Working Paper: A Case Study of Materials Development Fostered by the MVHS CoreModels Project

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Introduction

The Maryland Virtual High School of Science and Mathematics was funded by the National Science Foundation in 1994 to create a Internet based community of teachers working together to integrate computational modeling into their classes. As others have found (Mandinach and Cline, 1994; Roberts & Barclay, 1988; Stratford, 1996) it proved challenging to achieve a broad-based adoption of modeling tools and curricula and especially effective classroom implementation of standards based modeling activities. Although the project successfully created an online community around collaborative computational modeling, teachers were frustrated by a lack of modeling activities correlated with national and state goals. Developing and refining such activities was an initial task of the MVHS CoreModels Project in 1997. Creating flexible modeling units tailored to state standards and curriculum goals, and developing close collaborations among teachers of specific scientific domains were steps in the goal of supporting teachers in becoming sustained and thoughtful users of CoreModels materials and system dynamics modeling.

In addition to actually providing teachers with modeling activities, the CoreModels materials development process achieved other goals. The collaboration among teachers in refining materials promoted teacher ownership of the product and process. Development of materials focused teachers on the sequence of presentation of topics and models, the sequence of presentation of STELLA (dynamics modeling software) skills, writing clearer instructions and asking better questions. From 1997 through 2000, teacher leaders guided the development or adaptation of biology activities including deer population dynamics, the carbon cycle, stream water quality, glucose regulation, natural selection, human genetic conditions, and enzyme reactions. Physics modeling packets were designed to help students investigate kinematics, dynamics, momentum, applications of force, free fall, projectile motion, universal gravitation, and Newtonian cooling. In earth science, the project created activities focusing on the water cycle, the rock cycle, erosion and soil loss, earth energy balance, hurricanes, volcano ash transport and orbits. Chemistry packets included radioactive decay, diffusion, kinetics, chemical equilibrium and Rutherford's gold foil experiment.

Three CoreModels regional centers divided responsibility for working with teachers from thirteen districts in Maryland. The Northern Region Center Director, Don Shaffer, oversaw the development of biology materials and the Western Region Center Director, Charlotte Trout, took charge of the development of physics materials. Central Region Center Director, Susan Ragan, handled the review and editing process, as well as integrating mathematics materials with these content areas. During the first year of the project, 8 biology and physics supporting teachers (STs) piloted activities in these subject areas. Thirty additional biology and physics teachers enacted these activities during the second year of the project. Development of earth science, environmental science, and chemistry materials did not begin until spring 1999 in preparation for accepting teachers of these subject areas in the third year of the project.

Prior to the project, as part of her involvement in the first MVHS project, the physics leader had developed a basic worksheet for simple kinematics (with STELLA instructions) and several one-page worksheets for other models. Students did some models "off-the cuff" with verbal instructions. The biology leader had developed the stream model during his work with the first MVHS project, but it took him an additional 18 months to develop a student guide for this activity that other teachers could use successfully in the classroom. Development of a teacher’s guide took even longer. Since the beginning of CoreModels, he has coordinated biology materials development and continued to revise a core group of biology materials based on his own classroom experiences as well as feedback from the supporting teachers and new participating teachers.

It is important to understand that the Central Region always had at least twice as many teachers as either of the other regions. Thus this region started with 4 STs, while the Western and Northern Regions had 2 each. In addition, the Central Region Center Director, in being released half time for two separate grants, had more freedom and could arrange her time more easily. She was located in the same office at Montgomery Blair High School with the Project Director/Principal Investigator, so that daily interaction occurred between the two. These factors led to a greater influence of Central Region activities on the project as a whole.

Although the main body of this paper represents the ideas of all the authors, the three Center Directors responded to several requests from the project director to give their perspective on the CoreModels activity development process. Don Shaffer, the Northern Region Center Director is alternately referred to as the biology leader. Direct statements from Don are labeled DS. Charlotte Trout, the Western Region Center Director is alternately referred to as the physics leader. Direct statements from Charlotte are labeled CT. Direct statements from Central Region Center Director Susan Ragan are labeled SR.

The rest of this paper will consist of three main sections. In the first section, the purpose of materials development and CoreModels materials in particular will be explored. We will first consider the general purpose of materials development as part of a teacher inservice or educational research effort. Then we will investigate how the make up of CoreModels materials fostered the project's goals. The second section will detail a chronological history of materials development from fall 1997 through the 2000 school year. The third section will examine how several issues, including materials revisions, teacher collaboration, and management problems, affected the development process. A final section will put the successes and trials of the CoreModels materials development effort into perspective and consider recommendations for the future.

Purpose of Materials Development and CoreModels Materials

Purpose of Materials Development

In looking back on the materials development process during the spring of 2000, the physics leader wrote

> Before materials are developed, those involved in the process should know the primary purpose of the materials. I think our primary purpose has changed each year and that has been a large contributor to the confusion. When we started we felt we had to have everything spelled out and ready to go, emphasizing collaboration only between STs and CDs. We were talking about final copies of materials. By the second summer, we were looking for much broader collaboration and were focused not on the product but on the process. CT

Along the same vein, the biology leader added

> Also at issue is whether the primary goal of materials development should be the quality of the materials, the degree of student learning which they elicit, or the process of developing them and the relationship to teacher professional growth. DS

CoreModels leaders had to make "a critical decision in the design of professional development… whether to engage teachers in curriculum development or help them learn to use existing materials (Mundry and Loucks-Horsley, 1996). Through an effective curriculum development process teachers may become more attuned to students' needs and develop a feeling of ownership over the academic program. But teachers may not be able to fashion a meaningful and coherent curriculum due to a lack of time and content knowledge. Leaders must decide how each teacher will be involved in the process. If curriculum development opportunities will be limited to a few teachers, the project must provide opportunities for others "to engage in their own learning of science and mathematics" and "to decide how to use the new materials in classrooms" (Mundry and Loucks-Horsley, 1996). Interaction between "leaders", "curriculum developers", and "users" should include the opportunity for teachers to reflect on their classroom practice in implementing the units, providing insight for future refinement to both developers and users.

Our emphasis on product during the first year was a reaction to the dissatisfaction during our previous work with the lack of effective modeling materials. As time went on, we saw the process of developing and refining modeling activities as inseparable from the professional development process – for ourselves (the project leaders) and our teacher participants. The main result of all educational research in mathematics and science should be a change in individuals and in the culture. (Sabelli, 2001) A process of creating or adapting curriculum as part of a inservice/research project must result in the growth of teachers and leaders and in change in the culture to provide greater support for such collaboration.

Curriculum design is just the center around which discussion and important ideas go on. It is a tool for other questions to be addressed. It is a vehicle to hammer out issues and bring together teachers to think through these issues. What is the framework on which we are building curriculum? Goals and benchmarks are not enough. We also need to consider the best way to bring out student difficulties, abilities, and cognitive skills so they are visible to the teacher. " Issues are the important contribution. Curriculum is the glue. It is a useful byproduct/set of prototypes" (Beverly Hunter, 1994).

Having examples or prototypes as starting points for teacher training and classroom enactment jump-starts the process. The biology leader agreed that teachers should be brought into the development process, but that

> I'm just arguing that a core group of 4 or 5 models for each of the subject areas be developed by or under the care and guidance of a CD. Pairing is a nice idea, but we know what a stumbling block communication is. These are the core of what we present to the teachers in the summer and to the outside world. This leaves a lot of model topics out there for others to develop and time for them to evolve and ripen. DS

But he also agreed that

> The collaborative process of developing and refining the materials has provided increases in their overall quality as well as promoted teacher ownership of the product and process. The open ended process of materials development and revision has also provided significant challenges and resulted in an ongoing, sometimes heated debate, especially among center directors. DS

The debate among the leadership team was part of the process of people change and learning that is always a significant outcome of an effective research project. The Western Region Center Director explained how her role as physics leader helped her grow

> Having to write materials to present to others so that would see the advantage of using STELLA in their classroom forced me to focus in many ways. It was a very positive experience for me in my classroom and in working with various teachers across the state. I saw things clearer at each step of the way. I wish the collaboration had been stronger and I wish there had been a set of standards for others to follow. CT

The process of enacting modeling activity prototypes as part of the <u>community effort</u> to clarify goals and highlight student learning difficulties can be confused with the process of revising an activity so it more closely fits the needs of a <u>particular teacher and students</u>. The first alternative is collaborative – with the goal of improving the prototype activities **and** teacher understanding. Leadership is crucial in carrying out this development, enactment, reflection, and refinement process. The second alternative is more likely to occur when an individual teacher makes changes in a particular activity – with or without the help of a more knowledgeable peer. The Central Region Center Director was focusing on the second alternative when she wrote

> One goal was to support teachers in the use of computer modeling in their classes. To do that, we had to develop activities. How do we support teachers? Do we let them do their own revisions and keep them secret - only known to themselves? Do we demand that everyone do things the same way? Do we

> encourage their active participation in the revision process and disseminate those revisions, risking confusion in the process? From my recent experience using CoreModels activities in math classes, I know that I pick and choose what I want to use and when I want to use it. I adapt my teaching to the situation. I guess I have that goal in mind for our CoreModels teachers when they do computer modeling. SR

And yet this leader seems to also advocate for somehow including this teacher in improving the activity prototypes

> The CD believed that listening to PT's ideas and responding to them would empower the PTs and make them feel like valuable contributors to the activity development process. SR

Engaged teachers naturally create their own classroom materials. How do we tap this creative strength - and sense of ownership – while providing guidance to help them recognize the weaknesses in materials/process that may occur? Looking at classrooms of teachers involved in a project like CoreModels tells us what might be achieved when teachers design, build, and sustain the programs conceptual framework, the curriculum, and their own community of practice. "CoreModels teachers have a level of ownership over their modeling curriculum and classroom activities that is central to their teaching of these concepts." (Friedman and Culp, 2001)

As a REPP research project, the goal of CoreModels was to investigate student enactment of modeling activities in the classroom. It had some of the characteristics of a design project and some of the characteristics of a larger scale implementation project. Not all of the sixty some teacher participants were interested or equipped to be directly involved in developing modeling curriculum – other than reflecting and providing feedback to the development team. But many were interested in modifying materials to fit their own needs. As such, CoreModels has lessons for other implementation projects. Large-scale projects have tackled the issue of teachers modifying materials.

> Scaling is a major thrust of educational reform initiatives; without broad impact in a large number of schools reforms run the risk of making no lasting change on the educational landscape. One of the clear lessons from our work is that curricular programs can not be 'scaled' in the sense of providing cookie-cutter curriculum that researchers feel must be implemented in a particular way in a wide variety of school settings. The resources and constraints that individual teachers encounter are divers and cannot all lead to the same enactment. We obviously want our curriculum to be adopted by as many teachers as possible, but we do not prescribe, or even anticipate that they will all enact it the same way. We build curricula that we fully expect will be adapted by teachers to their local classrooms. We think that this flexibility is one of the real strengths of our curricular programs. (Songer & McDonald, 2001)

Such implementation projects start with well-tested activities. In a project like CoreModels, curriculum development may play a crucial role in driving the evolution of even less involved teachers' thinking about modeling and systems thinking over time. "Discussions during reviews of new curricular units, or during teachers' reports on their trials of new units with their students, were often occasions for particularly productive discussions of the function and purpose of modeling and the learning goals teachers were associating with the units. During the latest stages of the program, these discussions about learning goals led to discussions of the appropriate assessment practices to associate with these curricular units… In sum, these teachers used the curricular writing and revision process to develop and clarify their own goals and expectations for modeling and systems thinking within their curricula". (Friedman and Culp, 2001)

The two networks of curriculum developers and classroom implementers interacted primarily during face-to-face workshop sessions. During workshops and some online interactions, teachers' discussions of their real life experiences with the curricula intersected with the developing thinking of the core curriculum team. "These conversations were the key moments when the "big ideas" of systems thinking and modeling (especially about learning goals and optimal curricular and pedagogical approaches) combined with teachers' "real life" concerns and enthusiasms. The culture of this program framed both the "big ideas" and the "real life concerns" as being valid and important issues. Consequently, these conversations allowed teachers to explore, over time, how they might change their beliefs and practices in order to work more effectively with their students with these tools and curriculum." (Friedman and Culp, 2001)

Much of the discussion of this section has focussed on the benefits to teachers in working together in creating and refining modeling activities. We will look as the pitfalls of this collaborative process in a later discussion on revision and collaboration.

Purpose and Characteristics of CoreModels Materials

This section discusses the general purpose and characteristics of the series of CoreModels modeling activities. Then the make up of the student guide and of the teacher guide is examined. Finally, a few issues involved in designating an "official version" of an activity packet are considered.

CoreModels has attempted to relate our modeling activities to two things: important student goals (CLG and National Benchmarks) and tasks and questions that will bring out student difficulties, student abilities and cognitive skills so they are visible to the teacher. In designing each activity, we must ask these and answer them.

- How does the teacher know what is holding the student back?
- What previous skills are we assuming?
- What sequence of complexity will work?

The physics leader quickly realized that the conceptual framework of her subject required that she consider the overall set of activities. She focused on a sequence of presentation of topics and models, and a sequence of presentation of STELLA skills in mapping modeling activities to the conceptual framework. As time went on, her overall focus included writing clearer instructions and asking better questions and including motivational information. Why we should use these packets in our classes?

This teacher realized that there were many possible purposes in CoreModels materials. These include learning opportunities for teachers as well as students. Presenting STELLA within content areas so teachers can quickly see its usefulness, showing sequencing of content, modeling and system ideas to teachers, involving teachers in constructivist thinking elicited by the materials design, getting teachers to collaborate and thus share ideas about teaching are all possibilities. Exposing students to computer modeling and/or systems thinking, giving students alternative activities (modeling) for learning the content, having students gain greater facility in interpreting behavior over time graphs, meeting the requirements of state CLGs may receive different emphasis within a particular activity. At any particular time, the relative importance of each of these goals has varied for each teacher leader and each teacher. But teacher leaders have agreed that

- our materials exhibit a hands-on, constructivist approach
- our materials address important concepts/content and
- our materials should ask the bigger questions: graph interpretation (what does this graph actually mean), generic processes (in graphs, science skills & processes), real world applications, systems common themes, connection within and beyond a discipline, extensions

We also agreed that modeling units to be developed would fit the existing Maryland science curriculum to avoid making modeling an "extra" curricular area that teachers would not find time to use. Instead modeling would be integrated as a mode of inquiry into existing curriculum structures.

Procedures to be followed in the student guides were designed so that classroom activity implementation would be as free as possible from logistical problems. Freeing teachers from such concerns allows them to spend their time facilitating students in critical thinking processes, not logistics. The questions in the student guide were designed to elicit an array of higher order thinking processes including; sophisticated graph and data interpretation skills, prediction, systems thinking, making connections between computer model results and the real world i.e., actual organisms in the laboratory or outside environment. The

Student Guides were crafted with a scaffolding approach in order to provide the stepping stones necessary to help elevate students to the higher order thinking levels. Careful consideration was given in the materials design to allow all levels of students to achieve of these high expectations.

In order for the student guide to work smoothly, activity designers must be aware of sticking points such as problems in students understanding of how to manipulate the model interface. It must provide very thoughtful scaffolding, having questions and/or directions to take students through an understanding of basic concepts and interpretation of model output, especially graphs. It should be limited in length to two 90-minute periods or 3 45-minute periods, the time limit most teachers are willing to spend on modeling activities. Yet the guide must be thorough enough to help students reach a critical depth of understanding, which often entails twenty to twenty-five questions. There must be enough space to answer questions completely – lines not empty space. A guide that fails logistically often results in disaster. Then teachers quit before guiding students through higher order thinking questions.

The teacher guides provide a variety of resources including; an activity overview, lesson plan tips, answer keys, a correlation between the materials and state standards (Maryland Core Learning Goals), National Benchmarks (AAAS) and a constructivist approach (5 Es). The teachers guide should have a concise unit overview that references the particular CLG expectations (the text of these belongs in the appendix). Most of the guide is taken up with lesson plans with best practices and teacher tips. These plans include descriptions of possible pre-modeling activities (wet labs), introduction remarks, day1 and day2 activities. The discussion for day 1 must cover critical logistics, expectations, graph interpretations, and limited essential pre-requisite knowledge. Day 2 remarks should focus on a foreshadowing for higher concepts, real world applications, and system thinking common themes. Working with students in the computer lab each day requires additional information. On day 1, teachers need to know about logistics, tips, and expectations of how far students should get. Day 2 tips include interacting with or interrogating students on graph interpretation, HOT, real world applications, etc. The guide must include an answer key and appendices showing various stages of the model and model output, equations, Benchmarks match, CLG match, and references.

The goal of CoreModels materials collaboration was to improve prototype activities and increase teacher understanding of effective pedagogy to help students become subject area modelers. Thus unless teachers needed to make changes to reflect objectives for a modified course of study (AP, environmental science versus biology) they were expected to try the original activity version before making modifications. Teachers were cautioned against assuming that their students were less intelligent than those of the original author. First and foremost, only materials already tried in front of a classroom should be presented to other teachers. Review of modified packets by subject area leaders was required before they were publicly distributed as CoreModels activities. The guidelines above were implicitly accepted by most of the leadership team most of the time. Even with these substantial challenges, we were able to settle on some generic versions of many activities by the end of the project.

Chronological Retrospective of CoreModels Materials Development

Initial Activity Development, 1997-1998 School Year

When the CoreModels project began, we had two center directors with experience in STELLA in biology and physics instruction. We also had 8 supporting teachers to train. Both CDs taught in a 4-by-4 block that meant they could teach the same course twice during a single school year. Therefore, in the fall of 1997, the two CDs wrote and field-tested activities with their own students. They used the same materials to train the STs. By the spring of 1998, the STs piloted the materials with their own students and provided feedback to the developers. Developers rewrote text when clarification was requested. In late spring, the leadership team asked the STs to write activity packets in the format that had been agreed upon.

As discussed above, an important consideration in developing materials is that they offer a variety of activities that target the core curriculum and span the scope of the curriculum. We wanted to promote much deeper thinking about the content and concepts that teachers were already teaching, not to add more to the load of an often already overburdened curriculum. The biology leader initiated the development of almost all of the biology activity packets. He was given time to do this through half time released position funded by the NSF grant. This time/funding commitment was essential in getting the biology classroom implementation portion of the program “off the ground”. Teachers coming into the program were provided with a group of classroom ready materials that spanned the core curriculum in their subject area. Although no other biology teacher has created a model or activity packet from scratch, many have eagerly participated in revisions. This is not surprising, considering the substantial time commitment necessary in creating an original model along with pertinent activities. The supporting teachers contributed significantly by adapting, modifying, and creating alternative versions so that by the end of the first year, most of the biology materials included work by several teachers. The development of the biology computer model activities has been, and continues to be, a fundamentally collaborative process. Almost all of the dozen or so biology packets have two to four teachers’ names on their cover sheet, indicating significant contributions to their development or revision.

By the end of December the physics leader had created simple student activity sheets for models of free fall, tailgate, applications of force (including rocket and parachute), harmonic motion (emphasizing conservation of momentum), universal gravitation, conservation of heat, Newtonian cooling, Coulomb’s law, Ohm’s law, and capacitance. All of these activities were class tested and all the mechanics activities were deemed as good CLG matches. Some of the activity sheets had already been dispersed to the other physics teachers by this time.

In the first year of the project, the physics leader and physics STs met once to discuss current materials as well as other possible models and the materials that would be written for them. Creating a student guide for current activities entailed adding additional directions, content information, and resources. Teachers’ guides were also needed. The four packets written by the physics leader contained lab activities as well as model activities in most cases and followed the suggested guidelines for constructivist based activities at the time. Teacher sections and appendices were included. One of the 4 packets contained 5 different models, one of which borrowed heavily from an earlier MVHS project. Because one person worked on these, a sequence to the packets became obvious and it was possible to construct the packets so that they not only showed the development of physics concepts but also the development of STELLA skills. This was a major benefit. This sequencing of the concepts and models may have taken many more years to recognize without the materials development effort.

Each of the STs wrote one packet. The packets from the STs were much less complete. One had well thought out activities for the students but seemed a bit out of sequence. Another was nothing more than a resubmission of the original one page activity given to that teacher by the CD as a possible starting point. The third teacher had included a lab activity and a constructivist structure, but again, the packet didn’t resonate well with the sequence that was arising from the other packets. The CD reworked several of the packets so that they fell into the sequence and so that there was uniformity in presentation and appearance.

It should be noted that the CDs had prior experience with STELLA and were released half time to work on CoreModels, whereas the STs were full-time teachers and had just learned STELLA for the first time. Activity development requires knowledge and released time. Field-testing and revisions are critical to producing a product that can be widely used.

Summer 1998 Participating Teacher Workshops

Workshops in the Central, Northern, and Western regions were scheduled so that material developers could participate in each one. Sessions introduced biology and physics teachers to computer modeling through the instructional activities which had been developed and field-tested by the MVHS center directors and supporting teachers. During the first week of the workshop after a series of presentations by center directors and supporting teachers, the teachers worked through the MVHS activity packets in hands-on labs in the same way in which their students would during the school year. This gave the teachers an understanding of both the frustrations and the learning made possible in an environment in which students build models to represent real-world systems and use models to test hypotheses.

During the second week of the workshop, the teachers worked in pairs to present an MVHS activity to students attending a related workshop. This practice teaching allowed the teachers to see firsthand the kinds of errors commonly made by students as they work with the computer models. Teachers also worked in groups to reexamine models presented during the first week, to suggest and develop modifications to the models or the materials and to explore models which would be of interest to their students.

The biology teachers examined 9 models and activity packets. These included the enzyme, deer population, stream, and carbon cycle packets. The physics materials for the first summer workshop consisted of 8 activity packets. All these packets contained laboratory activities as well as STELLA activities. Only one or two contained possible rubrics for assessing completed student work. The materials were presented at the Central Workshop in late June and suggestions regarding wording of questions and instructions were incorporated into early revisions. Teachers exchanged ideas about appropriate activities to precede and follow the use of the models in classes. The remaining two workshops had a similar approach. Physics teachers quickly grasped the advantage of a sequencing of materials and the power of using the modeling software. They were well prepared with lab activities on their own, so that leaders did not spend time adding them to materials. All project leaders received feedback that helped in learning how to write clearer questions.

Development and Revision, 1998-1999 school year

Biology participating teachers generally used the existing materials during the first semester, but began showing interest in developing new models and materials by the second half of the year. They also contributed feedback on the materials based on their implementation experience. This was particularly valuable when discussions were held with teacher leaders near the time of classroom implementation of the activities. This ongoing collaborative process of materials development was expected to become continually richer as long as experienced teachers stayed involved in the program.

During the summer, it was anticipated that deer population would be the first modeling activity enacted by classes in the fall. Therefore, a detailed description of using STELLA icons to build the model was included in the materials. Once school started, some teachers decided to use the Carbon Cycle model as the first modeling experience. After helping a class build that complicated model, the Central Region Center Director rewrote the directions to lead the students through the model-building process. Testing it at another school showed that after the revision, the Carbon Cycle activity proceeded much more smoothly.

The physics team never experienced the level of collaboration on materials that the biology team seemed to enjoy. There was dialogue between the teachers and the physics leader who tried to incorporate all suggestions that seemed to improve the packets. In the fall, the CD took all the suggested changes (mostly rephrasing of student questions) and edited the materials, making the "new" versions available at a fall meeting attended by teachers from all three regions. At that meeting an additional packet (now nine in all) appeared based on the suggestion and work of a first year teacher who attended the Western workshop. Later in that year, another Western teacher developed an additional packet based on summer discussions and using a differential approach. It was circulated to several teachers.

Physics teachers throughout the state used these edited materials during the first three months of the 1998-1999 school year. Teachers with applied physics classes or physical science classes modified the materials, generally with the assistance of a teacher leader, to fit the needs of their students. For example, since two teachers wished to use the Simple Kinematics and Free Fall packets for freshmen taking Matter and Energy, the Blair physics teacher worked with the Central Region Center Director to re-write the packets with directions and questions appropriate for ninth graders. Also, some teachers began sharing new models and materials they designed to teach these models. To the physics leader it seemed that the whole process also began to spin out of control since these materials were not reviewed before dissemination.

During the Western Regional Workshop in December a discussion arose among physics teachers about the types of questions included in the activity packets. Responding to this discussion, the physics leader conducted a partial revision of physics materials reemphasizing student learning goals for the second semester. These revised materials required additional higher order thinking of the students and made stronger connections between the various packets. The revised materials were first tested in the Western Region Center Director's classes.

The biology and physics materials were written so that student answers and directions were interspersed in the same packet. For large schools with limited paper, this caused a problem. Central Region Center Director Susan Ragan changed the layout of three packets so that a classroom set of directions could be used by several classes while question and answer sheets were provided for each student. An experienced editor accepted a contract to edit CoreModels materials for future publication. She worked closely with the CRCD to present content and pedagogy in a visually pleasing manner. Having an editor on board allowed the CoreModels teachers to concentrate on the models and the student questions rather than the layout and appearance.

In response to a variety of teacher requests, work was started on supplementary materials focusing on content background and math background. Since many texts have little information on the carbon cycle, supplementary materials were added to that packet. Some biology packets require curve fitting and calculation of growth rates, so explanations of math concepts were added. To assist those who forget some of the basic STELLA operations, a set of reference sheets to be posted in the classroom or kept in a notebook was developed. Common modeling errors were compiled into a set of debugging hints for teacher and student use.

During the 1998-99 school year, while CDs were supporting their PTs in physics and biology, the physics leader accelerated the development and testing of chemistry activities and the biology leader took on the development of environmental science activities. The project director worked on the design of earth science activities. With only a short time to get ready for summer training of environmental science, earth science, and chemistry teachers, leaders concentrated on creating clear student activity sheets. Unlike the previous year, there were no STs to field-test materials as they were being developed (the STs did not teach those subjects). Consequently, the chemistry, environmental science and earth science materials were in a much rougher form in the summer of 1999 than the biology and physics materials had been the previous summer. The CD authors had tested their activities in their own classrooms (and perhaps one other), but the earth science activities had little or no testing. Clearly, the project leadership team was overextended.

Previous experience had shown that modifications would be made during the summer and next school year. Teacher guides and fancy formatting would be added as the student activities were tested and refined. Several of the models were cross curricular and had been used extensively. Others had been used in the past in a few classes. Experience had taught that quality is more important than quantity since during 1998-99 90% of the classroom implementation focused on the four or five most popular biology and physics activity packets.

One bright spot was the email chemistry collaboration between the physics/chemistry leader and the project director, who was not an expert in chemistry. She reviewed the model and materials and asked questions as they were developed.

> The collaboration was like a breath of fresh air. It was the first time that anyone had looked over my shoulder while I was creating and it took a lot of the “fear” out of the process. I wish all our materials had this amount of energy put into them. CT

Summer 1999 Participating Teacher Workshops

The 1999 summer workshops followed the successful format of the year before. But during the summer of 1999, the three CDs conducted training with less support from one another. This caused confusion because the author was not available to train neophytes with their materials. For example, a graph packet was developed during the Central Region workshop. Did the other regions benefit as much from the packet when those teachers did not participate in its creation? Would a survey show that the packet was used most often with students of Central Region teachers, even though it was distributed to all?

By the arrival of the summer workshops, packets that had never been seen by the physics leader were being presented to the second cadre of physics teachers. In most cases these materials had simple editing changes for presentation, but occasionally, important concepts had disappeared or been "dumbed down". If these packets had been presented as alternatives to the original and explanations provided as to why they were altered, teachers could have been engaged in a worthwhile discussion, with the author of the original version presenting her point of view. But materials seemed to be coming out of nowhere and there was no longer a control on the "official" workshop version. Some materials bore no revision date or author, so there was often confusion and frustration in preparing for a workshop when a CD had to present materials written by someone else.

By design, chemistry materials were presented at the summer workshops in less than complete shape, with the idea that teachers would collaborate to complete teacher guides and improve student questions. The CD who wrote the chemistry materials could not do extensive training with those materials at the Central Region workshop. Consequently, a ST took over. Without the benefit of the author's presence, the PTs struggled to understand the material. Many of them returned during the summer to help the Central Region CD revise the packets to include the support these teachers felt they needed for classroom implementation. According to the chemistry leader

> Collaboration seemed to involve only one or two teachers and focused on their idea of what would work in their classroom and some of the least significant packets became the most argued over, while the packets that had the most to teach fell into disuse. CT

The CD who wrote the environmental science packets did a one-day crash training at the Central Region workshop. No training on the environmental science packets was conducted at the Western Region, as teachers there concentrated on other subject areas. As author, the Northern Region CD was available to conduct more relaxed training for environmental science modeling at that workshop.

The project director worked informally with earth science teachers at the Central Regional Workshop. The teachers worked through a different modeling activity each day of the first week. It was clear that these teachers had many ideas about improving materials, but they needed classroom implementation experience as well as a deeper understanding of system dynamics before they could modify the materials without extensive guidance. One of the teachers came back later in the summer to work with the project director on adding missing instructions to some activities.

During the workshops, more experienced teachers worked on a variety of more formal activity assessments, rubrics, scoring tools and other support materials.

Development and Revision, 1999-2000 school year

During the 1999-2000 school year, field-testing of activity packets continued. The biology packets seemed to be well accepted as distributed. Physics teachers adapted the materials to their own needs. Chemistry packets were uneven. Teachers from all the regions would need to review these activities during the next summer so all points of view can be heard. Earth science packets were field-tested for the first time during the 1999-2000 school year and would need the same in-depth review. There are many problems with them; but no one has the time to devote to meeting with teachers to improve them. Environmental science was lowest priority, since the few teachers that were enacting these materials were also working with biology or earth science.

Meanwhile, the physics leader was piloting a third version of the Physics materials in her classroom. These materials asked students to prepare prediction graphs prior to entering the computer lab, saving on lab time and on cheating (using the computer to see the graph). The activities also ask students to compare model results with experimental results, completing the circle from experiment to equation to model to experiment. These materials are in their second cycle and need another revision to fit the current approach to teaching the content as well. A similar approach regarding the application of model to experiment was added to some of the advanced chemistry materials. However, the physics leader was not eager to share this approach due to revision overload. She suspected that people were tired of seeing a new flavor of the month at every meeting.

This modification of materials for a particular classroom is often reasonable. But it was apparent form the Feb 5 project wide meeting, that confusion existed.

> While the physics leader had been under the impression that certain versions were in use only in certain districts, the teachers using them thought that these modified versions were the “official” versions and proceeded to tell other districts that they were using “old” versions. The sad part of this is that the teacher who was told this had spent considerable time the previous year working with the physics leader to improve a packet for use in her classroom and all the modifications in that version came after classroom practice. CT

There seemed to be much tighter control of the biology materials than there was of the chemistry and physics. This may have been affected by the personality characteristics of the content leaders or of physics teachers versus biology teachers. Adapting physics materials to a wider audience may have played a part. The biology leader seemed to have a handle on the “right” version of the biology materials, whereas physics leader lost a sense of the “official” version of the physics activities and never posted an official version on the web.

Materials Revisions, Teacher Collaboration, and Management Problems

Revision Issues

Not only did activity developers try to create flexible materials by indicating sections teachers could omit if they were strapped for time, but they also included tips for adapting the activity to basic or advanced classes, different lab situations, etc. Nevertheless, several units were revised many times. Oftentimes this was done in a coordinated way under the direction of a subject area leader. Other times, however, materials were revised as an “individualized” activity for a particular level class or for a particular teacher’s goals. This happened in work sessions between a teacher leader and another teacher as they prepared for upcoming modeling sessions in the neophyte’s classroom. Some teachers also revised materials on their own and contributed them back to the group. Keeping track of multiple versions was a problem. Subject area leaders were sometimes concerned that the latter two processes resulted in a “dumbing down” of the activity. Scaling up adoption of modeling activities must be concerned with this problem and Project SCALE (Synergy Communities Aggregating Learning about Education) has brought educators and researchers working in a common science area (water quality) together, in part, to address this issue. The CoreModels Project Director is a member of the SCALE team.

Biology materials, especially the student guides have undergone numerous revisions, and in some cases several different versions have evolved. Collaboration in numerous workshops, site visits and email correspondence allowed for gathering a wide variety of feedback from classroom implementation experiences. This feedback resulted in numerous revisions of materials, improving both activity logistics and the quality of the critical thinking questions. In some cases center directors have gathered the feedback and coordinated these revisions. In others, teachers have struck out on their own in making revisions and alternate versions.

The revision process has brought up many issues. Some of the issues are:

- having numerous versions of activities to track; confusion in following a teacher’s reference to a particular version
- deciding which if any version should be the official version, which version(s) should be distributed to new teachers to the program or to those outside the program,
- judging which versions incorporate real improvements, which offer mainly personal or stylistic differences

- providing a particular set of material development guidelines, if any, to promote some uniformity in the programs materials
- determining whether to modify some materials to make allowances for lower achieving students or to find alternate ways of fostering the goals of the more generic version
- promoting alternate versions tailored to a particular student level, course content or specific teachers goals
- avoiding bruising egos

During the 1998-1999 field testing, teachers in the Central Region requested editing changes such as separating student answers from student directions to save paper. The Central Region CD accommodated these requests and disseminated the alternate versions to others through the Saturday workshops held throughout the year. Other, more substantive changes were also made at the request of the region's PTs. This caused a great deal of consternation among the original authors. The Central Region CD favored teacher involvement in the process of activity development over standardization. When the revisions were sent to the other regions, the CDs were unsure what to do with them. Not being part of the dialogue that brought about the changes resulted in an uncomfortable feeling of a lack of control and input. This was the beginning of dissension among project leaders. One group disliked the alternate versions because there was no consistent labeling of packets determined ahead of time so telling one version from the next was confusing.

The problem was exacerbated during the next school year since authors of activities were often not available to provide summer training. The author of draft activity should participate in the training so that the underlying intent and philosophy are not lost. Summer training should focus on a few of the most important models so slower learners are not overwhelmed. Other models can be made available for those who move more quickly. We need to strive for a balance between breadth and depth. When we move too fast, people get lost and frustrated.

Collaboration

Teachers have written classroom materials for themselves for centuries, but it is more productive to share them with colleagues to get their advice and insights. It can also be a lot of fun. This is especially true if collaborators have a similar view of student abilities, the content area and the value of this activity in the classroom. (add Bev stuff) Collaboration works best when there is a starting point and the two teachers can get together face to face to suggest ideas for improving the materials or adapting them for specific uses. It is more productive after rough versions of the materials have been used in the classroom. The fact that there was no time for other teachers to try chemistry materials before they were presented caused frustration. However, the online chemistry collaboration discussed earlier was an important exception that shows that collaboration can occur through email if both parties continually "talk".

Other teachers will defer to a content area leader unless a conscious effort is made to encourage collaboration. The series of steps given below is one possible collaborative process

1. Find a partner to work with - someone in your subject area, someone close by (or a very good online correspondent), someone with a similar educational philosophy, preferably with a different array of classes (different levels or time blocks or ...)
2. You and your partner develop some materials for your classroom, try them out in your classroom, and make changes.
3. Meet together to discuss your materials. Why its important to use this approach. What do the students learn? How is this better than other approaches? How does it tie-in to the curriculum?
4. Swap materials and try each others in your classroom.
5. Meet again and discuss experiences, changes, etc. Refine the materials
6. Try the new materials in your respective classrooms
7. Present to a larger group - following the guidelines below. Elicit suggestions from this larger group and answer questions by reflecting back on your classroom experience.
8. Have the larger group try the materials and report on their experiences. Incorporate relevant experiences into the refinement of the materials.
9. Assess whether you have achieved your purpose for developing the materials in the first place.

Some materials were developed using a process that included some of these steps. Nuclear chemistry, braking distance, Franco's differential equations approach all got some of this (not all steps, but some)

For successful large group training, teachers must understand the intent of the materials. They are also encouraged by first person accounts of how the activities work in a real classroom. Therefore

1. The developer must be present at training on his/her materials – or
2. The developer must train anyone who presents his/her materials and that 2nd person must have used them in his/her own classroom.

When the developer presents his/her materials, and participants suggest changes, the developer can consider whether they are warranted. The developer can discuss the rationale for the original version with the participants, perhaps pointing out their misunderstanding or perhaps giving examples of how on level kids were able to handle the activity. The second alternative requires trust to be built up between the developer and his/her assistant. They've discussed things a lot, the assistant has pointed out improvements to the developer after classroom use. In this case, the assistant is pretty much able to represent to developer's point of view at a workshop. If participants want changes, then the assistant will communicate with the developer before sitting down to work with the teachers.

As has been pointed out, CoreModels leaders took on too much so that developers could be at every workshop. Since this is not an unusual situation, developers should recruit collaborators. They should think about closely working with someone who comes to appreciate their point of view. Unfortunately, personality characteristics come into play - often the people most qualified to be assistants are those who love to do their own thing!

People and Management Problems

The CoreModels Project Director was responsible for overall project leadership. Center Directors, who also served as content area leaders, were responsible for leadership within their region and in developing content materials. The Project Director had experience in leading the previous MVHS project. Working with the other three CoreModels directors was exhilarating but challenging. As the Western Director noted:

> As a department chair, I can't tell people what to do, I have to lead by example and suggestion. This works well in a department, but may not be the best elsewhere. It's hard to adapt to new roles. CT

Part of the project director's job should have been to work with the leadership team to develop guidelines for revising materials, and more importantly, for disseminating revisions. Developers were frustrated in spending hours writing an activity, using it with students and then rewriting it, only to have someone throw 90% of it away before even trying it with their students. We all know this happens with activities we present at conferences, but we don't see it. In a project like this, we know about it.

We started with grand ideas about a cover sheet for the materials which would show the revision and who had used them. This got lost along the way. We also never had all the materials "proofed" by "experts". Managing this process was tedious. The project director set up a database for reporting teacher classroom enactment of activities. The same thing should have been done for tracking versions of materials.

The project director had a problem giving explicit directions to the rest of the leadership team. This was partly due to her deep respect for everyone. But it was also due to the tremendous tension she felt between collaboration and leadership and a lack of expertise in leading adults. An important aspect of leadership is in prioritizing the work that needs to be done. Part of the problem the center directors had with their positions as regional and content leaders stems a lack of clearly spelled out priorities, either developed by the project director or developed collaboratively. Time for such collaboration became scarcer as time went on.

> We don't spend enough time together talking and planning. I feel that we have lost a sense of camaraderie that we had prior to last summer. We did not recognize the training we would need to better understand our roles and to

> perform them more comfortably. We did not reach out for expert help. We relied on our teacher skills and intuition developed over years of experience. SR

Although the project director made some inquired into leaders who could provide training on teaching adults and took several workshops herself, she found that many generalities were difficult to apply to such a complex program as CoreModels. What was needed was a close mentor experienced in all aspects of SMT education research. One solution would have been reaching out to EDC or advisory board leaders for more help.

Discussion and Future Directions

The CoreModels Project had some of the characteristics of a small activity development design project and some of the characteristics of a larger implementation project. Not distinguishing between these two characteristics may have been the greatest cause of problems within the project. Yet the lack of psychic and physical "distance" between developers and implementers was also a great strength. Perhaps distinguishing roles more carefully, so the developers were not also in charge of implementation within their district would have resulted in more explicit expectations for both aspects of the project.

Several key factors contributed to the success of the project (Friedman and Culp, 2001)

- The close-knit, peer-to-peer structure of the CoreModels community
- The presence of a core group of relatively senior and especially dedicated teachers who were able to act as a vanguard in exploring the relative value of student-driven model construction and open-ended inquiry into systems
- Its sustained, long-term commitment to curriculum development, testing and revision
- Its open structure, which allowed teachers to adapt and adopt modeling curricula in ways that were realistic for their own particular classrooms.

These factors have led to CoreModels teachers' high level of ownership over their curriculum and classroom activities. The project experienced a tension between the last two factors above, reflecting how developers and implementers view scaling up of materials adoption. On the one hand, MVHS leaders want to disseminate their activities to a broader population of teachers while somehow ensuring that teachers retain the qualities that made them successful. On the other hand, we know that professional development is local. The same characteristics of the peer to peer structure of CoreModels will be needed for successful large-scale local adoption or adaptation of these activities. The Synergy Communities project is investigating how teachers can adapt such curricula. As a member of Synergy, the CoreModels project director will share her experience and benefit from that of others in exploring how teachers customize innovative science curricula to address the needs of their own classrooms. In partnership with researchers at the University of South Carolina, this project seeks to document the challenges teachers face as they customize curricula for new educational settings and the ways in which "flexibly adaptive" curricular design and professional development can support the customization process.'
(http://scale.soe.berkeley.edu:8080/scale/)

The second factor listed above is sure to be key in successful local professional development – especially focused around curriculum design or adaptation. The critical mass of outstanding, committed teachers has been mentioned elsewhere. It was extremely fortunate that we could recruit such leaders. Most of the supporting teacher knew little about modeling but were extremely dedicated and competent science specialists. The CoreModels project has demonstrated how teachers without extensive access to specialists work with one another to bring a promising and innovative practice like modeling into their science classrooms.

The time needed for curriculum development was much greater than program leaders originally envisioned. Materials needed to be written, tried in a classroom, rewritten and disseminated, tried in many more classrooms and revised again. This process became a never ending responsibility for a small subset of the teachers, while many other teachers devoted considerable energy to helping with unit development that fit particularly well with their curriculum. In an ongoing project, teachers are involved in different aspects of curriculum development depending on their current experience and interest. A large enough yet flexible and close enough community is important. Then teachers can participate in different parts of the process depending on their time with the project, interest, ability, etc. In an on-going district based project, some people would be joining curriculum writing, while others would be reporting on their trials of new units (or old or revised ones) with students. A close knit, peer-to-peer community structure would facilitate and be facilitated by such a flexible development paradigm.

The second section of this paper put forward the idea of curriculum development as an activity around with discussion of standards and student learning difficulties takes place. The CoreModels project invited teachers into an engaged learning experience. Initially, the project provided teachers with materials tied to Maryland Core Learning Goals to help them integrate modeling software (STELLA) into their curriculum. But they were also involved through collaborative groups in the development of these materials and in the training of new participants. This set the stage for explorations into the cognitive purposes of modeling, the relationship between modeling and content knowledge, and the role of classroom discourse in generating and supporting engaged student learning. During workshops, teachers shared their growing understanding and "these conversations were the crucial turning point in the group's overall shift toward understanding modeling as a way for their students to pursue open-ended inquiries rather than as a tool for reinforcement of content knowledge" (Friedman and Culp, 2001).

The move of experienced teachers away from paper based packets may cause rethinking of the materials development process. Video can be used to show teachers more and less structured teaching scenarios. Discussions with physics teachers have focused on a "path for teachers" from using simulations and being tied to student activity sheets to a more open, model building paradigm. We see this being built into future projects – and would like to use video for to capture these paradigms for workshop discussion. How the whole process paper based "units" develops is questionable as teachers develop expertise and more interest in student model building.

CoreModels teachers are part of a community of practice. They may follow an activity designed by others, but they learn along with their students and expect to feed back their understanding of the successes and difficulties that occurred. They may create an activity for others to use, but do so as part of a community accountable to peers who will collaborate in reviewing their work. To maximize such information flow, the MVHS community is creating the WebSim/CMDE environment. Each WebSim includes a digital notebook and interactive student and teacher guides and online assessments. The student guide consists of a series of simulation pages enhanced with a scaffolding approach that restricts variable manipulation and helps students connect their ideas to the simulation output (Linn and Hsi, 2000, p. 74). Each page includes an area on the left presenting abbreviated directions and providing form input. The main area is used for graphical output of the simulation, with a description at the top of the page. Links on the page allow access to the digital notebook, background information, text data output and supplementary graphs.

To efficiently produce these materials, an innovative collaborative materials development environment (CMDE) will allow developers to work together to integrate WebSims into a guided inquiry pedagogy. The environment will simplify online student assessment and successive refinement of materials. The process of refining and tracking modeling activities, described earlier will be simplified through the CMDE. In the CoreModels project, teachers did not have an easy means of sharing and modifying files. On the one hand, it was difficult to monitor materials that individual teachers might disseminate. Content team review was often delayed until workshop meetings, so teachers had to wait even longer to try out improvements. MVHS will create the CMDE because our community needs a method to encourage and manage the strands of activity modification that our 60 plus high school science teachers have taken on. In addition, there is a need to support teachers in a variety of roles, including materials development. The CMDE will also provide a mechanism for review by additional teachers and by scientists, as well as efficient revision or redesign.

The first step in creating a WebSim to submit a message to the relevant MVHS discussion forum to solicit team members to work on the project. A request is submitted to the project assistant to create an online project development space. Figure 2 illustrates the following tasks:

1. Create online directory structure. The following subdirectories will be created under the Orbit Development Directory

Images	Model	Scripts

HTML (Current Teacher and Student Guides, Forms under development)	Notebook	Development Discussion

2. Create group identity for directory permissions and set passwords for web access
3. Convert and modify activity components to proper format
4. Place generic scripts, forms, and an empty notebook in their proper directories and initiate the orbit development discussion.

The team leaders, with help from the project staff, will use the tools in the form directory to create a general submission/graph form for the simulation. (See Figure 3) The goal is to first create a generic web page without any scaffolding in restriction of variables so that entry of mass of the orbiting body, initial radius of the orbit, initial velocity of the planet, and mass of the body being orbited results in a depiction of the orbit. The basic simulation is then available to the team as they work together to determine the sequencing of simulation scenarios as described in IV above.

The important collaboration involves creating the student and teacher guides. Porting the student guide to the web involves 1) providing scaffolding with directions and content information 2) adding questions to the digital notebook (saved in an underlying database) 3) creating pages for student assessment. Currently, the notebook supports text questions and answers and includes tools for adding them. Future capabilities might include the ability of students to add concept maps and graph predictions created with online tools. An interactive teacher guide can invoke the simulation to depict results matched to the notebook answer key.

The teachers will be guided in the work described above by WebSim standards developed based on our work in CoreModels. These will emphasize connection to national goals and adoption of pedagogical strategies such as the use of pivotal cases (Linn and His, 2000) and questions which help students connect graphical output to real world behavior. In addition to the development team, teachers interested in using the simulation comprise the review team. They may read and post to the development discussion and post to their own copy of the digital notebook to critique questions and add notes suggesting additional simulation pages, questions or resources

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