School. These students learned technology skills through authentic curriculum application. This instructor used ST/SD to present course material to students, and introduced his class to STELLA II simulation software through pre-built ST/SD models on lab computers. Students utilized technology skills to manipulate the models relevant to their course of study.

Group #3: Twelve 11th/12th grade students in a social studies course, ***Systems Thinking and Computer Modeling***, at Sturgeon Bay High School. Students were instructed in the design, construction, and operation of original ST/SD models and used STELLA II simulation software. Several models were produced that demonstrated the complex nature of systems interactions. Students thinking, writing, data collection and summary and presentation, as well as technology, skills were all stretched in this systems-focused course.

4.3 Data Sources

Students in the study were pre-tested for attitudes toward technology and education, and ability to use technology appropriately and significantly in identifying variables that effect systems. Both pre- and post-class exercises centered on a "teacher shortage" scenario article. Pre-test performances were gathered at the start of the semester and post-test performances were gathered at the end of the semester. These measures were then analyzed to show growth in the areas of ST/SD skills.

Instructor and student input was gathered electronically during this fall 2001 period to construct a "thick description" of the teaching and learning process during this period.

4.4 Data Analysis

Pre and post performances were gathered shortly after the close of the fall 2000 semester. The researchers then convened in February 2001 and conducted scoring sessions using the established ST/SD rubric. A procedure of pilot scoring was conducted prior to undertaking the scoring of all the performances. This procedure addressed the issue of consistency in scoring and variability among interpretations of the performance rubric. Performances were analyzed by at least four researchers with small discrepancies settled through dialogue and discussion. Although the scorers were very consistent throughout the procedure, any discrepancies of more that 2 points were re-scored by an outside interpreters.

4.5 Validity/Reliability Measures

When conducting classroom research via quasi-experimental design, it is impossible to "control" for all variables that may affect the outcome of given studies. Nonetheless, several steps to address potential bias were undertaken in this study. The following triangulation procedures were employed in this study (Creswell, 2001). The use of multiple settings and multiple instructors assured a more accurate picture of student gains in the areas of ST/SD skills. In addition, the scoring procedure of using multiple coders added to the likelihood of accurate performance scores.

5.0 Results

The following scores represent the pre and post-test performances of individual students in this study in the four skill areas of diagnostic, systems-as-cause, operational, and causal loop thinking. The results are broken down into the three classroom groups:

Group 1(pre/post)

(DT)	2/3	1/2	2/3	1/2	1/2	1/1	2/3	1/3	2/2	1/1	2/3	1/2
(SCT)	2/3	2/3	1/2	1/2	2/2	1/2	2/2	2/3	1/2	3/4	3/4	2/2
(OT)	2/3	2/3	2/2	1/2	2/2	1/1	2/2	1/2	1/3	1/2	2/3	1/2

(CLT)	2/3	1/2	1/2	1/2	1/2	1/2	1/2	1/2	1/3	1/2	1/2	1/1

Group 2 (pre/post)

(DT)	1/4	1/2	1/4	1/2	1/1	1/3	1/2	1/1	1/2
(SCT)	2/3	2/2	2/3	1/2	2/2	1/3	2/2	2/3	2/2
(OT)	1/3	1/2	1/3	1/2	1/2	2/3	2/3	2/2	1/1
(CLT)	1/3	1/1	1/2	1/1	1/1	1/2	1/1	1/2	1/1

Group 3 (pre/post)

(DT)	1/2	2/3	1/2	1/3	1/2	1/2	1/3	1/2	1/2
(SCT)	1/2	2/3	1/2	1/3	2/2	1/3	2/4	2/3	1/2
(OT)	1/2	2/3	1/2	1/2	2/2	1/3	1/2	1/2	1/2
(CLT)	1/2	2/3	1/1	1/3	1/2	1/4	1/2	1/2	1/3

6.0 Discussion of Student Performances

The results of our study on the integration of technology through ST/SD modeling in three high school classrooms suggested significant gains in students' problem solving abilities and critical thinking skills related to "real world" issues. This was evident in their ability to apply systems thinking skills to various problems, most notably in constructing models focusing on the "Teacher Shortage" scenario. Students were also able to identify and understand dynamic feedback systems both with and without the direct usage assistance of computer simulation through STELLA II.

Overall, This study indicated that students became more adept in the four target areas of 1) dynamic thinking, 2) systems-as-cause thinking, 3) operational thinking, 4) closed-loop thinking. Students became more proficient at framing problems or issues in terms of patterns of behavior over time; at "bounding" a model by identifying which variables to leave in and which to leave out; at identifying causality and its dimensionality—seeing it as an ongoing, interdependent process, rather than a one-time, one-directional event caused by independent factors. It is likely that these students will transfer their ST/SD skills to new problems outside of the classroom.

7.0 Student Responses/Feedback

A summary of student responses and feedback to ST/SD modeling and use of the STELLA II software was overwhelmingly positive and indicated a strong perceived use outside of the classroom (Ziegelbauer 2001). Students indicated overall excitement about

using their newly developed skills in life outside of school and expressed a strong desire to get further training and practice in ST/SD modeling. They also expressed a feeling of "empowerment" in being able to deal with problems and issues in the world.

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Appendix A: Pre- and post-class assessment exercise.

A writing exercise based on a teacher shortage scenario was posed to the high school students before and after the class.

Written responses to the scenario before and after the courses described above provided the basis for applying the SD Rubrics presented in Appendix B.

Appendix B:

Systems Thinking Rubrics

- Dynamic Thinking
- Systems-as-Cause Thinking
- Operational Thinking
- Closed-Loop Thinking

Dynamic Thinking	
Advanced Dynamic Thinking	· Qualitatively or quantitatively describes the issue as a pattern of behavior over time.. · Produces a BOT graph, accurately labeled, showing the changing value of a single vari multiple points in time, and includes a projection of behavior into the future
Proficient Dynamic Thinking	· Describes a pattern of change in behavior over time. · Produces a BOT graph, accurately labeled, showing the changing value of a single vari multiple points in time
Basic Dynamic Thinking	· Identifies the issue as a pattern of behavior that shows some change. · Produces a graph that shows a linear pattern.
Minimal Dynamic Thinking	· Identifies a behavior at a given point in time · Produces a timeline or list of events

Systems as Cause Thinking	
Advanced Systems-as-Cause Thinking	· Identifies the key variables as either controllable or outside of one's control in the syst the behavior pattern observed. · Develops hypotheses (model, theory or explanation) to explain the interrelationships a to the behavior pattern.
Proficient Systems-as-Cause Thinking	· Identifies the key variables in the system as they relate to the behavior pattern observe · Develops hypotheses (model, theory or explanation) to explain the interrelationships a to the behavior pattern.
Basic Systems-as-Cause Thinking	· Identifies variables in the system. · Offers simple explanations for simple relationships within variables in the pattern.
Minimal Systems-as-Cause Thinking	· Unable to identify the variables.

Operational Thinking	
Advanced Operational Thinking	· Description/model is precise in wording and accurate in identifying the process · Description/model accurately identifies "stock" and "flow" infrastructures with identifyi points…
Proficient Operational Thinking	· Description/model accurately focuses on the actual "process" vs. "factors"
Basic Operational Thinking	· Description/model includes both "factors" and "process"
Minimal Operational Thinking	· Description/model is primarily a list of external factors with some attempt at "proces

Causal Loop Thinking	
Advanced Causal Loop Thinking	· Description/model joins the “stock” and “flow” infrastructures together to form multiple · Description/model identfies possible/viable secondary consequesnces/unintended outcon
Proficient Causal Loop Thinking	· Description/model joins the “stock” and “flow” infrastructures together to form feedback · Multiple closed loop views are identified.
Basic Causal Loop Thinking	· Description/model joins the “stock” and “flow” infrastructures together to form feedback · Single circular causal loop is identified.
Minimal Causal Loop Thinking	

Appendix C:

Sustaining Effective Educational Change:
Systems Perspectives and Sustainable Development Applications in K-12 Education

Course Number: ED & HUD 795-6
Number of Credits: Three (3) Graduate Credits
Instructor: Dr. Larry Smith, Social Change and Development, UW-Green Bay
Dates/Times:

- Wednesday, June 12 (8:30 AM-4:00 PM);
- Wednesday, June 19 (8:30 AM-4:00 PM);
- Monday, June 24 (8:30 AM-4:00 PM);
- Wednesday, August 14 (8:30 AM-4:00 PM);
- A minimum of eleven hours of applied classroom learning during the fall of 2002;
- One follow-up meeting in November (either a Friday evening or Saturday morning) to be determined by course participants at the first class session.

Location: Green Bay Area, TBD

Course Emphasis:
Successful applications of systems and sustainable development perspectives abound in many United States and international locations and throughout K-12 curriculum areas. Applications range from obvious areas of science and mathematics to social science and even literature and support curriculum from kindergarden and lower elementary grades to advanced placement high school courses. Many practitioners argue that these applications are especially beneficial for students toward the lower end of distributions of conventional perspectives on student ability. Practitioners also indicate that as a school system experiences infusion of systems perspectives students begin to serve as disseminators of the perspectives thus creating incentive for other participants in the system to explore using the tools too. Virtually any K-12 teacher can apply or adapt existing examples to support instruction in almost any curriculum area in innovative ways that have proven successful in other settings.

Course Rationale:
System perspectives and sustainable development are rapidly growing interactive themes in K-12 education around the world. This course introduces and overviews applications of these two symbiotic themes and helps participants develop skill to find, assess and build-on relevant aspects of this growing body of application for use in their own contexts.

Course Description:
Educators will explore sustainable development and systems-related K-12 applications and support each participant's exploration of relevant applications and development of extensive core bibliography and historical perspectives from which to adapt applications for their own contexts.

Course Objectives:

1. Explore sustainable development applications in K-12 education with emphasis on systems-related aspects of these applications
2. Explore systems applications in K-12 education
    a. Introduce system-thinking concepts
    b. Introduce system dynamic modeling and applications to sustainable development issues, like the functioning of global natural cycles, population, economic activity and related waste, that can be accessed for K-12 applications
    c. Work with elementary system dynamic models for classroom application
3. Develop core bibliographies and overviews of historical perspectives related to potentially relevant applications in educational settings
4. Collaborate in grade-level and content groups, both within the class and in collaboration with the
   evolving national and global network of K-12 practitioners when possible, to develop applications relevant to their work
5. Collaboratively support and assess class member's applications in their work environments

Course Requirements:

1. Read and discuss assigned material from the four required texts and selected introductory materials from the Creative Learning Exchange and the MIT System Dynamics in Education Project

2. Develop a bibliography on system thinking and sustainable development with emphasis on K-12 applications

3. Participate in grade level and content related affinity groups, as feasible given course enrollment, or interact electronically with practitioners from around the world, to support individual participant's objectives

4. Select relevant affinity group and personal reading material based on reviewing book reviews and other brief overviews of available materials to support these affinity groups

5. Develop a bibliography of subject-focused materials and develop an application-focused core bibliography of especially relevant material from the extensive bibliography

6. Develop timelines and overviews of behaviors over time* relevant to system dynamics and its applications in K-12, sustainable development and its applications in K-12, specific timelines related to systems and sustainability applications in selected affinity group areas and for personally selected areas of potential application
   (* Behaviors over time (BOT), which are often graphed to generate behavior over time graphs (BOTGs), are used in system dynamics to focus attention on the behavior of aspects of a system as they change over time. In some other contexts data incorporated in a BOTG are sometimes called time-series data.)

7. Develop one or more systems related teaching unit(s) and/or sustainable development teaching unit(s) (or other appropriate work-supporting application) for use in participant's work setting (Note: it is possible and most likely that any given teaching unit will incorporate both sustainable development and systems aspects.)

8. Write reflections on assigned readings and other course activities and on participant's own evolving insights related to sustainable development and systems perspectives and potential applications in her own work

9. Share insights within affinity groups and document this sharing via e-mail and in class discussions and reports

Required Reading:

AtKisson, Alan. *Believing Cassandra: An Optimist Looks at a Pessimist's World*. White River Junction, VT: Chelsea Green Publishing, 1999.

Kim, Daniel. *Introduction to Systems Thinking*. Williston, VT: Pegasus Communications. 1999

Pointing, Clive. *A Green History of the World: The Environment and the Collapse of Great Civilizations.* London: Penguin, 1991 Paperback edition. New York: Penguin USA. 1993.

Sussman, Art. Sussman, Art. *Dr. Art's Guide to Planet Earth for Earthlings Ages 12 to 120*. White River Junction, VT: Chelsea Green Pub. Co. and San Francisco: WestEd. 2000.

Focused material for affinity groups or individual topics will be selected from sources like those listed below:

Selected material from the Creative Learning Exchange, http://clexchange.org
and the MIT System Dynamics in Education Project, http://sysdyn.mit.edu

Sweeney, Linda Booth. *When A Butterfly Sneezes: A guide for Helping Kids Explore* Interconnections in our World Through Favorite Stories. Waltham, MA: Pegasus Communications. 2001.

Evaluation and Assessment:

A general course portfolio will contain all of the following materials and provide the basis for all evaluation:

1. General Readings, one-page reflections, and input to class discussion	20%
2. General systems and sustainability bibliographies and time lines	10%
3. Affinity group or individual project work	25%
4. Focused systems and sustainability bibliographies and time lines	10%
5. Teaching units or other relevant applications	20%
6. Classroom application and self reflection on the experience (8-10 pages)	15%

Course Schedule:

Class I: Wednesday, June 12, 2002 (8:30 AM-4:00 PM)

Assignment

- ✓ Find hard copy and electronically published reviews of course texts and bring copies of two or three of the more relevant ones of these for each of the books, by AtKisson, Pointing and Sussman, to class.
- ✓ Read introductory material and the first two or three chapters of the three general course texts (by AtKisson, Pointing, and Sussman) and all of Kim's brief *Introduction to Systems Thinking.*
- ✓ Find hard copy and electronically published reviews of each of the text books and explore the Creative Learning Exchange, http://clexchange.org and the MIT System Dynamics in Education Project, http://sysdyn.mit.edu and other K-12 application sites you find there.

Class Activities

Get acquainted and explore range of interests and possible applications among class members (8:30-9:15 AM)

Introduction to Sustainable Development (9:15-10:00 AM)

- Discussion of Sustainable Development history and concepts
- Overview Discussion of Sustainable Development's History
- Discussion of Prospects for A Sustainable Future and links to K-12 practice

Break (10:00-10:15 AM)

Introduction to System Thinking (10:15-11:45 AM)

- Discussion of System Thinking history and concepts
- Discussion of System Thinking tools

- Introduction to System Dynamic Modeling
  - Discussion of System Dynamic Modeling concepts
  - Discussion of System Dynamic Modeling tools and resources

Working lunch (12:00-12:45 PM)

Bring brown bag or purchase lunch in UW-Green Bay Cafeteria. This working lunch will continue discussions from the morning and provide an opportunity for class participants to begin to form into working groups with similar interests and K-12 contexts.

Meet in a classroom with computers available for each student. (1:00-3:00 PM)

- **Explore computer-based sustainable development and system dynamic resources**
- Introduction to bibliographic resources available on and off campus by a Cofrin Library instructional staff member
- Introduction to System Dynamic software and demonstration of alternative software and discussion of how to acquire it (Note: Use of system dynamics software is not required of students in this course, but it will be demonstrated and its use will be encouraged where appropriate.)

(3:15-4:00 PM) Review planned course activities and revise as appropriate given the distribution of interests among course participants.

Class II: Wednesday, June 19, 2002 (8:30 AM-4:00 PM)

Assignment

- ✓ Read at least three of the, for you, more potentially relevant chapters, including at least AtKisson's Chapter 4 "It's the System" of each of the books, by AtKisson, Pointing and Sussman, and write at least one, and probably several, brief reflections integrating your response to some or all of your readings to share with class members.
- ✓ Continue to explore the Creative Learning Exchange, http://clexchange.org and the MIT System Dynamics in Education Project, http://sysdyn.mit.edu and other K-12 application sites and write a brief reflection on what you have found and how you think you may use it.
- ✓ Share your reflections on text and web resources electronically throughout the week with class interest group members and with Larry as relevant. Keep a journal of your reactions to the material or copies (electronic journals and copies of exchanges will be fine) of your electronic exchanges if they are extensive enough to reflect your reactions for inclusion in your course portfolio.

Class Activities

(8:30-9:15 AM) Preliminary dialogue in curriculum or other application interest groups with brief status reports to the larger class

(9:15-10:00 AM) Continued Discussion of Sustainable Development

- · History and concepts
- · Deeper Discussion of Sustainable Development's History with emphasis on key events and dates. Begin to develop an overview timeline for cultural acceptance of Sustainable Development as a significant topic.
- · Continue discussion of prospects for a sustainable future and links to K-12 practice

Break (10:00-10:15 AM)

Continued Discussion of System Thinking and Modeling (10:15-11:45 AM)

- · Discussion of System Thinking history and concepts
- · Discussion of System Thinking tools
- · Exploration of systems thinking applications

Continued exploration of System Dynamic Modeling (SDM) and alternatives to formal modeling

- · Demonstration of SDM of specific historical examples from Pointing
- · Discussion of student reaction to the first week's interaction with System Dynamic Modeling tools and resources
- · Discussion of how students who don't feel comfortable with SDM software can proceed to integrate Systems Perspectives into their classrooms.

Working lunch (12:00-12:45 PM)

(1:00-3:00 PM) Meet in a classroom with computers available for each student.

- · **Continue to explore computer-based sustainable development and system dynamic resources**
- · Continue to explore bibliographic resources available on and off campus
- · Continue demonstrations of System Dynamic and alternatives to formal systems modeling

(3:15-4:00 PM) Review planned course activities and revise as appropriate
Class III: Monday, June 24, 2002 (8:30 AM-4:00 PM)

Assignment

- ✓ Read at least three more of the, for you, more potentially relevant chapters, including at least AtKisson's Chapter 9 "The Innovation Diffusion Game" and Chapter 10 "Accelerate to Survive," of each of the books, by AtKisson, Pointing and Sussman, and write at least one, and probably several, brief reflections integrating your response to some or all of your readings to share with class members.
- ✓ Write a brief (one or two page) prospectus for one or more Sustainable Development and Systems Perspective (or System Dynamic Modeling) applications you plan to develop for use in your work.
- ✓ Continue to share your reflections on text and web resources electronically throughout the week with class interest group members and with Larry as relevant. Keep a journal of your reactions to the material or copies (electronic journals and copies of exchanges will be fine) of your electronic exchanges, if they are extensive enough to reflect your reactions to the course material, for inclusion in your course portfolio.

Class Activities

(8:30-9:15 AM) Preliminary dialogue in curriculum or other application interest groups with brief status reports to the larger class

(9:15-10:00 AM) Continued Discussion of Sustainable Development

- · History and concepts
- · Continue and deepen Discussion of Sustainable Development's History with emphasis on key events and dates. Continue to elaborate the previous class's timeline for global and United States cultural acceptance of Sustainable Development as a significant topic.
- · Continue discussion of prospects for a sustainable future and links to K-12 practice

Break (10:00-10:15 AM)

Continued Discussion of System Thinking and Modeling (10:15-11:45 AM)

- · Discussion of System Thinking history and concepts
- · Discussion of System Thinking tools
- · Exploration of systems thinking applications

Continued exploration of System Dynamic Modeling (SDM) and alternatives to formal modeling

- · Additional demonstrations of SDM of specific historical examples from Pointing
- · Discussion of student reaction to previous interaction with System Dynamic Modeling tools and resources
- · Continued discussion of how students who don't feel comfortable with SDM software can proceed to integrate Systems Perspectives into their work.

Working lunch (12:00-12:45 PM)

(1:00-3:00 PM) Meet in a classroom with computers available for each student.

- · **Continue to explore computer-based sustainable development and system dynamic resources**
- · Continue to explore bibliographic resources available on and off campus
- · Continue demonstrations of System Dynamic and alternatives to formal systems modeling

(3:15-4:00 PM) Schedule class member presentations of preliminary applications of Sustainable Development & System Thinking (or System Dynamic Modeling) to your coming fall work setting for the August 14 class.

Class IV: Wednesday, August 14, 2002 (8:30 AM-4:00 PM)

Assignment

- ✓ Prepare a preliminary application of Sustainable Development and System Thinking (or System Dynamic Modeling) to your coming fall work setting. Bring enough supportive material to be able to demonstrate your proposed application to the class.

Class Activities

(8:30-9:15 AM) Preliminary dialogue in curriculum or other application interest groups with brief status reports to the larger class

(9:15 AM-3:00 PM) Individual presentations, followed by class discussion and suggestions for improvement, of preliminary applications of Sustainable Development and System Thinking (or System Dynamic Modeling) to the coming fall work setting (With appropriate breaks and a working lunch)

(3:15-4:00 PM) Review planned activities and set the final schedule for the final course meeting on a Friday evening or Saturday in November.

Class V: (To be arranged for a Friday evening or Saturday morning in November to be scheduled on August 14)

Assignment

- ✓ **Utilize Sustainable Development and System Thinking, or System Dynamic Modeling, in at least one work related activity before the scheduled final class meeting in November. Accumulate all course related materials, especially materials documenting your work-related application, and a self reflection on the experience of applying course perspectives in your work into a portfolio documenting your work in the class and submit the portfolio and a postage-paid self-addressed container for return of the portfolio at the final class session. Note, electronic portfolios, in Windows or Rich Text Formats, are encouraged, but not required.**

Class Activities

Brief summary presentation of course, work related experience, and anticipated further use of these tools and perspectives by each class member