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MODELING PHYSICS: SYSTEM DYNAMICS IN PHYSICS EDUCATION

by Horst P. Schecker, Institute of Physics Education, University of Bremen, Germany

Conceptual learning

Physics is a heap of formulas; when you want to solve a problem you just have to choose the proper equation, fill in numbers, and calculate the missing value.

Many students share this view about physics — at least about physics instruction. On the other hand physicists rightly claim that the power of physics lies in describing a great variety of phenomena by a very limited set of fundamental laws and principles. Students often fail to make distinctions between the *power tools* of physics (as Macdonald, Redish & Wilson call them) and the *gimmicks*, e.g. functions describing special forms of motion. Fundamental laws like $F=m \cdot a$ are considered as *just another equation* of the same quality as $s(t)=1/2gt^2$ (for the free fall of bodies). One of the reasons is that physics instruction puts too much weight on the *gimmicks*, e.g. when typical textbook problems concentrate on solving equation systems and calculating numbers.

System dynamics modeling can help to shift the focus towards more qualitative conceptual learning. Modeling physical phenomena means applying the fundamental concepts and laws and leaving the tedious task of solving equations to the computer. Dynamic modeling requires the students to analyze a phenomenon and develop the model *him- or herself*. The students are introduced into the strategy of expert problem solvers, i.e. to concentrate on a conceptual and semi-quantitative analysis. Before special functional relationships can be used in STELLA-models, the relevant quantities have to be defined and the structure, i.e. the *conceptual features* of the model, must be formulated. The physical assumptions are completely explicit in the graphical model structure. The modeling system supports the learner both in constructing the model and exploring its physical adequacy through simulation runs.

The conceptual structure of force & motion

Models within a certain domain of physics have common core structures that visualize the power tools. Models about force and motion for ex-

***Physics** continued on page 3*

GETTING IT GOING. . .!

Wow...that's just what I need to get my kids to see the "whole picture" in my ____________ class!"

Sound familiar? When I was fortuitous to encounter systems thinking and dynamic modeling (again) this was my response as well. Fifteen years ago I had the opportunity to develop simple systems models of ecosystem cycles using DYNAMO, and then in the summer of 1995 I was introduced to STELLA at a technology seminar. During that time span I moved from the world of research science into teaching high school physics and environmental studies. The applications for systems thinking and dynamic modeling in all areas of my high school were obvious. But how do I start? Who will work with me? How do I make it fit?

At Champlain Valley Union High School we are noted for our innovative curriculum development and the use of technology in our classrooms. I have taught the past three years in a classroom setting with 18 Power PCUs, e-mail and direct Internet access for all students, and a curriculum rich in technological applications. Incoming students (Grade 9) participate in a Core program with an interdisciplinary focus. The remainder of the program is traditional in structure but often inno-

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FROM THE EDITOR. . .

The conference is shaping up nicely. If you have not registered and intend to do so, please fax or call immediately. We did have to turn people away at the first ST&DM conference in 1994. If you no longer have the registration forms from the last newsletter or the brochure mailing, we would be happy to supply them.

As you can see from the Update column, different activities are going on both in the United States and internationally. The SyM Bowl is a new venture and will hopefully eventually take its place along with other academic competitions such as the Academic Decathlon and the Science Olympiad. They had an exciting beginning in Portland. It rewards students for modeling, something which is important and may be one of the leverage points in our interest in encouraging systems education. Jay Forrester has maintained from the very beginning that we should be encouraging students to actually model. The SyM Bowl does that, thanks to the hard work of those in Portland who got it off the ground.

We look forward to greeting old friends and meeting new ones at the conference in July.

Lees Stuntz (stuntzln@tiac.net)

UPDATES. . .

SyM Bowl

Hello, colleagues and friends of System Dynamics: Many of you are aware of the CC-STADUS grant in Portland OR. This grant, obtained from NSF by Diana Fisher and Ron Zaraza of Portland Public Schools, was designed to train high school teachers to use System Dynamics in their curriculum, including teaching students how to develop models.

I am a medical school faculty member and biomedical researcher (pharmacology and behavioral neuroscience) with an intense interest in the application of SD modeling to biology and medicine. I participated in the writing of the CC-STADUS grant, and have worked closely on its execution over the past three years, including attending the K-12 conferences in Concord (94) and Tucson (95).

Even before the preparation of this grant about 4 years ago, I speculated about the possibility of a "modeling and simulation fair", analogous to a science fair. Students would develop and test a model of interest to them, and would present the results to an open house audience.

By last summer it appeared that we were approaching a critical mass of students who were actively building models, and we decided to conduct a trial run. Tim Joy, high school English (!) teacher and CC-STADUS core team member agreed to work on this with me. I had an opportunity to discuss this briefly with Jay Forrester, Nan Lux, and Lees Stuntz during a visit to MIT in Dec. 95.

April 26 it actually happened. It is called SyM Bowl (Systems Modeling Bowl; we did not want a "modeling fair" to be perceived as a fashion show (!)). Wayne Wakeland, Assoc. Prof. System Science at Portland State University volunteered to organize and supervise the judges (greatly appreciated!).

We expected between 12 and 18 teams for this first effort. Models were developed by teams of 2-4 students, who develop a substantial document which describes a statement of the problem, the perceived audience, the purpose of the model, reference behavior, the structure of the model (including a description of each individual element), the behavior of the model, conclusions, and future directions. This document was judged in the week preceding April 26.

Franklin (Diana) had 7 teams from her full-year modeling class. Wilson (Scott Guthrie's class) had 6 teams from a full-year modeling class. Tim Joy (CC-STADUS core team and SyM Bowl co-chair) had two teams of sophomores from his after-school SD "club" at LaSalle HS. Finally, there was a team of 2 from Sunset High School, coached by Matt Hiefield (CC-STADUS core team), again, an after-school "club".

The six judges were just superb. In addition to Wayne they included two practicing business consultants (Michael Johnson and Pat Barton), two teachers (Ron Zaraza and Teresa Hazel) and an MD/Ph.D. student from the medical school (Frank Lotrich). Michael is working on a Ph.D. in Systems Science at Portland State, Pat received an MS in the systems program at Dartmouth, Ron is a PI on the CC-STADUS grant, Teresa is one of the former trainees, and Frank is a graduate student in my lab and a modeler for about three years. What more could we ask?

The judges met Thursday evening to review the reports they had received a week earlier, and they identified several "very likely" and several "probable" candidates for the top five, but they kept the door open for others based on the morning demonstrations and discussion.

From 9-11:30 there was a poster presentation and demo, with computers set up on each table. Students attended the tables and were available to discuss the model and answer questions. During lunch the judges choose the top five teams, based on their written report and open house demo. Following lunch, these top five teams each made a 15-minute presentation with overhead transparencies, again covering the materials described above.

UPDATES *continued on page 11*

Modeling Physics, *continued from page 1*

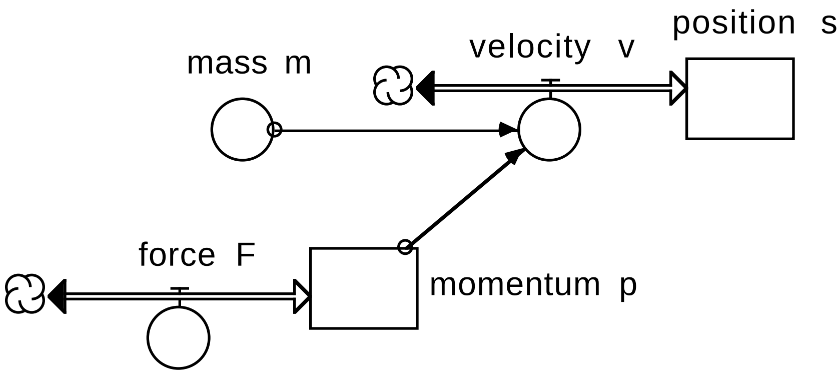

Figure #1 Core structure of force & motion models in mechanics. The net force F exerted on an object causes a change of its momentum $\Delta p = F \cdot \Delta t$ (Newton's second law). The object's velocity is given by $v = p/m$. The velocity acts as the rate of change of position s: $\Delta s = v \cdot \Delta t$.

ample contain the chain force→momentum→velocity→position as shown in Figure #1. The core model is based on Newton's second law ($F(t) = \Delta p/\Delta t$) and the definitions of velocity ($v(t) = \Delta s/\Delta t$) and momentum ($p = m \cdot v$).

The basic structure is easily reproduced by students for new problems. Physical pondering can concentrate on the question *which forces are exerted* on the body in a given situation. The forces can either be constant (e.g. weight), or depend on position (gravitation), velocity (friction) and even time, but always the principles of Newtonian mechanics are clearly visualized. The same basic model applies for pendula, parachutists and planets as well as for charged particles in a mass spectrom-

***Physics** continued on next page*

The Second Systems Thinking and Dynamic Modeling Conference

July 17-19, 1996

Wheaton College
Norton, Massachusetts
(easily accessible to both Boston, MA and Providence, RI)

- Sessions focusing on:
  Systems tools for use in the classrooms and in the educational organization
  Organizational change using the systems approach
  Curriculum examples and innovations utilizing systems tools and dynamic modeling
- Addresses by world renown figures in the fields of system dynamics and systems thinking.
- Time to talk, to learn from colleagues from across the country

Preceding the International System Dynamics Conference,
to be held in Boston July 21-26, 1996

Modeling Physics, *continued from previous page*

eter. You only have to work out which particular forces act in the particular case. Other core structures exist for electromagnetism or radioactive decay. Students learn that physics is "easy"—in the sense that many different examples can be explained with the same small set of conceptual instruments.

The motion of meteors

For students in mechanics classes one of the most interesting applications of the Newtonian structure was the motion of meteors in the atmosphere of the Earth. The model in Figure #4 describes this phenomenon. The teaching unit starts with measuring the motion of paper cones dropping from the ceiling. The effects of velocity, shape, cross section area and air density on friction are described semi-quantitatively. Afterwards the students look up the functional relationship between drag and these quantities in the textbook.

The next step lies in modeling the motion of a parachutist (see Figure #3). The students are familiar with the dynamic core model from earlier examples. They concentrate on modeling the drag force and assessing realistic values for the parameters, like the cross section of an open parachute. Group work on this model does not take more than one lesson.

The parachute model can easily be adapted to the fall of a meteor in another unit of group work. Although this phenomenon seems to be quite different, only a few changes are necessary. Mainly a second feedback loop has to be added that runs from *height* to *air density*. In the parachute model air density can be considered as a constant. Now the change of air density with height becomes a central feature. With STELLA this relationship can be defined by a graphical converter using data from a corresponding table in a handbook. Although the model simplifies the mo-

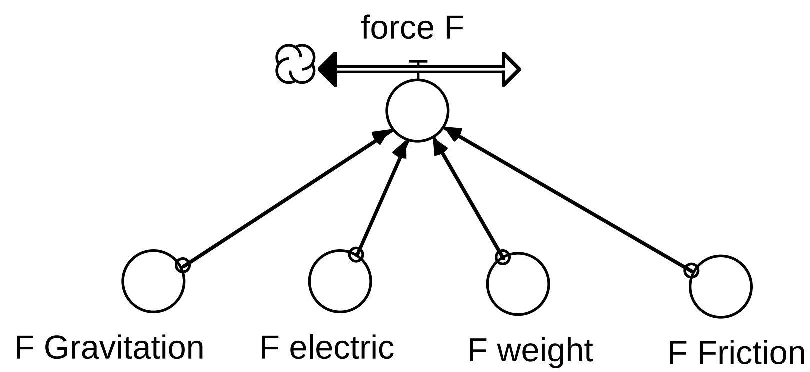

Figure #2 The main question in building models in mechanics is: Which single forces are acting on the body and sum up to the net force F?

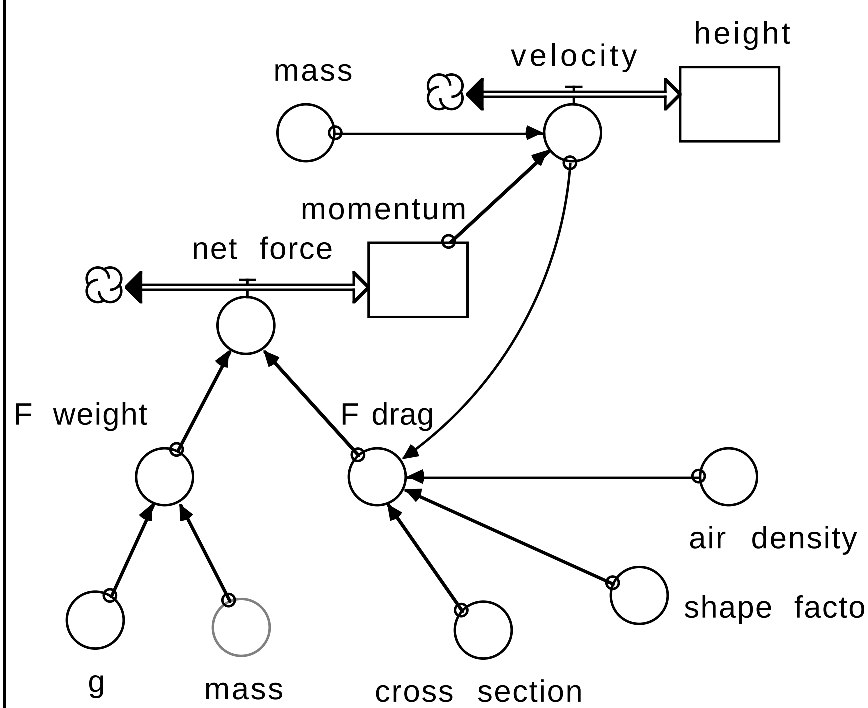

Figure #3 Parachuting. The upper part of the model consists of the force & motion core model. Two forces act on the parachutist: weight and drag. The feedback loop from velocity to drag demonstrates that drag increases with velocity (dragμv^2).

tion—in that it is only one-dimensional—the major effects can be studied. The meteor enters the atmosphere with super-terminal velocity. In order to plot the brake deceleration, the function for acceleration is added to model (a=F/m).

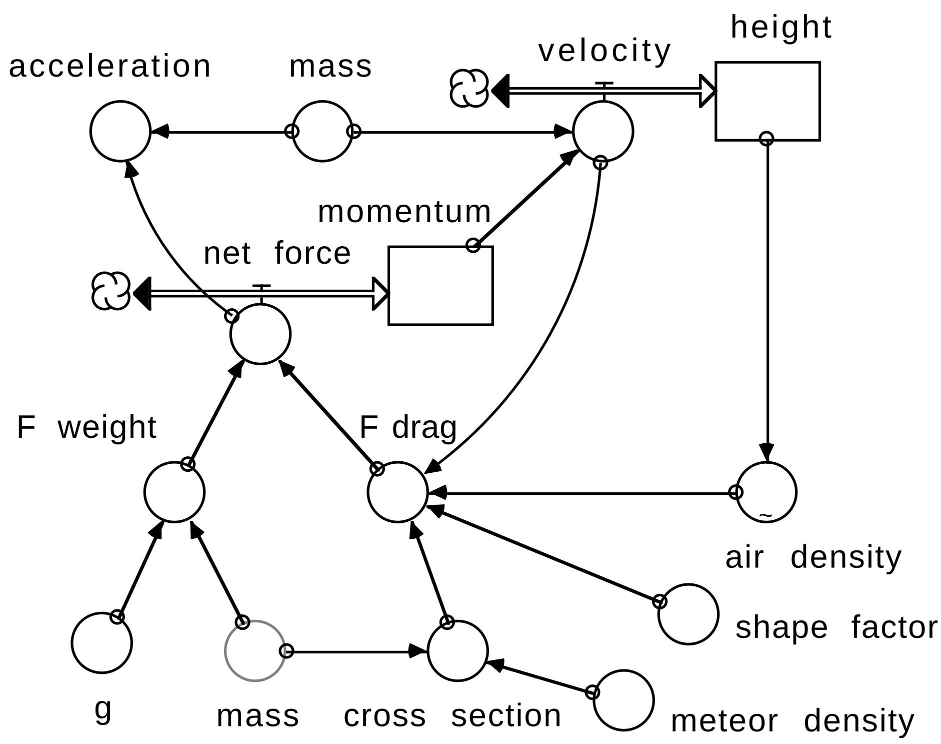

Figure #4A STELLA model of a meteor fall.

The standard structure is applied with two forces (weight and drag).Two feedback loops run from velocity to drag and from displacement via air density to drag. Mass and density of the meteor are modeled as separate parameters to calculate cross sections for different types of meteors (iron, stone).

```
height(t) = height(t - dt) + (velocity) * dt
INIT height = 100000 {m, approx. border of the atmosphere}
INFLOWS:
    velocity = momentum/mass
momentum(t) = momentum(t - dt) + (net_force) * dt
INIT momentum = -10000 {m/s; meteor velocity}*mass {kg; meteor mass}
INFLOWS:
    net_force = F_weight+F_drag
acceleration = net_force/mass {m/s^2}
cross_section = (3*mass/(4*PI*meteor_density))^(2/3)*PI
{m^2; cross section can be calculated for differen types of meteors: ston iron}
F_drag = - 1/2*cross_section*air_density*shape_factor*velocity*ABS(velocity)
{air friction: F~v^2, anti-parallel to velocity}
F_weight = mass*g {N; considered to be approx. constant}
g = -9.81 {m/s^2 (at zero height)}
mass = 500 {kg}
meteor_density = 8000 {kg/m^3; iron (stone: 3500 kg/m^3)}
shape_factor = 2
air_density = GRAPH(height
```

Figure #4B Equations of the meteor model. Data for the graphical converter air_density=GRAPH (height) can e.g. be found in the Handbook for Physics and Chemistry.

Physics *continued on next page*

Modeling Physics*, continued from previous page*

Before the model is tested in a simulation run, the students should be prompted to make predictions for the v(t) and a(t) graphs they expect. The graphs actually produced by the model are surprising. Figure #5 shows graphs for three types of meteors. For understanding the shapes of the v(t) and a(t) graphs it takes an effort to discuss the contrary effects of decreasing velocity and increasing air density on drag. Instead of a monotonic tendency the acceleration has a peak with maximum of several hundred g (see Figure #5A). This graph illustrates why most meteors melt away in the atmosphere under the influence of high friction forces. The velocity of the stone meteor (Figure #5B) nearly decelerates to zero before it reaches the ground. The big iron meteor hits the Earth with an enormous impact. This explains why only medium size meteorites can be dug from the soil: The small ones melt in the atmosphere and the big ones evaporate on hitting the ground.

One of the reasons why the students found the meteor unit so stimulating was that—as a student put it—"one did not know what comes out". The phenomenon is too complex for a quick estimation. In conventional instruction *mathematical* boundaries limit the set of investigations for school physics because of the need to use calculus. In school mechanics bodies move with uniform velocity or with uniform acceleration because under these assumptions the 'laws', rather the 'equations', of motion become relatively simple. The differential equations can be solved with a limited amount of algebra and calculus. The motion of parachutists is not examined because it is too 'difficult'; which means that the equations cannot be solved on school level. System dynamics tools break down these boundaries and extend the scope of instruction far beyond the physics of air tracks and vacuum pipes.

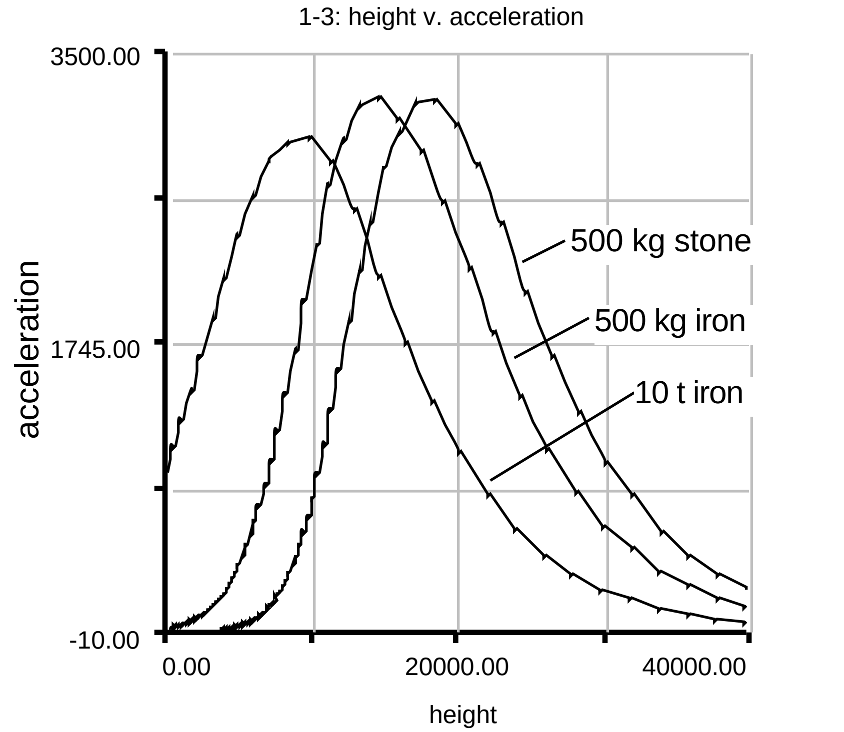

Figure #5A Deceleration of different types of meteors predicted by the model. Values of several hundred g are reached (compare: -10 m/s^2 = 1 g is the acceleration of a free falling body).

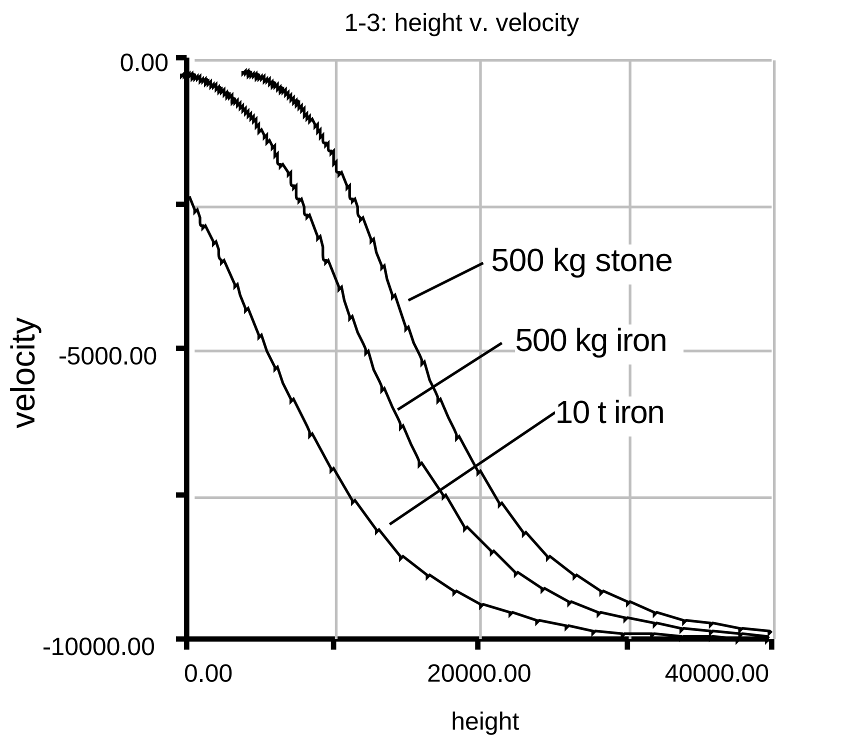

Figure #5B Velocities of different types of meteors. The stone meteor slows down from -10,000 m/s at a height of 40,000 m to nearly 0 m/s at ground level. The big iron meteor still has an enormous kinetic energy when it hits the ground.

Projects at the University of Bremen

The fact that system dynamics modeling is a context-free tool for many domains of physics and allows students to build their own physical models was the starting point for the *Computers in Physics Education Group* at the University of Bremen to engage in development and research in the area of computer aided modeling in 1988. At that time we browsed through a great number of ready-made simulation programs already available. They tended to be limited to single specific phenomena; the theoretical assumptions that went into the source code were not made explicit, and the prerequisite for realizing own ideas afforded the students to learn a programming language. When we accidentally came across STELLA we were stunned by its power. There it was: the multi-purpose, open-ended, and user-friendly tool we had waited for.

From 1988 to 1992 a pilot project "Computers in Physics Education" at the University of Bremen received a federal grant. The project developed teacher-training materials with a large selection of models for various domains like mechanics, oscillations, electrodynamics and radioactivity. The materials were field tested in high school physics courses in the State of Bremen (students aged 16 to 19). The courses frequently worked with STELLA over a period of 6 months up to three years. A follow up project spread the ideas to other states of the Federal Republic of Germany and to other subjects like mathematics and biology.

Standard examples for dynamic modeling in an 11th grade mechanics course (students aged 16 to 17) are:

- Kinematics:
  - bicycle race (uniform motion),
  - free falling bodies (uniform acceleration)
  - shot-putting (two-dimensional motion)
- Dynamics:
  - motion of a parachutist
  - a meteor enters the atmosphere
  - goalkick (friction forces in two dimensions)
- Work: stretching a rubber band
- Momentum: launch of a toy-rocket

In an advanced level physics course these units cover about 30% from a total of 80 lessons in 5 months, including experiments, calculations and modeling. Computer usage both in group work and in the class forum is limited to about 10% of the course time. This shows that computer-based modeling *does not replace* deductions, experiments or calculus-based approaches. Instead it rather *enriches* the spectrum of methodological means.

It works

From evaluating long-term case-studies in several schools we found that system dynamics in physics *works*—in the sense that students actively engage in modeling in small groups and that interesting new examples can be dealt with in class. In an interview a student said after five months of working with STELLA:

> *"In the beginning the computer was a bit too much in the foreground. The question was: How does STELLA work? This may have been necessary because the computer had to be explained to the class. But now it just works, because most of the people have got it. Together we think about the problem, and then - bang - the inputs are made. That is no problem anymore. It just was in the beginning, when we had to learn it a bit."*

The evaluation gives evidence that the modeling system really served the students as a *tool* for solving physical problems. When students failed to arrive at a proper model, the reasons in most cases did not lie in the system dynamics approach but in the more complex cases which posed a greater physical challenge.

We found that the use of modeling systems improves the opportunities of students to formulate goals for own physical investigations and to follow individual paths to solutions—provided that the overall teaching strategy is in accordance with the *constructivist principle* of open-ended learning environments in which students can bring in their own ideas (cf. Forrester's idea of learner-directed learning).

What we do want to know more about is *how* making models fosters the development of physical understanding. Our hypothesis is that the equivalence of graphical STELLA-model structures with the basic theoretical structures, e.g. in Newtonian dynamics, forms an additional *input channel* for physical theory, complementary to equations and descriptions in sentences. Furthermore the need to decide whether a physical quantity is a *rate of change* or a *state* variable often triggers interesting discussions in class that deepen the understanding of physical quantities like *current* (rate of change of *charge*) or *energy* (state variable, effected by the rate *power*). But we also know that not all of the students profit from system dynamics modeling. Some cling to the 'formulas' and others feel overburdened because of the more complex examples.

Current research

In 1996 a grant from the German Science Foundation started a new research project on physical understanding by system dynamics. We want to

Physics *continued on next page*

Modeling Physics, *continued from previous page*

analyze in depth what is going in students' minds when they work with a graphical modeling package. A second issue is the transfer of modeling competence from physics to non-scientific domains. The empirical studies are done in a high-school physics course (advanced level) over 2 semesters (mechanics and fields).

STELLA will also be used in a new research project funded by the European Community: *Labwork in Science Education*. Together with colleagues from France a joint task group works on integrating micro-based laboratories with computer-based modeling. The aim is to bridge the gap between experiment and theory by working on an experiment and a dynamic model in parallel. Experiments serve as empirical starting points for modeling, while modeling results stimulate new experiments or new ways of evaluating experimental data. One example is a close mapping of measurements from decay experiments with corresponding decay-models. The approach will be published in a new International Handbook of Science Education.

[1]*Horst P. Schecker holds the position of Research Fellow in Physics Education in the Institute of Physics Education at the University of Bremen. His postdoctoral thesis for qualification as a university professor is about system dynamics modeling in physics education.*
[2]*MacDonald, W.M., Redish, E.F. & Wilson J.M.: The M.U.P.P.E.T. Manifesto. In: Computers in Physics Education, July/August 1988, 23-30.*
[3]*Horst P. Schecker, Thomas Bethge, and Hans Niedderer.*
[4]*Forrester, J.W.: System dynamics as a foundation for pre-college education. Cambridge, MA: MIT, System Dynamics Group 1990.*
[5]*Tobin, K. & Fraser, B.J. (eds.): International Handbook of Science Education. Kluwer, The Netherlands (in preparation).*

MODELING PHYSICS—THE BOOK

The author of this article has written a book on *Modeling Physics*. that provides the educational rationale for using system dynamics in physics instruction as well as more than thirty fully documented STELLA-models and research results. The book takes a specific perspective on using system dynamics methods and graphics-oriented modeling software in upper secondary physics. The German manuscript is being translated by Jay Forrester's group at M.I.T. The materials will be spread by the Creative Learning Exchange. The STELLA-models can be copied from the WWW-site of the Institute of Physics Education Homepage:

http://www.physik.uni-bremen.de/physics.education/homepage.html

Here is an overview of the content of *Modeling Physics*:

Part I. Basics

Chapter 1. Starter: Modeling radioactive decay

Chapter 2. "Computer-based, graphics-oriented, system dynamics modeling—An introduction

Chapter 3. Numerics

Chapter 4. Why we should use modeling systems in physics education

Chapter 5. How to use modeling systems in the physics classroom

Part II. Modeling Packages

Chapter 6. Overview about physical domains

Chapter 7. Dynamics: force & motion

Chapter 8. Friction: Raindrops, parachutists and meteors

Chapter 9. Fields: Planets, spacecraft and ions

Chapter 10. Mechanical oscillations

Chapter 11. Capacitors and inductors

Chapter 12. Radioactive decay.

Chapter 13. Energy.

Part III. Research

Chapter 14. Research results about modeling systems in science instruction

Chapter 15. A case study from mechanics

Chapter 16. Effects of system dynamics modeling on physics instruction

Getting It Going. . .! continued from page 1

vative in delivery, for example the use of a 4 period day and a graduation project requirement for seniors. SD and STELLA seemed like superb additions to our critical thinking components in the curriculum.

In September of 1995 I began the crusade by "beating the bushes", talking to people, slipping "intro" materials into the e-mail system, and reading to expand my own background. A critical mass seemed apparent by late October so I used e-mail to enlist members in the CVU System Dynamics Study Group. The initial assemblage of 4 students, 6 faculty, the Principal, the main office secretary, and the district legal consul (he had been to a Senge workshop!) met and formulated a work/study plan. At the heart of the program was training for all members. This was addressed through the Road Maps series and in small seminars. As the work of the group moved beyond the introductory SD concepts and settled into developing and refining STELLA models, several members "dispersed". The remaining core group of 9 focused on Road Maps and other readings. We recommend "Introduction to Computer Simulation" by Nancy Roberts(et al), "Principles of Systems" by J. Forrester, "Classroom Dynamics" by Mandinach and Cline, and "Dynamic Modeling" By Ruth and Hannon.

As we were contemplating our next series of steps, in December 1995, I joined the K-12 SDEP listserv and sent out a "feeler" message seeking advice on where to go from here. The advantage of any listserv is its capacity to tap into the collective wisdom on a global basis. Ironically, we found our next steps in a response from self-anointed "pinheads" from a small college 12 miles north of our school. John Heinbokel and Jeff Potash are well know to some in the SD community and serve on the faculty at Trinity College of Vermont. After several conversations and meetings it was apparent that our focus on infusing systems thinking/modeling into all areas in the curriculum would meld nicely with their course titled "Plagues and People". This curriculum studies the system structure of plagues from the Athenian plague to the current scourge of AIDS. Models are developed with biological, social, economic, and political components directed towards assessing the impact of plagues upon human history. Professors Heinbokel and Potash have developed a superb STELLA Tutorial and Tutorial Companion for training "rookies". The course is being run this semester with a mixed enrollment of teachers and students, including groups from the 9th grade Core program. Having students in your education course certainly alters the dynamics!

Currently, and as a result of the emergence of the SD Study Group and our connection to the Trinity College System Dynamics Group, we are proceeding in several directions in our efforts to infuse systems thinking into curriculum. One Core team has presented students with the principles of systems thinking and has begun building basic population models. The initial presentations were given to the 9th graders by 11th and 12th grade students from the SD Study Group. This core group will expand their scope to include the social studies and English teachers. A second core team is developing a systems based, multi-disciplinary unit to open the 1996-7 school year. A group of students and teachers are developing a work plan for assessing the curriculum in all areas of the school and developing a rationale for inclusion of systems thinking and dynamic modeling in these areas. The students will present their rationale and sample models for each area during department meetings in May. They hope this will stir the faculty into seeing the value of this learning tool and begin the long process of infusing systems thinking into the entire spectrum of course offerings. Students in Environmental Science have been using systems thinking throughout their course as concepts presented related to population, biodiversity, and global climate change (the backbone of the curriculum taken from the World Resource Institute materials) has been presented with causal loops and concept maps. A group of students have been using the Tutorial and Companion to learn STELLA. Of note is the new text, "Living in the Environment" by G. Tyler Miller, Jr., which is systems based and has numerous STELLA models within the text. Students in Physics were all exposed to STELLA models during the first semester and a second unit is being planned. As we offer Physics for 2 years, we are evaluating second-year student's use of modeling to determine its applicability for expanded inclusion in the first year.

The number of teachers and students expressing interest and dropping in to "see what we are up to", has steadily increased. A student brought the Supply and Demand unit from Road Maps #6 to the economics teacher, several students have brought models into their mathematics classes, one student has designed his Senior project around systems thinking and dynamic modeling. We are making the first preliminary steps which we think will be effective in evolving a systems thread in all of our curricular areas. We have consciously chose this path for numerous reasons not the least being that we felt sure that the best way to kill a new and useful idea was to hold an in-service on it! We hope to see many of you at the Systems Thinking and Dynamic Modeling Conference in July to update our findings and see how all of you are "getting it going".

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TEACHERS WHO MAKE A DIFFERENCE

CCHS chemistry teacher Al Powers inspires his students

by Tom Curtin

Bronson Alcott, philosopher, Concord Superintendent of Schools in the 1860's, and father of Louisa May Alcott, noted that "teaching is an instinct of the heart. . . the mind refuses to be driven by mechanism, it moves by magnetism." What drew this quote to mind was seeing the many students who returned to Concord-Carlisle High School just prior to the Christmas break to visit their former teachers. Listening to the conversations of returnees and talking to their teachers afterwards made me all the more aware of the profound role teachers play as mentors to young people. No matter how successful or how well-adjusted they and their families may be, students need the support of an adult who cares about them, who has some distance from family.

One such adult is chemistry teacher Al Powers. In his twenty-two years at CCHS, following twelve years teaching in independent and innovative public schools, Powers has inspired hundreds of students to achieve excellence. Two of his most recent successes were 1995 graduates Daniel Phillips and Yoshiki Torii who in consecutive years placed fifth in New England in the American Chemistry Competition exam, a competition in which both private and public school participate.

National Leader in Systems Thinking

One aspect of Powers' effectiveness is his creative teaching technique. He is a national leader in the application of systems thinking and system-dynamics in the classroom through the use of the program STELLA. Using computer simulations and other methods of student-centered and student-directed learning, students, as individuals and as teams, create and conduct their own investigations and data analyses. Powers finds it exciting to engage students in the use of computer models that clarify real laboratory experiences.

Al Powers *(Photo by Lois d'Annunzio)*

One former students observed that "everything makes sense when you really make yourself think about it. . . I think it leads to more thinking and inquisitiveness at all times, not just in chemistry." Another noted that STELLA was a favorite part of the course. "Being a visual learner, it really helped me to see the reactions in easy schematics. The graphs produced were even more helpful. My father and I spent long hours discussing the graphs and talking about the initial change and what was the reaction to that change." Powers makes chemistry come alive for all levels of his students. For example, on e can go by his room in the afternoon and see students of all abilities working on projects that they have designed.

Started Science Olympiad Team

Powers started the Science Olympiad Team in 1986. In its first eight years the team won the state championship four times and came in second twice. One parent was delighted that the Science Olympiad Team had turned his daughter on to science. He drove his daughter to school every day during Christmas vacation so she and her group "could work on a machine that used different forms of energy transfers to separate paper clips, toothpicks and marbles. She never knew that science could be so much fun."

Powers' contributions were recognized nationally last year when he received the Tandy Technology Award fro Teaching Excellence in Mathematics, Science and Computer Science. He has also been nominated four times for the highest of awards, the National Science Foundation's Presidential Award for Excellence in Science and Mathematics Teaching.

Instinct of the Heart

More valuable, however, are the relationships Powers has with present and former students. He is among the first—if not the first— to communicate regularly with his former students by e-mail through which he shares new academic problems, life's experiences and jokes. His "instinct of the heart" is summarized well by another student:

Perhaps one of the best things about Mr. Powers' class was that he was excited to be teaching it. He loved the subject and he loved his students. He treated everyone with a respect that some teachers overlook. I was never intimidated in his class. . .Rather, I felt encouraged to accomplish great things. He did the same for everyone—whether they were male or female, whether they were struggling in the class or breezing by. His enthusiasm and respect for us gave us confidence in our abilities and a desire to perform well. Being in Mr. Powers' class was one of the most rewarding experiences of my high school career. Not only did I have a great teacher, but I gained a friend."

Tom Curtin is a member of the CCHS guidance department. This article is reprinted with permission from the Carlisle Mosquito, January 26, 1996.

Updates. . . continued from page 2

The five finalist teams included 2 teams from Franklin, two (i.e. both!) teams of sophomores (!) from LaSalle HS (note they don't have a course!!), and one team from Wilson.

The presentations were excellent! They were nervous of course, but collectively did great. Honorable mentions: Sir Gawain (LaSalle) and Atmospheric CO2 (Wilson). 3rd was the population model (LaSalle), 2nd was a lung cancer epidemiology model (Franklin), and 1st, Estimates of time of death by body temperature (Franklin).

This latter team did real experiments, measuring the time required for a one-gallon jug of water to cool from 98.6 degrees to ambient. The jugs had (a) no towel (nude), (b) one towel (moderate clothing), (c) wet towel (wet clothes), and (d) two towels (heavy clothes). They were a little apologetic because they wanted to add wind chill factor and differences in surface temperature, but they said this made it too complicated! (for now!!)

Each member of the first place team will receive $250, 2nd place $150, and third place $75. Every member of the 5 finalist teams will receive an authoring copy of STELLA II. Additional financial support was also provided by High Performance Systems, for which we are very appreciative.

We have received support from the medical school and university at the President and VP levels. They have contributed copying expenses, space for the event, and picked up lunch for all the student teams and their advisors. I purposefully chose the med. school location because I have been diligently trying to “infect” the biomedical teaching and research community with SD, and this should provide a good vector.

We hope that this will be an ongoing event, and we are very interested in providing written materials, organizational advice, and moral support to anyone who wishes to follow in our footsteps. I'd like to see this expand into a national event, with significant publicity and scholarship prizes. In particular, as the outline for the reports gets tuned up we feel that this will constitute a valuable document regarding the conceptual development of any new model. This should be useful for teachers and practitioners at many levels.

I'd like to see our first prize escalate immediately from $250 per student to $500 to $1000, finally settling at $2500 for an Oregon State Champion 4 or 5 years from now. This would probable lead to a total budget of about $2.5K this year, to $5K, to $8K, to about $11-12K. I'd like to hold it at that level until it is possible to begin a separate national contest. (It WILL happen! $10K scholarship per first place team member...)

It seems like we could provide a schedule to show that an initial local event could grow to a state-wide event over about 4-5 years. If we can encourage this effort in several other states (AZ, MA, GA ?), then after they have about 3 years experience we could begin to consider a “playoff”.

Lest we lose the emphasis here, the real stars were the students. Unbelievable!

Ed Gallaher, Ph.D., Research Pharmacologist, Assoc. Prof. of Physiology/Pharmacology and Behavioral Neuroscience, Director, Center for Biological System Dynamics, Oregon Health Sciences University, Portland, OR 97201
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St. Albans Colllege, South Africa

We received a cheerful note form Carol Ashton, a teacher at St. Albans College in Garsfontein near Pretoria

Hello, Everyone! Exciting news. We have just had Andries Botha in to run a SystemsDynamics course for 20 of our boys over 2 days. I have seldom seen the pupils so excited and so involved. They worked solidly from 8 am to 4. 30pm with very short breaks in between. Their discussions weretotally focussed. They hardly asked to be excused. Many stayed on afterwards to complete their own models. We are on vacation for 4 weeks now, but I am sure that early next term I will be able to e-mail you some of their work. I must admit that after this 2nd two day course I am at last getting the hang of it. I am sure that I will be able to learn a lot from the pupils who were all coping very well. We now have 5 copies on the network for the boys to use. Some of them have entered competitions this year and they are hoping to have a model as part of their submission. We are the first school to be involved in this so I am hoping that if it comes off they will win the competion. Hopefully then more schools in S. A. will become involved. Best wishes,

Carol Ashton
CAA@stalban.pta.school.za

The Beer/Soda/Oil Biz Game

The "Beer Game", a simulation game which reveals to players the problems inherent in the production and disttribution of a single brand of beer, was first developed at MIT in the 1960's.

Now, Paul Monus of Lima, Ohio, with a team from BP Oil, has developed the Oil Biz Game. “The game is based on a system dynamics model of the logistics of acquiring and refining crude and then moving product to the terminals and finally to retail marketing. Players learn that looking at an entire process—this is what systems thinking is all about—is essential for gaining insights necessary to control the system as a whole.”

Several years ago, Will Glass-Husain created a version of the Beer Game game for high school students. Called the Soda Game, it is available on disk from the Creative Learning Exchange.

❖

NEW MATERIALS

The following materials are now available from the Creative Learning Exchnage. They are either new materials or those which were not listed on the List of Materials sent out last October. All new materials are available in disk as well as paper copy. A few are older documents now available on disk. Disk cost is $5.00; paper cost in parentheses.

5LESSOCC ***Getting Started: Five lesson plans to help teachers introduce System Dynamics to their students.*** Cathy Curry, BA, M.Sc. In Ed.
Five lesson plans, intended to complement the Road Maps series, which support the introduction of System Dynamics in the classroom. These five lesson plans are complete with class and homework assignments and will take teachers and students through the steps necessary in learning any new method. ($1.50)

TEACHIPL ***Teaching Systems Thinking to Children with Attention Deficit Disorder Through the Use of Mapping Software.*** Patricia London
(Lead article in the CLExchange newsletter, Winter/Spring 1996) The study of a project designed to determine if children with Attention Deficit Disorder could improve their understanding of causal relationships and visually diagram sequential information. ($1.00)

HISTORJP ***Building Systems into the History/Social Studies Curricula: Some Preliminary Thoughts.*** P. Jeffrey Potash
(The lead article in the CLExchange newsletter, Winter/Spring 1995) Thoughts on using systems thinking and dynamic modeling to improve levels of historical literacy. ($1.00)

MODPHYHS ***Modeling Physics: System Dynamics in Physics Education***. Dr. Horst P. Schecker
(Lead article in this issue of the CLExchange newsletter.) System Dynamics modeling helps to shift the focus of physics instruction towards more qualitative learning. Dynamic modeling requires students to analyze a phenomenon and develop the model, whereby they are introdyced into the strategy of expert problem-solvers, i.e. to concentratee on a conceptual aand semi-quantitative analysis. The modeling system supports the learner both in constructing the model and exploriing its physical adequacy through simulation runs. ($1.00)

STEVEC-S ***Steve's Dilemma***. Maury Cotter, D. Seymour, & J. Sensenbrenner
(Lead article in the CLExchange newsletter, Spring 1995) Excerpted from "Kidgets," this is a story about a child who has an intrinsic desire to learn and a learning style that conflicts with the standardd teaching style. The loops illustrate some very powerful messages about how we approach teaching and even how we structure our school systems. ($1.00)

INTERESTED IN INVESTING?

If you would like to invest in our effort here at the Creative Learning Exchange, your contribution would be appreciated. You may donate any amount you wish; perhaps $50 is a reasonable amount for a year. All contributions are tax-deductible.

I am sending ________ to *The Creative Learning Exchange* to help invest in the future of systems education.

Name____

Address____

Thank you!!

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