Innovation in Schools: A Model to Help Structure the Discussion and Guide the Search for Strategies

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1. Introduction

Schools are faced with many challenges and significant changes. Most school systems are responding to growing enrollments, replacing or refurbishing outdated buildings, upgrading teachers' skills, and finding replacements for teachers who are retiring. At the same time, schools are being asked to implement new teaching methods and technologies. Perhaps the most significant changes are in response to the call for greater accountability. Statewide standards and the "high-stakes" testing that goes along with those standards will have a major impact on curriculum and teaching methods. Many school systems are fearful about the process and apprehensive about the results. Experienced teachers and administrators know that curriculum changes required by statewide standards will not be straightforward and will create a whole new set of problems. How can schools respond in a manner that truly improves the quality of their teaching and the student outcomes they produce?

This paper serves two purposes:

- It describes a **model of educational innovation** that has been developed to help school board members, administrators, teachers, parents, students, and other community members understand the process of innovation and explore reasons why innovations often produce results other than the ones that are desired. The model was developed under the auspices of the Gordon Brown Fund, with the assistance of a group of educators who identified critical factors affecting innovation and the interactions among those factors. The paper presents the model in the context of a **hypothetical case study** of a community faced with an opportunity to make a major innovation in its schools' curriculum. While the case study involves a situation that many superintendents would like to have, implementing a new curriculum with funds from a generous bequest, it illustrates the difficulty of implementing change even in favorable circumstances. The model should also be relevant to more difficult situations in which change must come in response to external pressures such as "high stakes" testing.

- It describes **an approach, called System Dynamics**, for understanding the behavior of complex systems and the consequences of introducing change into those systems. The model of educational innovation is presented as an example that suggests how System Dynamics can be applied to a number of other complex problems facing educators. The paper illustrates the steps in a System Dynamics analysis of a problem. These include building a model that embodies the causal factors thought to be responsible for the problem and then using that model to examine potential strategies for dealing with the problem.

The model of educational innovation may have several uses for the reader. This paper might, for example, provide a framework for discussing a particular change being contemplated in your school or school system. The variables in the model and the "rules of thumb" derived from using the model are intended to be applicable to most schools.

Several questions derived from developing and working with the model are suggested in Section 6.1. These questions can help you and your colleagues in thinking about innovations you may be contemplating. The model itself is available (see Appendix A for details) and can be used to simulate alternative strategies for implementing innovations. Results of these simulations, while clearly not predictions, should provoke additional discussion and a more thoughtful approach to innovation. As an example of the System Dynamics approach, the model will hopefully interest some in applying the approach to their own problems. Section 6.4 describes a few “next steps” for learning more about System Dynamics.

The paper should be read as a “first draft”. It is meant to elicit comment and reaction rather than present a polished piece of work. Those of us who have been involved in the development of the model to date hope it will be more than an intellectual exercise. We hope it can become a tool for communities to examine how they view innovation, how they introduce innovations in their schools, and how that process can be made more effective.

As you read this paper, think about your own experience. Have innovations you participated in succeeded? If they did, what made the critical difference between success and failure? If they failed, what were the principal causes? What criteria are you using to define success and failure? Does the model we present in this paper match your experience to some extent? Are there additional factors we have missed? Is it relevant to other types of change you are considering? Please let us know. There are also some specific questions in Section 6.3 that you can respond to. Send comments to the author by e-mail at GBHirsch@aol.com or by mail to Gary Hirsch at 7 Highgate Road Wayland, Ma. 01778.

Members of the group that participated in the development of the model were:

Jay Forrester	MIT
Linda Greyser	Harvard Graduate School of Education
Gary Hirsch	Consultant
Sue Jamback	Chelmsford Public Charter School (Ma.)
Nancy Roberts	Lesley College
Steve Roderick	Lincoln-Sudbury High School (Ma.)
Ted Sizer	Coalition of Essential Schools
Lees Stuntz	Creative Learning Exchange
Tony Wagner	Institute for Responsive Education

2. Developing a Model of Innovation in Schools -- A Hypothetical Case Study

2.1 The Challenge Facing Anchor River Public Schools

Robert Harper faced a formidable challenge as the new superintendent of the Anchor River Public Schools. He had just replaced a superintendent who retired after a 20 year term marked by exceptional stability and very little programmatic change. In addition to the normal expectations for any new superintendent, Harper had an opportunity that could also become an ordeal. A wealthy resident of the town had bequeathed a large sum of money through the local educational foundation for a project that would make Anchor River's schools "truly excellent". Harper wasn't sure what the man had meant, but was determined to spend the money on a major improvement in the curriculum, which had barely been touched for years, rather than on the many small items on wish lists that had begun to appear on his desk. These ranged from athletic equipment and band uniforms to pet projects that a few teachers had dreamed about, but didn't dare ask for in the "steady-as-you-go" administration of his predecessor.

Harper wanted to implement a major curricular change that would fundamentally alter the way students learned. One possibility he had in mind was a major revamping of language arts instruction from the early grades through high school English courses. The bequest could pay for the large number of new texts, many hours of teacher training workshops and preparation time, and new computers and software needed to support the word processing component of the writing program. Such a program would affect all students in the district, emphasize higher level thinking rather than the rote memorization and sterile writing exercises typical of current language arts instruction, and help to improve communication skills in other subjects as well.

While he was excited about the possibilities, Harper got a knot in his stomach as he thought about the difficulty of implementing such an ambitious program in a district that had little significant change for many years. He remembered the strife that had been created in a school where he had his first teaching job, when a major change had been introduced in the mathematics curriculum. Teachers were expected to learn the new curriculum quickly with minimal preparation time and to teach it "by the book" without any opportunity to modify it to their own teaching style or children's learning styles. Teachers still managed to find ways of responding to this "threat" by doing things their own way and teaching the new curriculum with old methods that were totally inappropriate. They also held onto old topics they were comfortable with or that were required by the statewide curriculum. As a result, they had to rush through everything and didn't teach anything well. Student evaluations revealed worse outcomes, rather than improvement, which infuriated the teachers who were already upset by the new curriculum's demands. The community, whose expectations had been raised when the new curriculum was announced, lost confidence in the schools, making it difficult to introduce any curriculum changes for many years thereafter.

The response to "trial balloons" he floated with various constituencies increased Harper's anxieties. A school board member told him that his ideas sounded exciting, but hoped they wouldn't get in the way of her son learning whatever he needed to get into an Ivy League college. The teachers' union president was also mildly encouraging ("the teachers could use some updating"), but cautioned him about new programs that would violate work rules carefully negotiated with the previous superintendent that had resulted in many years of harmonious labor relations. Another school board member, who was a local businessman, said the students certainly needed something different, but wondered whether they needed to learn to write a business letter with proper spelling and grammar rather than “higher level thinking skills”. The newsletter from the state’s Superintendents Association sitting on his desk also warned of new state standards, backed by “high stakes” testing, that would dictate much of the curriculum in language arts and mathematics.

Harper was even troubled by how people spoke about innovation. Everyone was “for it”, but typically meant very different things. Innovation was a “grab bag” of ideas that included unconventional assignments such as getting physics students to design toy cars, more flexible scheduling, use of computers to teach everything (whether or not they really added value), evaluation of students’ academic progress based on portfolios of their work, professional development courses to give teachers new skills, and a wide array of other things. People seemed to think that as long as the Anchor River Schools could point to some number of these “innovations” going on, they had a good school system and didn’t need to do anything else. One teacher with a reputation for being creative confided in Harper that he would be able to recognize the few innovators in the schools because they would be the ones with “the arrows in their backs” from getting too far ahead of the crowd.

It was clear to Harper that, with this diversity of views and generally conservative mindset, a major curriculum change could be a disaster and get him fired. How could he go about implementing a large project that had a significant impact on how students learn, without creating many new problems? While he was worried, he also realized that he had some resources to draw on. The bequest would certainly help, although he had the usual pressures of people wanting the schools to run with less money so their taxes could be lowered. Some of them saw the bequest as a way of reducing tax revenues used by the schools. There was a significant amount of goodwill and trust between the schools and the community, a benefit of the previous superintendent’s conciliatory style. While teachers were not adventurous as a group, there was a generally positive climate and openness, if not eagerness, for change. In addition, in the last few years, the educational environment had changed. Education reform at the state level had put new pressures on local districts to meet higher standards. The availability and higher quality of current educational technology had made it clear that integrating technology into the teaching and learning process was necessary to prepare young people for the world in which they would live and work in the future. This could be Anchor River’s first and most important initiative in this area.

2.2 A Framework for Planning Innovation

After a board presentation at which Harper got the usual mixed reaction to his curriculum ideas, he was approached by an Anchor River resident who expressed some sympathy for his plight. Dr. Garvin indicated that a major part of the problem was the different “mental models” that people were using to evaluate Harper’s proposals. Harper recognized this term from a course he had taken on “Systems Thinking” the previous Summer. It turned out that Dr. Garvin taught a subject called System Dynamics at a university in a nearby city. Garvin volunteered to meet with a cross-section of people associated with the schools to help them think about the impacts a major curriculum innovation might have on the schools and how such an innovation might be implemented to yield the desired outcome rather than a number of unintended negative consequences. Harper assembled a working group that included one of his assistants, the teachers’ union president and several teachers from the “rank and file”, two school board members (a parent and a business person), another vocal parent, a computer expert from a local high-tech company (who had been donating her time to upgrade the curriculum), and a student representative who was a junior at the high school.

Dr. Garvin began the first meeting by giving some background on System Dynamics and how the group's work might proceed. He explained that the System Dynamics approach was developed by Jay Forrester and his colleagues at MIT in the 1950's and applies systems methods, originally developed in engineering disciplines, to human systems. System Dynamics emphasizes the relationship of a system's structure and its behavior over time and uses computer simulation with a model to understand how human systems might respond to various policies and other attempts to control or alter those systems. The techniques have been used to better understand the problems of industrial and service firms, health and human service delivery systems, cities, national economies, and the global ecosystem as well as to develop curricula for K-12 education.

One member of the group asked why they should develop a model rather than just surveying people about what change is needed and the potential problems that might result and then basing a plan on the survey's findings. Dr. Garvin responded with several points:

- Developing a model requires us to be explicit about our individual "mental models" of how a process such as innovation works, to examine gaps and inconsistencies in those mental models, and to create a coherent framework that represents a shared understanding of the process. Many of the difficulties in having constructive discussions about policy issues come from the array of incomplete and often conflicting mental models that people bring to the table. A model can provide a consistent framework for examining alternative policies and making better choices.

- A report presents a set of findings that can be discussed and criticized, but is nonetheless static. A model is, instead, organic and can be reshaped to incorporate additional contributions that help it to better explain what is going on in the real world. Being able to ask "what if?" questions with the model and assess the reasonableness of the answers adds to the value of this enrichment process.

- Computer simulations with a model help us to discover new things that were not apparent from simple visual inspections of the model. These revelations include finding unanticipated consequences of policies and leverage points at which small investments of effort yield disproportionately large results. Simulations also offer an opportunity to do "sensitivity analysis" in which parameters are changed in order to see the effect on the model's overall behavior. Sensitivity analysis usually reveals that many elements of a system do not meaningfully affect system performance while a small number of others have a critical impact and need to be studied more intensively.

This last point roused the skeptic in the group who said he knew that computer models required lots of data and the school system's data was a mess of paper records stored in boxes, old punch cards, and computer records in several incompatible formats. Dr. Garvin responded that System Dynamics models could be developed with very limited data, basing quantitative relationships initially on the expert judgment of people close to a problem and improving the model later as better data become available. For now though, their task would simply be to identify the impacts of innovation in a general sense and the critical factors that would make an innovation succeed or fail.

2.3 Developing a Model of Innovation

Dr. Garvin asked the group to describe the **variables** that characterize innovation in schools. (Variables included in the model are shown in Title Case. The first time each variable name appears, it is highlighted in **boldface**.)

2.3.1 Adopting Innovations

Dr. Harper began by offering the observation that innovation is actually a process of several steps. Some innovations are initiated, but never really adopted. Harper knew from his experiences years ago with the mathematics curriculum that innovation was not a *fait accompli*. Large portions of an innovation could fall by the wayside if teachers were not "on board". Innovations might be discarded because they are too difficult to implement or too different from what teachers are accustomed to. Other innovations are adopted, but have no impact on the quality of teaching or learning. A select few are adopted and do have a significant impact. Dr. Garvin sketched the process, shown in Figure 1, in which **Curriculum Innovations Initiated** become **Curriculum Innovations in Process** and some of those become **Curriculum Innovations Adopted**, based on a **Fraction Adopted**. The fraction not adopted become **Innovations Discarded**. The **Rate of Adoption** also depends on the **Time to Adopt Innovation**. Once adopted, they may produce some **Impact of Innovation**. After a period of time, **Curriculum Innovations Becoming Obsolete** reduce the level of Curriculum Innovations Adopted.

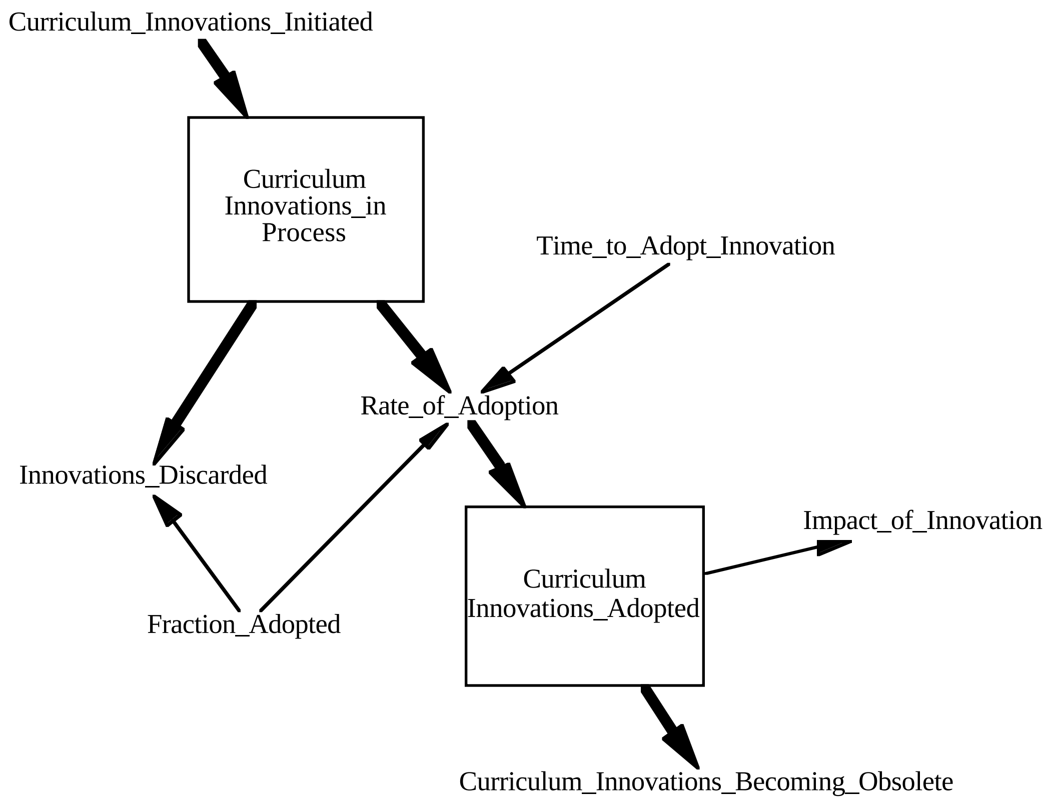

Figure 1: Process of Adopting Innovations

The group began discussing what factors affect the **Fraction Adopted** and the **Time to Adopt Innovation**. Dr. Gavin added the factors as they spoke and produced the diagram shown in Figure 2. The union president was adamant that no curriculum innovation can succeed if teachers are not motivated to adopt it. He felt **Teacher Motivation** was a critical factor. Harper added that **Structural Flexibility** is another relevant factor that affects the Fraction Adopted. He mentioned Seymour Sarason's work that he had read about earlier in his career. Sarason wrote about "regularities", aspects of structure in schools that are so well accepted that they are not even noticed. Incompatibility between an innovation and these regularities would greatly reduce the chances that an innovation could be successful. Regularities include rigid scheduling systems that break the day into short class periods and get in the way of many curriculum innovations at the middle and high school levels. Many curriculum innovations typically require longer, unstructured periods of time in which students can learn on their own or collaboratively with others. As Harper described this problem, the student confirmed it by complaining that one of the few stimulating classes she had taken was constantly being cut short by the bell, just as the discussion was getting really interesting and students were stimulated to think.

One of the teachers focused on the Time to Adopt Innovation. She said that the speed with which innovations are adopted depends on the **Hours Required for Curriculum Innovation** relative to the **Hours Available for Curriculum Innovation**. Expecting teachers to adopt new curricula while handling all of their other responsibilities typically allows too little time for the innovation and will stretch out the adoption process and may lower the Rate of Adoption to a trickle.

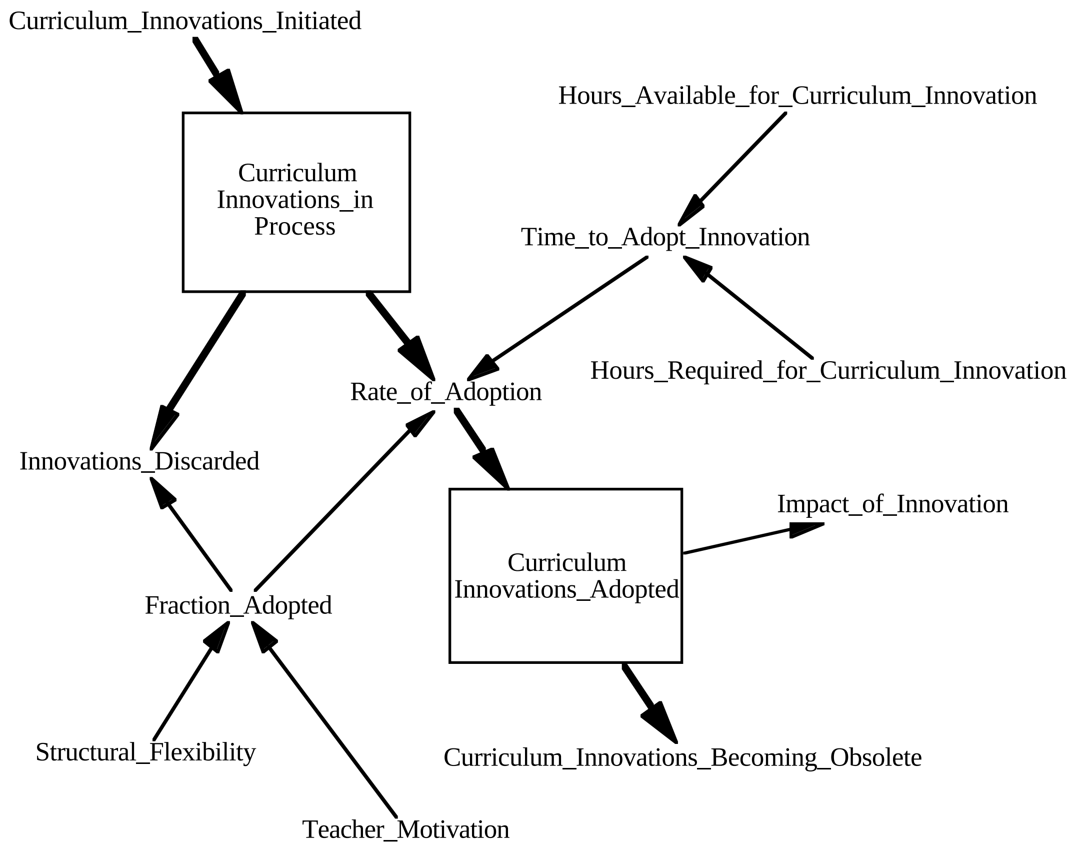

Figure 2: Factors Affecting Rate of Adoption of Curriculum Innovations

2.3.2 Teacher Motivation

Dr. Garvin asked the group to focus next on the factors that affect **Teacher Motivation**. If motivation can vary from low to high, what factors cause it to go up or down? Group members identified several variables that were diagrammed and are shown in Figure 3. One of the other teachers remarked that actual **Experience with Innovation** certainly affects motivation. That teacher reflected that there had been little innovation in this district and experience was therefore neutral right now, although teachers coming from elsewhere might have had different experiences. A bad experience, with results not meeting expectations, would quickly reduce motivation. The parent representative who was friendly with many teachers suggested that adding the new curriculum onto teachers' existing workload would create a great deal of **Stress on Teachers** that would reduce motivation. Another teacher indicated that teachers were already overworked and they would not be motivated to adopt a new curriculum unless there was a **Perceived Need for Innovation**. The new curriculum had to solve a problem that teachers could see or help them do something much better. The computer expert also suggested that, in her experience, teachers' **Awareness of Innovation Elsewhere** was a motivator for teachers who wanted to keep up with current trends.

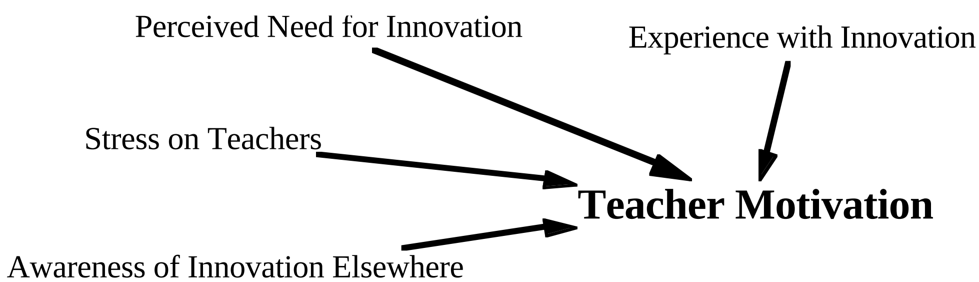

Figure 3: Factors Affecting Teacher Motivation

The skeptic in the group couldn't contain himself at this point. How can you put these "soft" variables on a computer without any data? Dr. Garvin explained that the group could assign rough magnitudes of effect to these factors. The purpose, again, was not to "predict" whether an innovation would succeed, but simply to get some help from the computer in understanding the interplay of these variables with each other and their ultimate effect on the innovation. He told the group that, "It is impossible to keep all of these interactions in our heads. Attempts to do so usually result in an incomplete picture that is somewhat biased by our own mental models."

Dr. Garvin focused on the variable Experience with Innovation and its effect on Teacher Motivation as an example. He asked the group to consider Experience with Innovation as a variable ranging from very bad to very good with neutral in the middle (scaled from -25 to +25 in this example). How would Teacher Motivation, which we might put on a scale from zero to one (low to high) change as a result? The group wrestled with the question for a while and ultimately decided that small changes would yield little effect, but extremes of good and bad experience might produce up to 50% changes in Teacher Motivation. Dr. Garvin drew the curve shown in Figure 4 and told them that this was not "cast in stone" and that they could come back to this relationship and try different shapes and values of the curve.

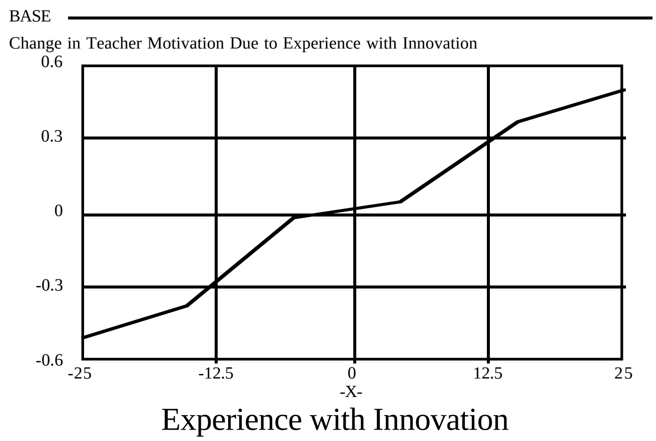

Figure 4: Relationship Between Experience with Innovation and Teacher Motivation -- Example of How “Soft” Relationships Can Be Quantified

Somewhat reassured, the group warmed to the task of “fleshing out” the model. The next question they focused on was how teachers, students, and the community at large perceive their Experience with Innovation. As they spoke, Dr. Garvin incorporated the additional factors as shown in Figure 5. Dr. Garvin asked whether Experience with Innovation is simply a direct effect of the Impact of Innovation. The group agreed that Experience with Innovation also depends on the community’s **Level of Expected Impact** and how the actual Impact of Innovation compares. If even a large fraction of the Level of Expected Impact is achieved, Experience with Innovation will improve over time. If that threshold is not reached and actual performance falls significantly below expectations, Experience with Innovation will decline. After some discussion, the group decided that the teachers and the community could be somewhat forgiving and that a curriculum innovation could produce a positive Experience with Innovation as long as its Impact of Innovation exceeded 70% of the Level of Expected Impact.

Dr. Harper’s assistant suggested that the reality is even more complicated. She had been doing a study of different approaches to evaluating student academic progress. She suggested that the way in which teachers, and everyone else, experience innovation is not based on actual impact, but on the **Measured Impact of Innovation** that is produced. Measured Impact of Innovation, in turn, depends on the **Mode of Student Evaluation** in effect. If an innovation is designed to enhance higher level thinking skills, but the Mode of Student Evaluation is largely based on tests that reward rote memorization, the impact of that innovation may be invisible. An innovation could conceivably succeed, but be judged a failure because its impact cannot be measured, given a mismatch with the Mode of Student Evaluation. They debated whether Mode of Student Evaluation could be characterized as a single variable and decided to adopt a scale in which traditional testing was at the low end, portfolio evaluations that some teachers were doing informally were in the middle, and “exhibitions”, in which students demonstrate what they have learned, at the high end.

Another person pointed out that the Mode of Student Evaluation could also affect the Perceived Need for Innovation. If the Mode of Student Evaluation tests only memorization and other low-level skills, it is difficult to perceive a difference between how students might ideally perform and the current status of **Students Capacity for Learning**. Someone else suggested that changing the Mode of Student Evaluation is, itself, another kind of innovation and requires dedicated effort of its own by teachers and administrators. The student member of the group expressed the hope that Students Capacity for Learning, or how much subject knowledge or skills students would actually learn, would be favorably affected by innovation. Wasn't that the point, after all?

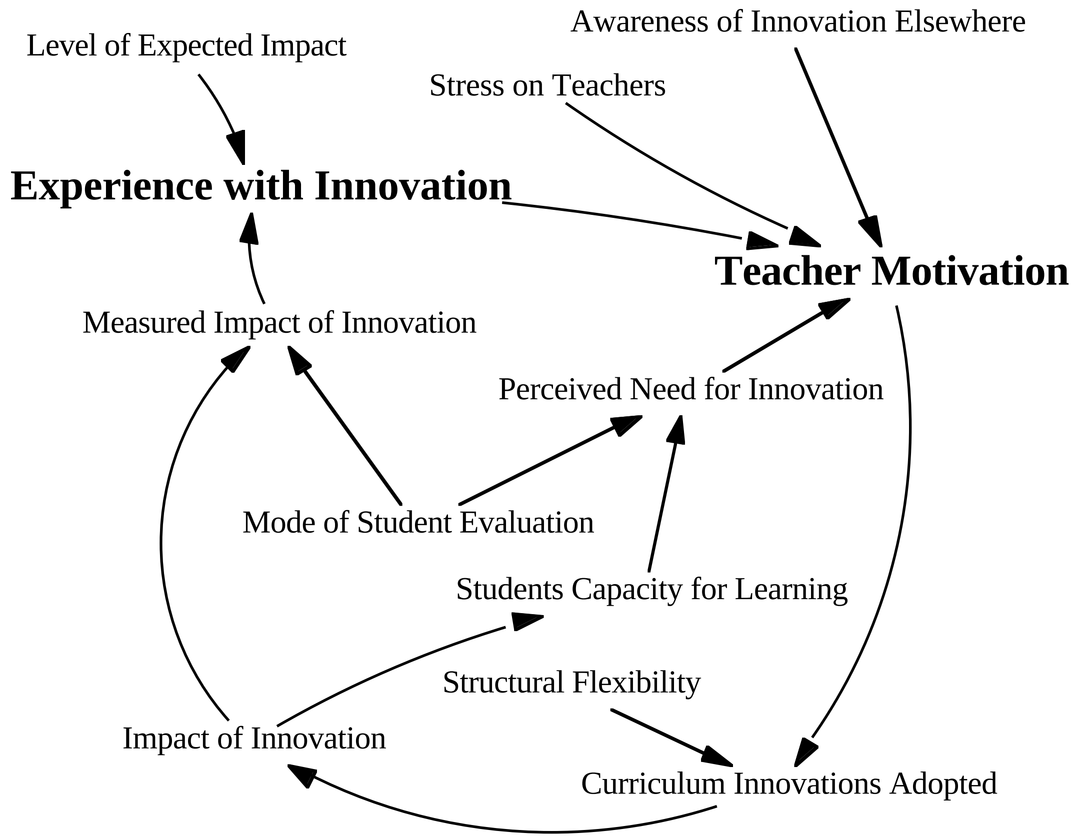

Figure 5: More Detailed View of Factors Affecting Teacher Motivation and Experience with Innovation

2.3.3 Community Response to Innovation

After they had finished discussing Teacher Motivation, Dr. Garvin asked the group to think about how other constituencies might respond to Experience with Innovation. What about the community, for example? Harper remembered the experience with the mathematics curriculum early in his career and how a bad implementation "poisoned the well" for later innovations by undermining the community's trust. He told the group that **Trust Between School and Community** is another important variable that is influenced by Experience with Innovation and affects the future climate for innovation as well. Dr. Garvin began a new diagram, shown in Figure 6 and asked what other variables affect the level of Trust Between School and Community. The union representative said that any **Conflict with Teachers** arising from innovation, coming after many years of congenial labor relations, would alarm the community and make it skeptical about whether or not the benefits of the new curriculum are worth the trouble.

The businessman on the school board, who favored a "back to basics" approach, said that if spending time on innovation detracted from students' **Performance on the Traditional Curriculum,** Trust Between School and Community would be sacrificed as well. The student representative pointed out that, if Students Capacity for Learning increased, **Hours Required for Traditional Curriculum** would actually decrease and there would be more Hours Available for Curriculum Innovation. The parent representative remarked that, with a high level of Trust Between School and Community, the community might also be willing to see **Tasks in Traditional Curriculum** eliminated and replaced by new programs rather than requiring that new programs be "add-ons" as had historically been the case. Cutting back the traditional curriculum would leave more Hours Available for Curriculum Innovation.

Dr. Garvin asked what other variables are affected by Trust Between School and Community. One of the school board members said that a community with a high level of trust might have more **Patience with Innovation**. They would be willing to wait longer to see results from innovative programs. The group discussed this variable for a while and decided that, based on current levels of Trust Between School and Community, the community might be willing to wait as long as three years for a major new program to have the majority of its impact. Greater Patience with Innovation would increase the likelihood that an innovation is viewed favorably and lead to improvements in Experience with Innovation. Less patience would allow the Level of Expected Impact to grow more quickly and make it harder to meet expectations.

One of the school board members also cautioned that a high level of Trust Between School and Community is necessary for changing Structural Flexibility and Mode of Student Evaluation. A lack of trust will create resistance to innovative approaches in these areas and a reversion to old ways of doing things if some innovation has already taken place.

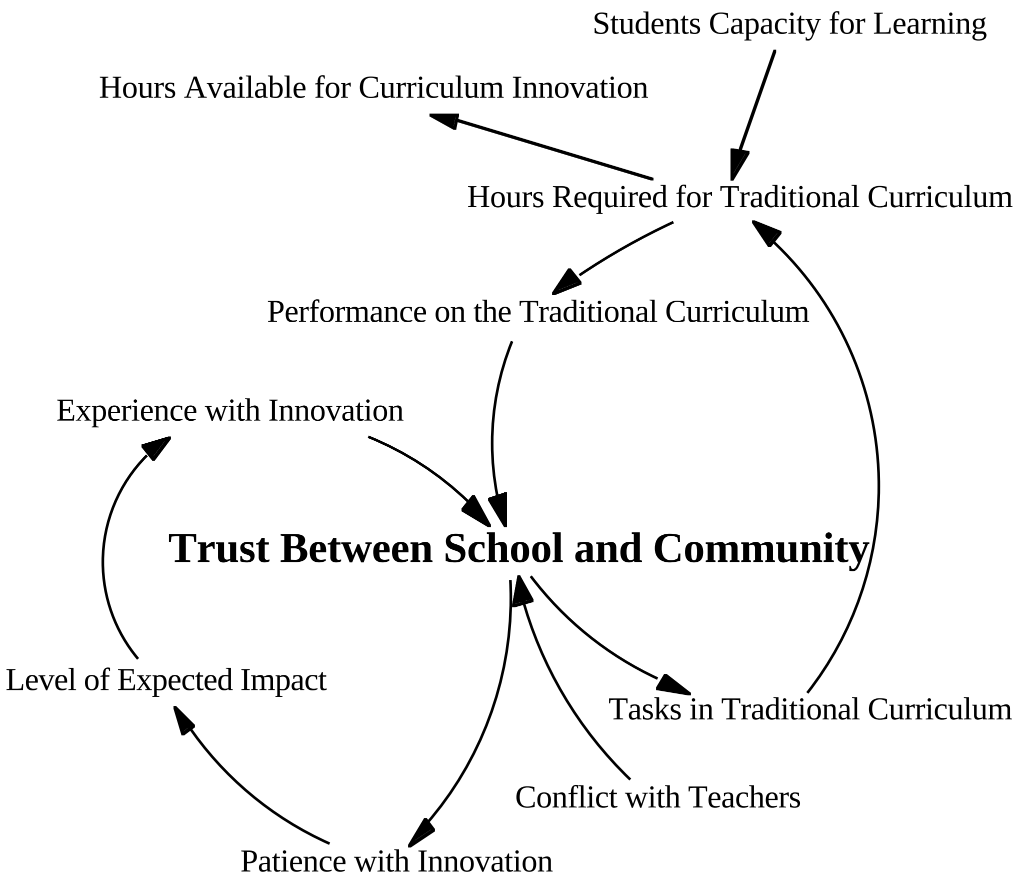

Figure 6: Factors Affecting Trust Between School and Community

The group went on in this manner for a while, identifying additional variables that affect innovation and, where helpful, describing relationships between variables as had been done with Teacher Motivation and Experience with Innovation. A second meeting allowed the group to reflect on and add to what they had done and put the pieces of the model together. After the second meeting, Dr. Garvin promised to get a computer model based on the group's work "up and running" and have it available for asking "What if?" questions at the next meeting.

2.4 Using the Model to Ask "What If?" Questions

Dr. Garvin began the next meeting by outlining the assumptions he had made in quantifying the model. He had tried to make it match the situation in Anchor River as closely as possible. As the simulation begins, students are evaluated with tests that largely reflect rote memorization. Scheduling and other aspects of school structure are very rigid. (Mode of Student Evaluation and Structural Flexibility were set at 0 and 0.1 respectively on a zero to one scale.) Experience with Innovation is very limited and neutral (set at 0). There is a medium level of Trust Between School and Community (0.5) since the school has done its job of traditional education adequately, but there are elements in the community who are constantly on guard for diversions from that traditional mission. Students Capacity for Learning reflects the traditional approach that is long on memorization and short on critical thinking skills. Teacher Motivation is at a medium level (0.5) since they are treated reasonably well as long as they fulfill their traditional role.

Against this backdrop, a major curriculum innovation project is launched. This major project is the only curriculum project going on. The project is expansive both in breadth (numbers of students affected) and depth (focusing on deeper understanding rather than rote memorization). As with the comprehensive language arts program being contemplated, changes are also designed to be generally applicable rather than being restricted to narrow curricular areas.

2.4.1 Curriculum Innovation Alone

The first simulation results (S1), shown in Figures 7A and 7B, were worrisome because they confirmed Harper's fears about the potential for disaster. The first graph showed that the Impact of Innovation fell far below the Level of Expected Impact and Measured Impact of Innovation was practically non-existent. Experience with Innovation quickly went negative as a result and got worse over time. Teacher Motivation dropped as a result and further reduced the level of Fraction Adopted and, as a result, Impact of Innovation. Trust Between the School and Community also fell and would have made it difficult to introduce any innovations in the future.

(All of the variables on this first graph are on a scale of 0 to 6 representing a range of no impact to significant impact. On the second graph, Experience with Innovation is a cumulative reflection of Measured Impact of Innovation relative to Level of Expected Impact and typically ranges from -40 (terrible) to +25 (excellent). If Measured Impact of Innovation exceeds some fraction of the Level of Expected Impact (70% as mentioned earlier), Experience with Innovation will grow over time. Teacher Motivation and Trust Between School and Community are both measured on a scale of 0 (very low) to 1 (very high) and vary over a range of 0 to 0.6 on the second graph. Numbers superimposed on the graph lines correspond to the variable names as shown in the legend below each graph. The scales on the vertical axes also correspond to the variables in the order listed (e.g., the third number on the top and bottom is the scale for the third variable listed. All simulations run over 100 months.)

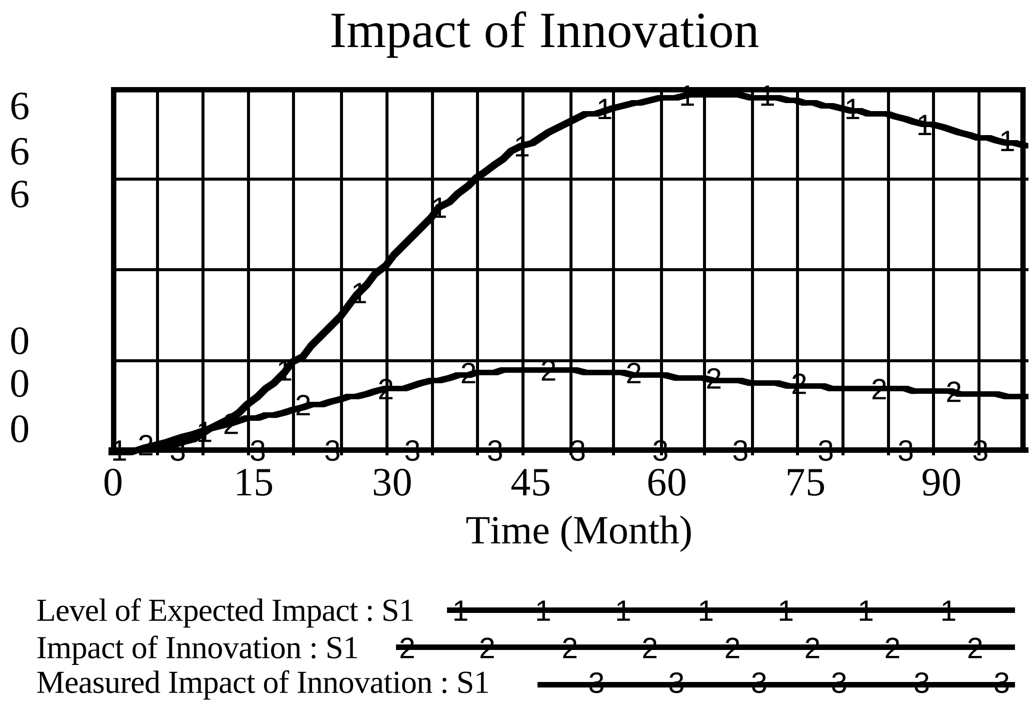

Figure 7A: Simulation with Curriculum Innovation Only -- Impact of Innovation

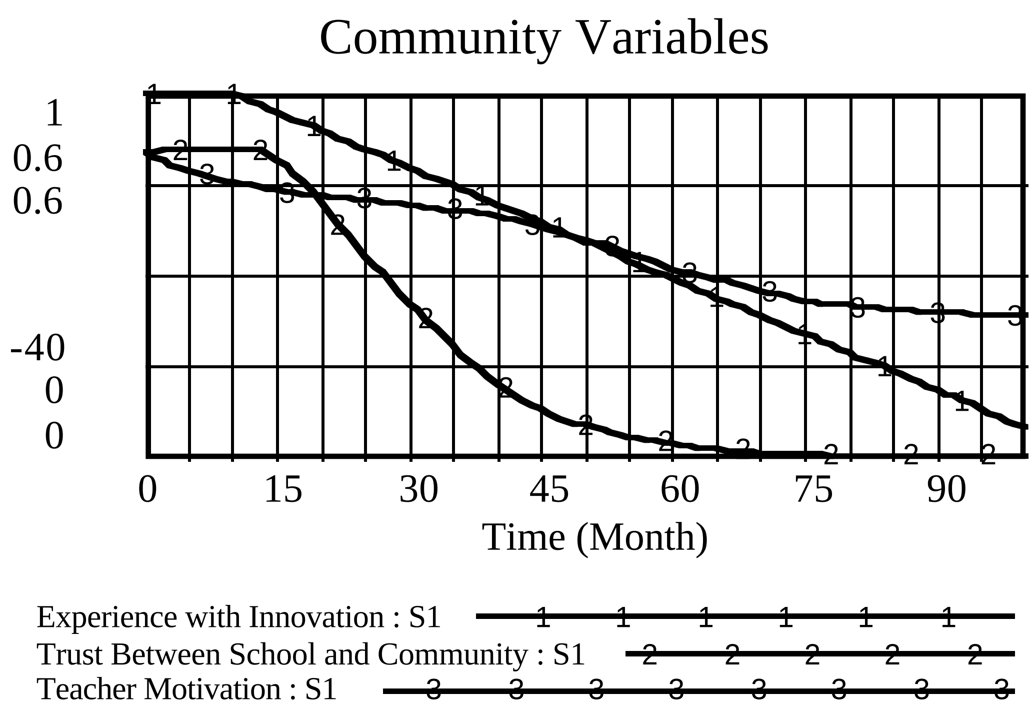

Figure 7B: Simulation with Curriculum Innovation Only -- Community Variables

People were discouraged at first, but then the skeptic said “Wait a minute, that’s a no brainer. Of course we got terrible results. We assumed that we couldn’t produce a

Measurable Impact of Innovation and positive Experience with Innovation without a Mode of Student Evaluation that recognized the impact. But we did nothing to develop the Mode of Student Evaluation beyond the standard tests and types of assignments that exist now." The teachers' union president added that it would be hard to have a suitable impact, let alone a measurable one, without some increase in Structural Flexibility. As described earlier, many activities in the new curriculum would be better suited to a collaborative learning format with groups of students working together over several hours rather than the traditional short class periods. Dr. Garvin confirmed this problem. He pointed to the relationships in Figure 2 and then showed that the Fraction Adopted remained low throughout this simulation as a result of low Structural Flexibility. Fraction Adopted fell even further when Teacher Motivation dropped later in the simulation in response to worsening Experience with Innovation.

2.4.2 Curriculum Innovation Combined with Other Programs

To remedy these problems, Dr. Garvin typed numbers into the computer that caused effort to be invested in developing the Mode of Student Evaluation and Structural Flexibility in addition to the curriculum project. He left everything else, including the major curriculum project, unchanged. All three programs began at the start of the simulation.

The results were even worse. This was becoming discouraging. But Dr. Garvin showed some additional results of the simulation (S2) that helped to explain why. As displayed in Figure 8, he showed how the Fraction Adopted had increased in response to the decision to increase the level of Structural Flexibility, as one might expect. (All variables on this graph are measured on scales of 0 to 1 and have ranges between 0 and 0.6 in this simulation.) Unfortunately, even though increases in Structural Flexibility were scheduled to begin at the start of the simulation, much of the improvement was delayed by spreading too few teacher hours among too many activities and came only after the curriculum project was already underway. As a result, the Fraction Adopted reached a peak of only about 0.5 which, by itself, would keep the Measured Impact of Innovation from reaching the 70% threshold (compared to Level of Expected Impact) that the group decided was necessary to produce positive change in Experience with Innovation.

There were other problems that made things worse. Dr. Garvin indicated that the benefit from increased Structural Flexibility was offset by the effect of a roughly 40% reduction in Hours Available for Curriculum Innovation (compared to the previous simulation (S1)) as a result of spending time to implement new Modes of Student Evaluation and increased Structural Flexibility. These efforts were going on at the exact same time the curriculum project was getting underway. Reducing the Hours Available for Curriculum Innovation had the effect of slowing the Rate of Adoption and kept the Curriculum Innovations Adopted lower than it otherwise would have been. Experience with Innovation fell further as a result and Teacher Motivation and Trust Between School and Community fell as well. This set off a "vicious cycle". Lower Teacher Motivation reduced the Fraction Adopted from the modest peak it had reached. Decreased Trust Between School and Community also caused a pullback in Structural Flexibility as the community became more conservative about new ways of doing things. The Fraction Adopted fell further as a result and sealed the fate of the curriculum innovation.

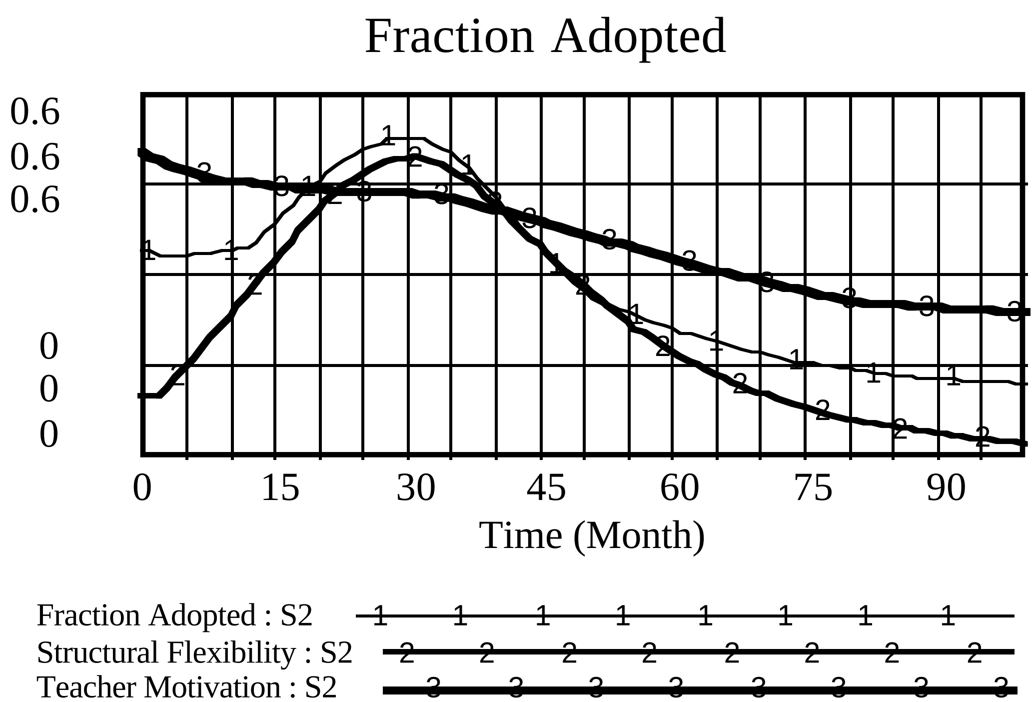

Figure 8: Limiting Factors in Simulation (S2) with Curriculum Innovation and Changes in Mode of Student Evaluation and Structural Flexibility

What could they do to avoid these problems? Dr. Garvin suggested that they again start developing the Mode of Student Evaluation and Structural Flexibility at the beginning of the simulation, but wait until two years had passed to launch the curriculum project. This would allow enough time to first develop the necessary preconditions for curriculum innovation and then have sufficient time available for the curriculum project.

The results of simulation (S3), shown in Figure 9A and 9B, were somewhat more encouraging. The Impact of Innovation and Measured Impact of Innovation, shown in the first graph, demonstrate some initial success of the curriculum as they exceed the Level of Expected Impact. However, Impact of Innovation reaches a limit and begins falling as the Level of Expected Impact continues to increase. The second graph shows how Experience with Innovation grew for a while, as a result, before reaching a peak and declining toward the end of the simulation. The decline was worsened as parts of the Curriculum Innovations Adopted became obsolete and Impact of Innovation and Measured Impact of Innovation fell further. The good news was that, as a result of this modestly positive pattern in Experience with Innovation, Teacher Motivation actually grew and remained at a higher level. Teacher Motivation also grew because there had been sufficient development in the Mode of Student Evaluation to increase the Perceived Need for Innovation. Trust Between School and Community also grew for a while before declining at the end of the simulation.

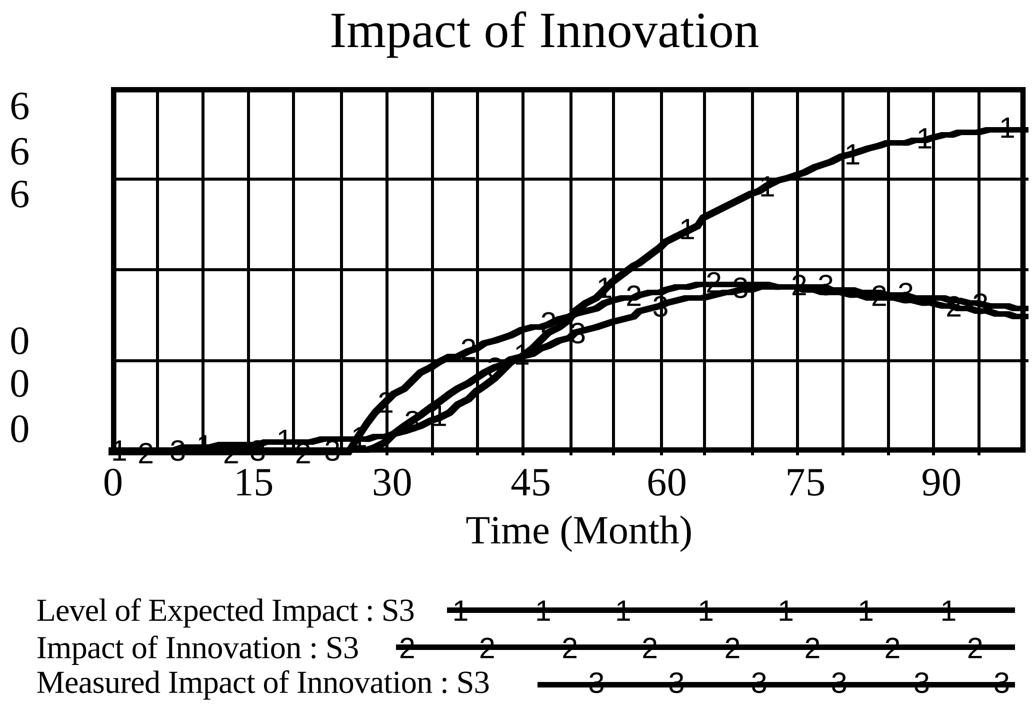

Figure 9A -- Curriculum Innovation (Starting After Two Years) Together with Changes in Mode of Student Evaluation and Structural Flexibility -- Impact of Innovation

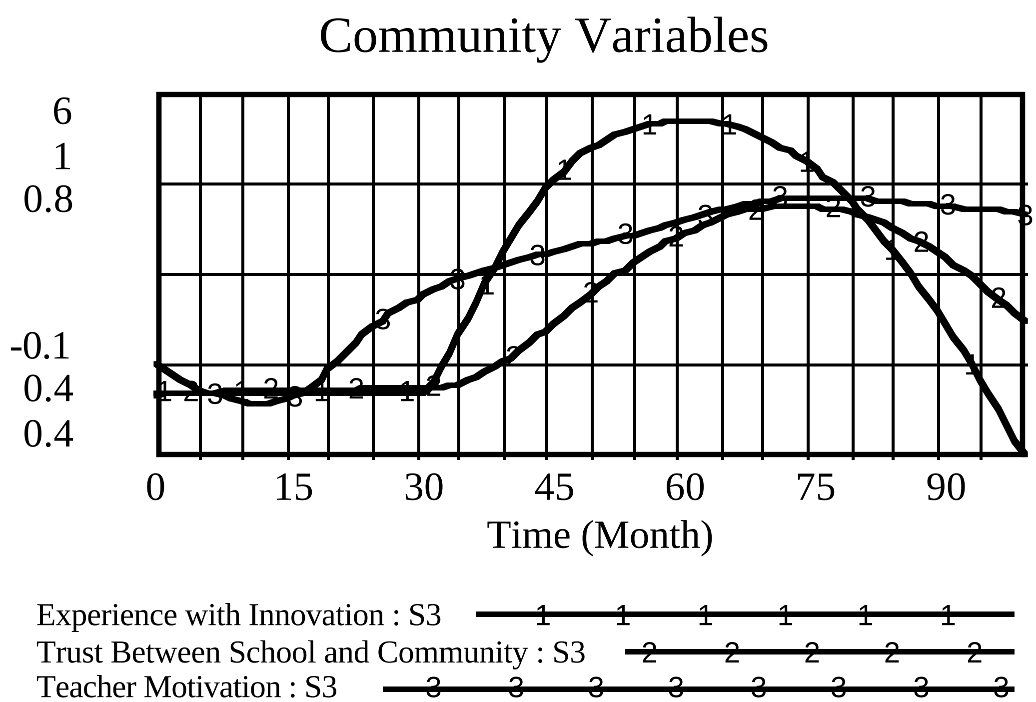

Figure 9B -- Curriculum Innovation (Starting After Two Years) Together with Changes in Mode of Student Evaluation and Structural Flexibility -- Community Variables

Dr. Garvin showed some additional results from the simulation (S3) that helped to explain the more favorable outcome. He indicated that, once Mode of Student Evaluation and Structural Flexibility had received sufficient attention and no longer needed time devoted to them, the Hours Available for Curriculum Innovation increased in time to support curriculum innovation just as it was coming “on stream”. In addition, as shown in Figure 10, Structural Flexibility increased early enough to produce a higher Fraction Adopted and Mode of Student Evaluation increased in time to assure that the Impact of Innovation would be translated into Measured Impact of Innovation. (Note that the vertical scales in Figure 10 are different than in Figure 8. Because values achieved are all higher, Fraction Adopted is on a scale of 0 to 1, Structural Flexibility ranges from 0 to 2, and Teacher Motivation goes from 0.4 to 0.8.) Experience with Innovation went up as a result rather than declining. Both Teacher Motivation and Trust Between School and Community went up as well. As shown in Figure 10, higher Teacher Motivation and Structural Flexibility allowed Fraction Adopted to increase and remain high. Higher Trust Between School and Community permitted Structural Flexibility and Mode of Student Evaluation to remain high as well.

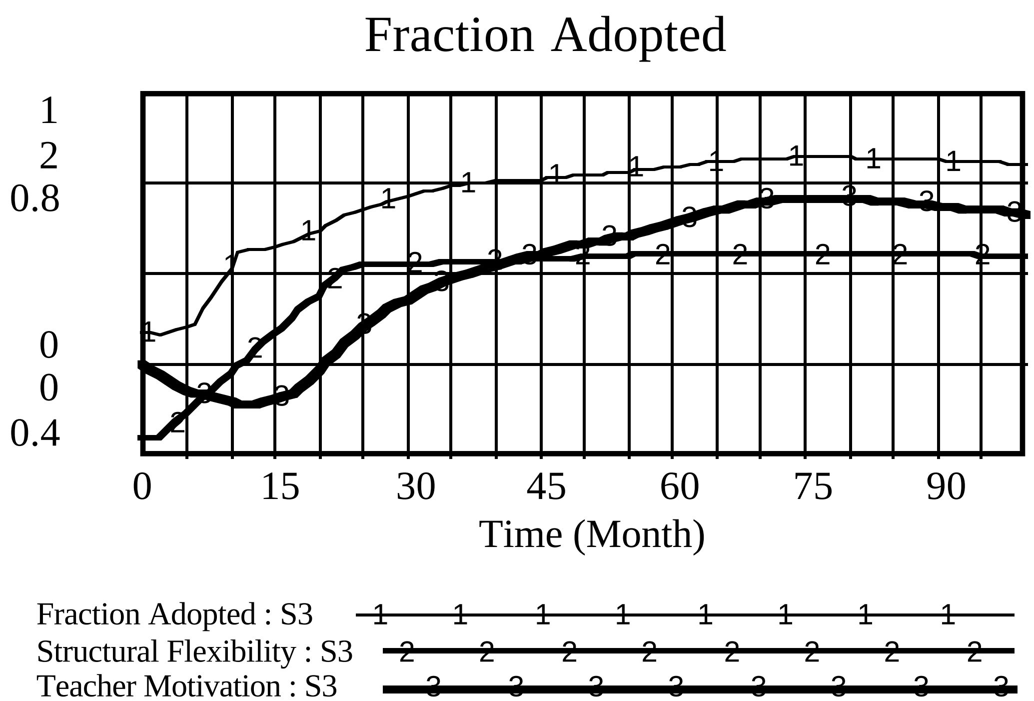

Figure 10: Fraction Adopted and Related Variables in Simulation with Curriculum Innovation (Starting After Two Years) Together with Changes in Mode of Student Evaluation and Structural Flexibility

Dr. Garvin explained another reason for the somewhat better results. He indicated that there were a set of reinforcing loops, diagrammed in Figure 11, that helped build on increases in Experience with Innovation. He explained that reinforcing loops are circular sets of relationships that amplify changes introduced into a system. They are responsible for different types of growth as varied as money in a savings account or world population.

As shown in Figure 11, one of the loops begins with successful Experience with Innovation which increases Teacher Motivation and, in turn, permits a larger Fraction Adopted. The larger Fraction Adopted increases Curriculum Innovations Adopted, allows more Impact of Innovation and Measured Impact of Innovation to be realized, and leads to more favorable Experience with Innovation. In the other two loops, favorable Experience with Innovation can increase Trust Between School and Community, which allows improvements in both Structural Flexibility and Mode of Student Evaluation. Increased Structural Flexibility again increases the Fraction Adopted and, through it, creates further improvement in Experience with Innovation. Improvements in the Mode of Student Evaluation help to increase the Measured Impact of Innovation which, in turn, also leads back to improved Experience with Innovation.

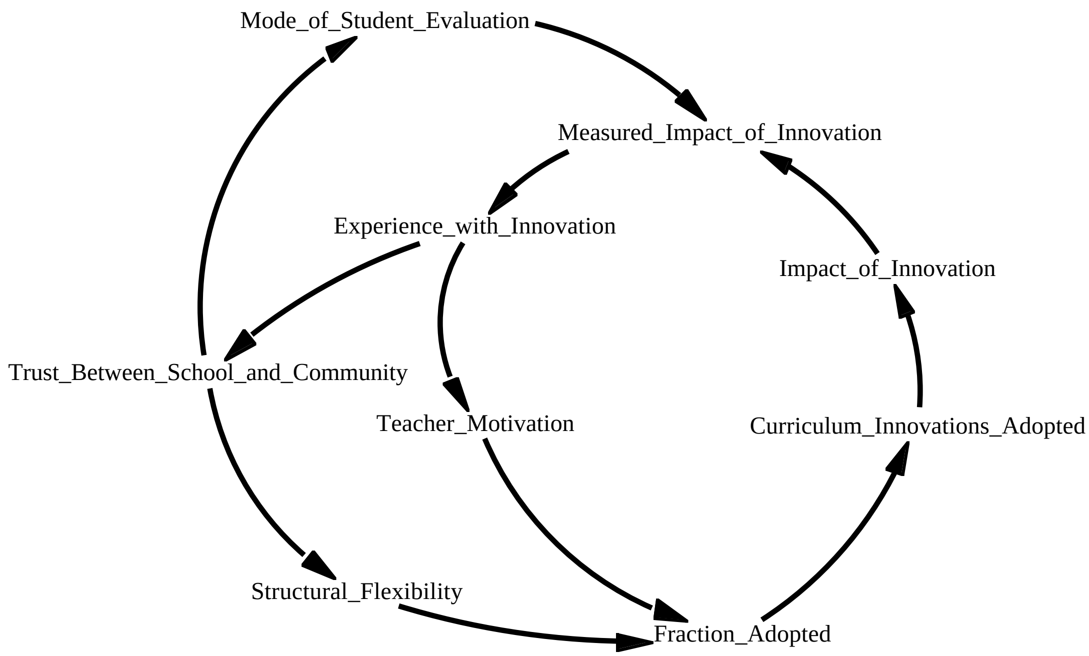

Figure 11: Reinforcing Loops That Amplify Changes in Experience with Innovation

Dr. Garvin indicated that reinforcing loops can provide leverage and help to overcome the inertia that often resists innovation in schools. Finding these loops allows us to identify interventions that can strengthen their reinforcing effects. However, they can also amplify changes that begin to occur in a downward direction. Unfavorable Experience with Innovation will create a “vicious cycle” that reduces Teacher Motivation, decreases the Fraction Adopted and Impact of Innovations, and further reduces Experience with Innovation. This sort of vicious cycle was exactly what produced the rapid deterioration at the end of the previous simulation (S2).

How could they eliminate the drop at the end of the simulation that represented a failure of the innovation to have a lasting effect, both on the curriculum and creating a favorable climate for future innovation? The student representative suggested that, even if it were successfully implemented, the new curriculum would add significantly to both student and teacher workloads if it were simply piled on top of the traditional curriculum that they were expected to cover. Could we simulate what might happen if the Tasks in Traditional Curriculum were cut back to make room for the new material? Ideally, this would create more Hours Available for Curriculum Innovation and lead to a more Rapid Rate of Adoption.

2.4.3 Eliminating Tasks in Traditional Curriculum

The results provided further encouragement. Dr. Garvin graphed the Experience with Innovation variable in this simulation (S4) (the upper curve) compared to the previous one (S3), as shown in Figure 12A. While Experience with Innovation also dropped off at the end of the simulation, as it had in the previous one, the result was still significantly better. (In Figure 12A, Experience with Innovation is graphed on a scale of (effectively) 0 to 10.) Graphs of other variables, shown in Figure 12B, helped to explain the comparatively better results. (In Figure 12B, Trust Between School and Community is again on a 0 to 1 scale. Tasks in Traditional Curriculum and Hours Required for Traditional Curriculum are both on scales of 100 to 150 per month. Hours Required for Traditional Curriculum include hours spent in the classroom, preparing for class, grading papers, etc. Students Capacity for Learning is on a scale of 0 to 6 out of a possible 10. Students Capacity for Learning is a measure of higher level thinking skills over and above rote memorization that had been typical of learning in Anchor River. A value of 0 would mean no capacity above rote memorization while a 10 would represent a broad array of higher level skills.)

As Dr. Garvin presented the results shown in Figure 12B, he also drew a pair of reinforcing loops, shown in Figure 13, that helped to explain what was happening. Additional Hours Available for Curriculum Innovation, produced by eliminating 20% of the Tasks in the Traditional Curriculum and thereby cutting Hours Required for the Traditional Curriculum, made it possible to increase Curriculum Innovations Adopted more quickly. The result was faster growth in Impact of Innovation. As indicated in the first loop, greater Impact of Innovation helped to increase Students Capacity for Learning and reduced Hours Required for Traditional Curriculum. The additional Hours Available for Curriculum Innovation that were gained as a result then helped to produce more Impact of Innovation. This was confirmed by the graph in Figure 12B that shows how growth in Trust Between School and Community and Students Capacity For Learning help to bring down the Tasks in Traditional Curriculum and Hours Required for Traditional Curriculum.

In the second loop, as Trust Between School and Community increased as a result of the favorable Experience with Innovation, further reductions were possible in the Tasks in Traditional Curriculum, leading to deeper reductions in Hours Required for Traditional Curriculum and additional increases in Hours Available for Curriculum Innovation. The result was, again, more rapid growth in Curriculum Innovations Adopted and Impact of Innovation and better Experience with Innovation and a higher level of Trust Between School and Community. Unfortunately, while these results were better, the Level of Expected Impact eventually exceeded the Measured Impact of Innovation and Experience with Innovation fell as it had in simulation (S3). Impact of Innovation was still too low relative to Level of Expected Impact to produce sustained improvement in Experience with Innovation.

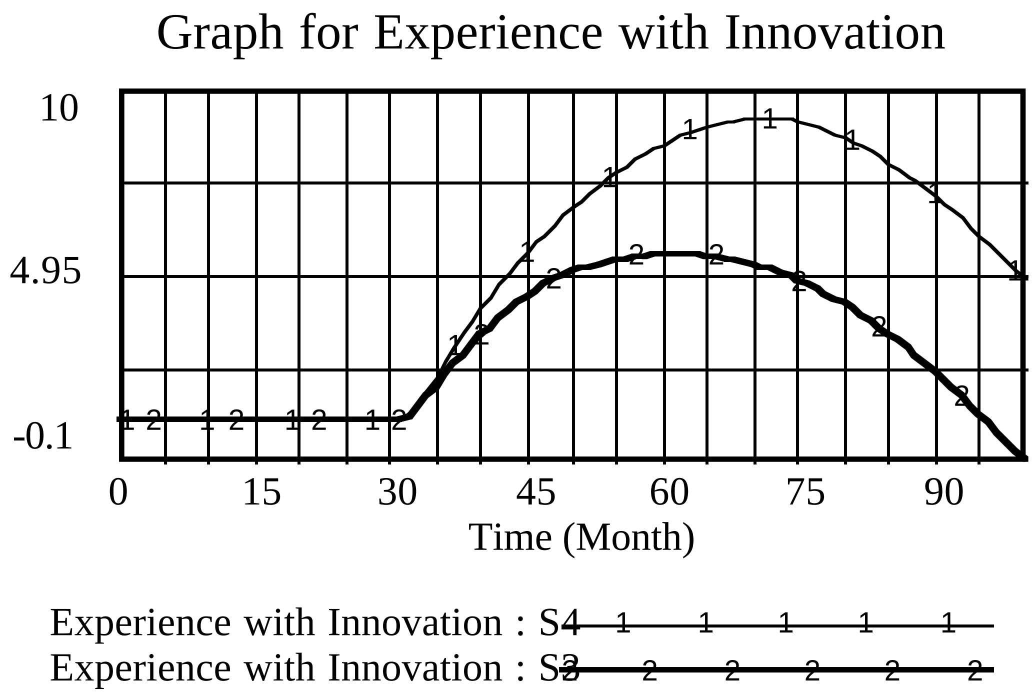

Figure 12A: Curriculum Innovation with Changes in Mode of Student Evaluation and Structural Flexibility and 20% Reduction in Tasks in Traditional Curriculum -- Comparison with Simulation without Reduction in Tasks in Traditional Curriculum

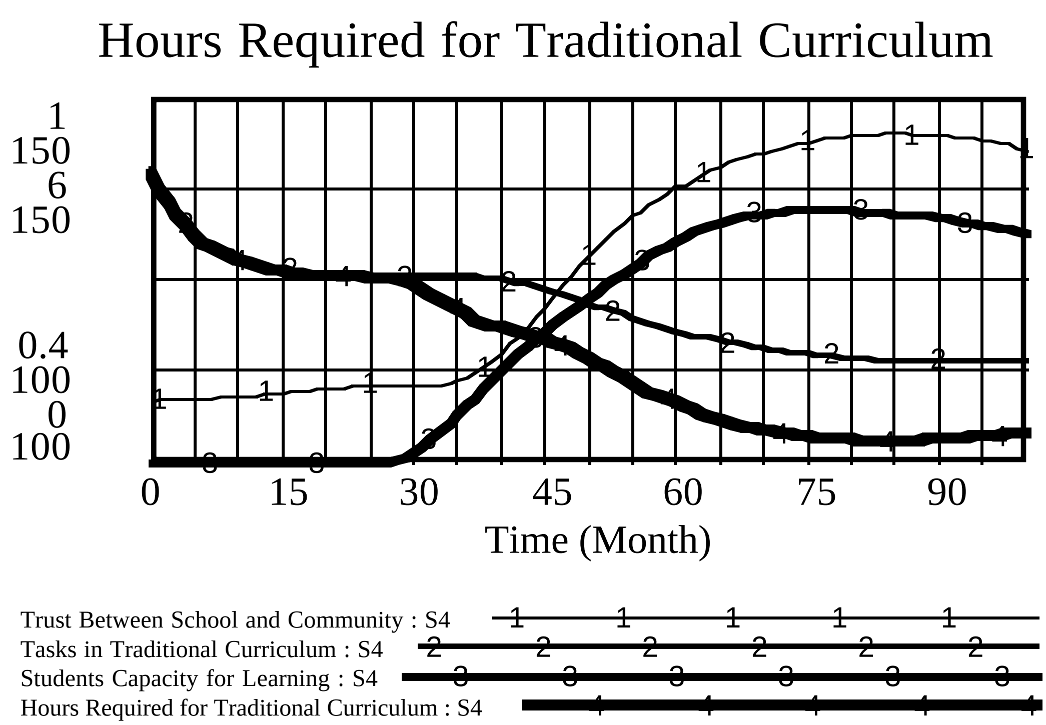

Figure 12B: Curriculum Innovation with Changes in Mode of Student Evaluation and Structural Flexibility and 20% Reduction in Tasks in Traditional Curriculum -- Effects on Hours Required for Traditional Curriculum and Trust Between School and Community

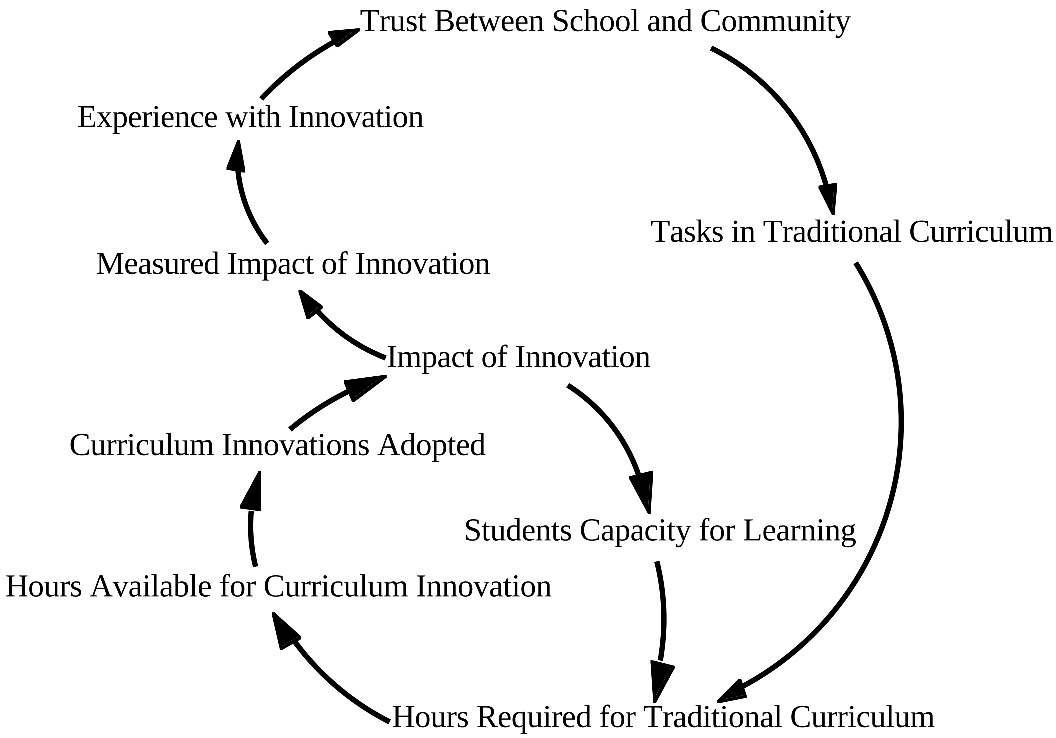

Figure 13: Reinforcing Loops That Amplify Increases in Impact of Innovation

One of the school board members cautioned that, while cutting the traditional curriculum appears to offer leverage, her experience was that schools are typically reluctant to cut any topics from their curriculum. Parents and other community members may also provide pressure against cutting curriculum for fear that students will miss something important. New programs are usually added to others already there, giving teachers more work to do and students even more material to store in their heads. She mentioned that a recent study of mathematics education, for example, cited the large number of topics covered as a key problem.

Other members of the group worried that it would be difficult to wait two years before launching the new curriculum project since people were anxious to spend the bequest. However, they understood how doing things in the proper sequence was necessary for achieving beneficial results in the long-run. They hoped that, when the time came, the model would be useful for communicating these ideas to the community.

2.4.4 Imposing External Standards

Despite these reservations, Harper was encouraged by the increasingly favorable results and thought that a major curriculum project could succeed as long as it was implemented carefully. However, something was still gnawing at him. While cutting back on Tasks in Traditional Curriculum appeared to produce better results, he remembered the newsletter sitting on his desk that talked about statewide standards designed to improve school performance. Harper knew that these standards and the standardized tests that usually came with them often added to the curriculum as schools tried to “teach to the test”. He asked Dr. Garvin to simulate the effect of expanding the Tasks in Traditional Curriculum by 20% rather than cutting back.

The results were scary. A 20% increase did not sound that bad, but effectively wiped out all of the time needed to implement the new curriculum. When the curriculum project was launched at the end of two years, as it had been in the previous simulations, the Fraction Adopted was low and very little adoption occurred, Measured Impact of Innovation fell far below the Level of Expected Impact, and Experience with Innovation headed steeply in a negative direction. Teacher Motivation and Trust Between School and Community dropped precipitously. The reason for these poor results became apparent when Dr. Garvin again showed them the graph of Hours Available for Curriculum Innovation. Increasing the Tasks in the Traditional Curriculum and, therefore, Hours Required for Traditional Curriculum left no time for implementing curriculum innovations. One member of the group voiced everyone's concerns when she said "How can you innovate when external standards are crowding the school day?"

Dr. Garvin tried to ease the growing anxiety in the room by saying, "Remember that these results are not predictions, but simply play out the assumptions and interactions that we have built into the model. What these results tell us is that an effective implementation strategy for a major curriculum project has to be designed with these contingencies in mind and must be resilient enough to do well in spite of these external pressures." The group agreed that it was valuable to have a framework for examining these issues and set a date for their next meeting to continue refining the model and using it to examine other "What if?" questions.

3. More Detailed Exploration of Model of Innovation in Schools

3.1 An Overview of the Model Developed So Far

When the group next met, Dr. Garvin thought it would be helpful to create an overview of the model they had developed so far. The diagram he drew, shown as Figure 14, provides an overview of innovation in schools as represented in the model. It presents innovation as a dynamic process in which Curriculum Innovations Initiated and, through Teacher Motivation, Curriculum Innovations Adopted, are affected by the school and community's Experience with Innovation. That experience reflects not only the actual Impact of Innovations, but the Measured Impact of Innovation as well. Being able to measure impact requires congruence between innovations attempted by schools and the Mode of Student Evaluation that is in effect. Some innovations may succeed in achieving their objectives, but be invisible if the measurement system cannot capture their impact.

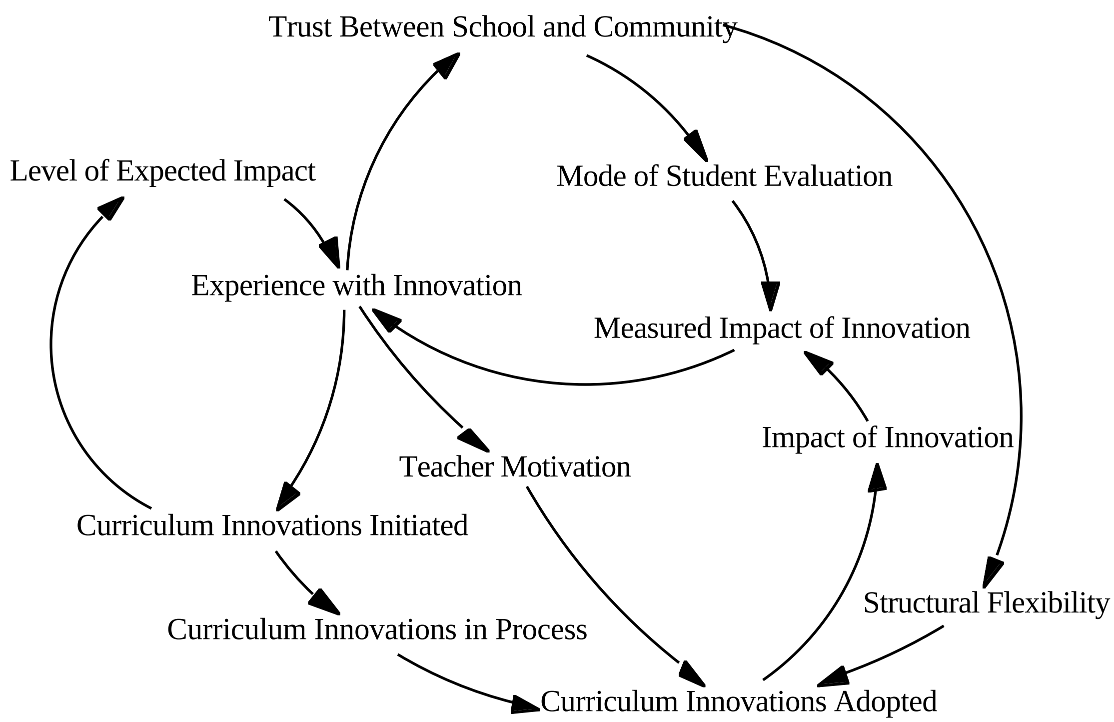

Figure 14: Overview of the Innovation Model

The actual Impact of Innovation will, of course, depend on whether or not they are successfully adopted. Such factors as Structural Flexibility (e.g., scheduling systems that permit longer class periods for activities that require them) will affect whether particular innovations can be successfully adopted. The level of Teacher Motivation will also affect whether innovations are successfully adopted since innovations usually represent additional work for teachers and they must have some reason for putting in the extra effort. Successful Experience with Innovation will affect Teacher Motivation and Trust Between Community and Schools.

3.2 A More Detailed Look at the Curriculum Innovation Process

The group wanted to go into more depth to better understand the process they were modeling. The model had already proven useful for framing some of the issues. Now they wanted to better understand and expand on the issues concerning innovation.

3.2.1 Process of Adopting Innovations

The group started by expanding on the part of the model shown in Figure 1 concerning the adoption of innovations. It began with a fundamental question: What are the characteristics of innovations that determine their impact? As people answered, Dr. Garvin drew the relationships among the variables as shown in Figure 15. One of the school board members volunteered that the most obvious characteristic is the **Breadth of Impact,** represented by the fraction of the student body it affects. Harper’s assistant, Ms. Green, added that **Generality of Applicability** is also important. An effective writing program, for example, would affect students’ performance in a variety of subjects such as history and biology as well as English. The student representative, who was becoming increasingly bored and frustrated with her assignments, suggested that an important distinguishing characteristic of innovations is their ability to promote a **Deeper Understanding vs. Rote Memorization**. The group agreed that these variables that define the magnitude of an innovation’s impact and also determine the Hours Required for Curriculum Innovation.

The teacher’s union President pointed out that **Distance from Current Practice** is also a determinant of the resources required. Innovations entailing methods that are a lot different than teachers now use can require a great deal of time for teacher learning and curriculum development**.** Curriculum Innovations in Process require teachers to invest significant numbers of hours. Even after an innovation has been adopted, time is still required to “polish” the innovation and teachers skills in using it. These **Hours Required for Maintenance of Adopted Innovations** could become substantial and take up much of the **Hours Available for Innovative Activity** after a successful curriculum project had been implemented. Hours Available for Innovative Activity includes Hours Available for Curriculum Innovation as well as hours for developing the Mode of Student Evaluation and Structural Flexibility.

At one point, one of the teachers got upset because the diagram that was evolving on the flip chart made it seem as if innovation could only come about as a result of large, systemwide projects. This teacher was one of the few innovators, the one who had made the “arrows in the back” comment to Harper a few months earlier. He protested that **Teacher Initiated Innovation** is equal to or more important than systemwide projects. Dr. Garvin asked what would affect the rate at which these Teacher Initiated Innovations occurred. The union President said that Teacher Motivation has an important effect since teachers already have plenty to do and innovation always takes extra effort. Harper told the group that he found teachers in the district somewhat motivated, or at least open to innovation, yet little had apparently occurred in the past. The union President chortled at the implicit assumption that teachers really had the freedom to innovate in the past. What teachers perceived as **Flexibility Given Teachers Re: Innovation** was as important a determinant as Teacher Motivation. The teachers in the room agreed that Harper’s predecessor had a way of making innovation risky and unpalatable by issuing reprimands if attempts at innovation were less than successful or if they succeeded, but were seen as undermining students performance on the real (traditional) curriculum.

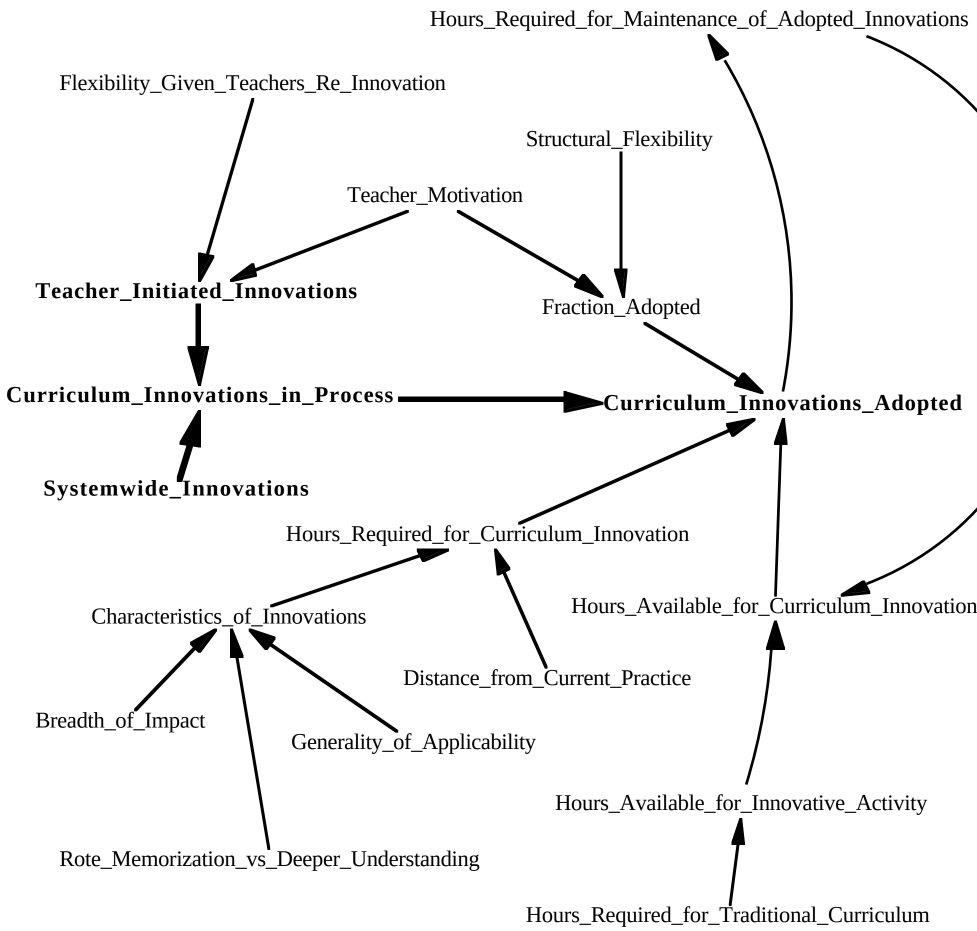

Figure 15: Process of Adopting Innovations

3.2.2 Impact of Innovation

The diagram on the flip chart was beginning to get very cluttered and the group had difficulty following the arrows. Dr. Garvin took a clean sheet of paper, put Curriculum Innovations Adopted at the left and asked the group to describe how innovations have their impact once they are adopted. The diagram shown in Figure 16 was the result.

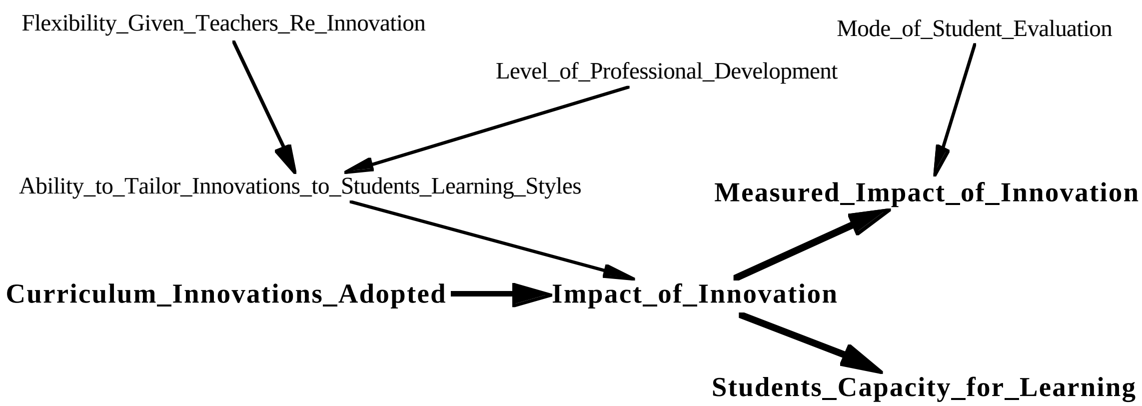

Figure 16: Impact of Innovation

Developing this diagram allowed the group to gain some insight about something they might have been missing until now. The parent representative was the first to recognize the omission. She knew from personal experience that innovations will have very little impact if they cannot be tailored to students' individual learning styles. Her son had a great deal of frustration with one of the few innovations the schools had adopted (it was trendy and all of the districts were doing it). Teachers were told that they had better not "screw it up" and therefore worked rigidly from the manual that came with the new curriculum. Unfortunately, it was taught in a way that did not at all match her son's learning style. Appeals to the teacher were met with the excuse "we have to do it that way." And "Why doesn't your son try harder. The other kids seem to get it." One of the teachers in the group remembered that curriculum project and how it was eventually abandoned when it became less trendy and was replaced by a newer fad.

Dr. Garvin added **Ability to Tailor Innovations to Students Learning Styles** and drew an arrow from it to Impact of Innovation. He asked what affected this Ability to Tailor Innovations. The union President said that Flexibility Given Teachers Re: Innovation perceived by teachers would have an important effect here as well. Just as had occurred in the situation the parent complained about, teachers will not tailor innovations if they perceive a lack of flexibility. A lack of flexibility may be communicated directly or indirectly in terms of the risks attached to deviations from a prescribed way of teaching. Another teacher said that the **Level of Professional Development** affects Ability to Tailor Innovations to Students Learning Styles. Anyone can take a "cookbook" approach to a new curriculum, but adapting curriculum to students' individual needs requires a high level of skill. The time spent on professional development and quality and relevance of the programs affect the level of skill teachers can bring to bear.

3.2.3 Sources of Resistance to Innovation

At this point, the skeptic in the group expressed a question that was on the minds of several other people as well. "With the potential for success-building-on-success offered by the reinforcing loops we saw diagrammed at the last meeting, why has innovation proven so difficult for schools?" Others in the group thought that some of the answers were relatively straightforward. As they had already discussed, innovations whose impact cannot be measured because students are evaluated based on narrow criteria will appear to fail even though they produce a positive effect on Students Capacity for Learning. A lack of Structural Flexibility will keep some innovations from being adopted or cause them to be adopted in a token manner that reduces their effectiveness.

Dr. Garvin pointed out that there are also dynamic processes that "push back" and create resistance to successful innovation. This "push back" comes from feedback loops that are called balancing loops. He diagrammed a simple one of these that is shown in Figure 17. It shows how Curriculum Innovations Initiated increase the Level of Expected Impact which, if it is not substantially matched by the Measured Impact of Innovation achieved, will lead to unfavorable Experience with Innovation and reduces Curriculum Innovations Initiated in the future. Dr. Garvin invited the group to find other balancing loops that might work to resist innovation.

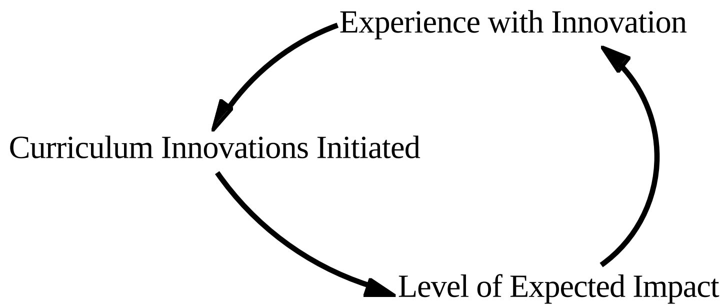

Figure 17: Balancing Loop Through Level of Expected Impact

Figure 18 shows a set of loops the group drew involving tension between innovative programs and the traditional curriculum. The diagram shows that if schools treat innovations as “add-ons” and Hours Required for Curriculum Innovations are added to Hours Required for Traditional Curriculum, the resulting Stress on Teachers will take its toll after a while and reduce Teacher Motivation. Lower Teacher Motivation would then lead to a smaller fraction of innovations being adopted and lower Rate of Adoption. Schools may try to reduce this Stress on Teachers by spreading innovations out over a longer period of time. This stretching out will also unfortunately reduce the Rate of Adoption. In both cases, Impact of Innovation would be lower. If the community has come to expect a Measured Impact of Innovation sooner than this stretching out allows, negative Experience with Innovation and loss of Trust Between School and Community may result. Again, poor Experience with Innovations will reduce Curriculum Innovations Initiated in the future.

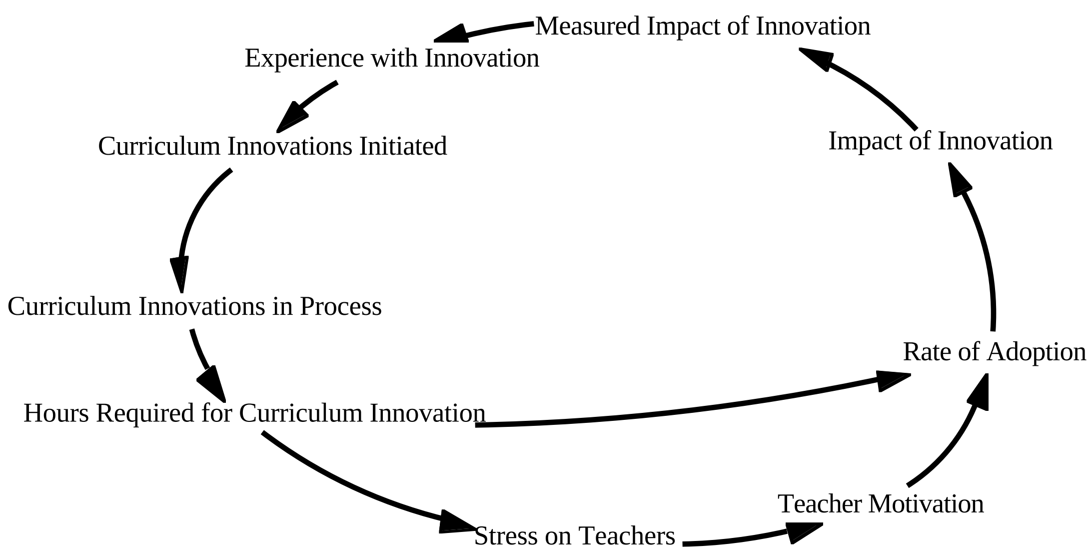

Figure 18: Balancing Loops Based on Time Allocation

Dr. Garvin pointed out that the potential for successful innovation could be improved by reducing the strength of the balancing forces. For example, making more time available by relieving teachers of some other duties would enable a school to reduce Stress on Teachers without slowing the Rate of Adoption too much.

4. Additional Simulations with the Innovation Model

4.1 Decisions and Characteristics That Can Be Varied

Now that they understood the model better at a detailed level, the group was eager to pose more "What if?" questions that could be answered with additional simulations. Dr. Garvin created a list of decisions contained in the model that the group could choose from. (Appendix A describes more specifically how to simulate different combinations of decisions and policies and school characteristics.) Some of the decisions were with regard to the magnitude and timing of:

- Systemwide Innovations (in curriculum)
- Teacher Initiated Innovations (in curriculum)
- Mode of Student Evaluation
- Structural Flexibility
- Flexibility Given Teachers Re Innovation

Design of the model also enabled the following to be changed:

- Decision to Eliminate Traditional Curriculum
- Hours Devoted to Professional Development
- Effect of External Standards

It was also possible to change:

- Initial Teacher Motivation
- Initial Trust Between School and Community

to create different starting points for the simulations. Initial values of Structural Flexibility, Mode of Student Evaluation, and Flexibility Given Teachers Re Innovation could also be varied.

4.2 Results of Additional Simulations

The group remembered that the earlier set of simulations had produced some results that were promising, but did not represent success in the sense of sustainable innovation. What other things might help improve the chances that innovation would succeed? Several changes were selected to simulate with the model. The first two emerged from the group's discussion of Impact of Innovation and how that depended on Ability to Tailor Innovations to Students Learning Styles.

- Increasing Hours Devoted to Professional Development
- Increasing the Flexibility Given Teachers Re: Innovation
- Approaches that combine several things at once

These would be added to changes in Mode of Student Evaluation and Structural Flexibility and a curriculum project launched two years later. This set had so far proven to be the minimum necessary for achieving any sort of acceptable results.

4.2.1 Increased Hours Devoted to Professional Development

The teachers' union President suggested that, with all of the demands of a major curriculum innovation, an increase in Hours Devoted to Professional Development activities is absolutely essential. Relationships shown in Figure 16 suggest that this will have a favorable effect on teachers' Ability to Tailor Innovations to Students Learning Styles, thereby increasing Impact of Innovation. An increased Level of Professional Development can also increase Teacher Motivation through greater Awareness of Innovations Adopted Elsewhere. Two simulations were done in which teachers Hours Devoted to Professional Development per month increases to 24 hours (S6) and 18 hours (S7) respectively from the 12 hours in the baseline assumptions. As indicated above, all other interventions are the same as the ones in the simulation that combined curriculum innovation with changes in Mode of Student Evaluation and Structural Flexibility (S3) that is used as a basis for comparison. Comparative results are shown in Figure 19.

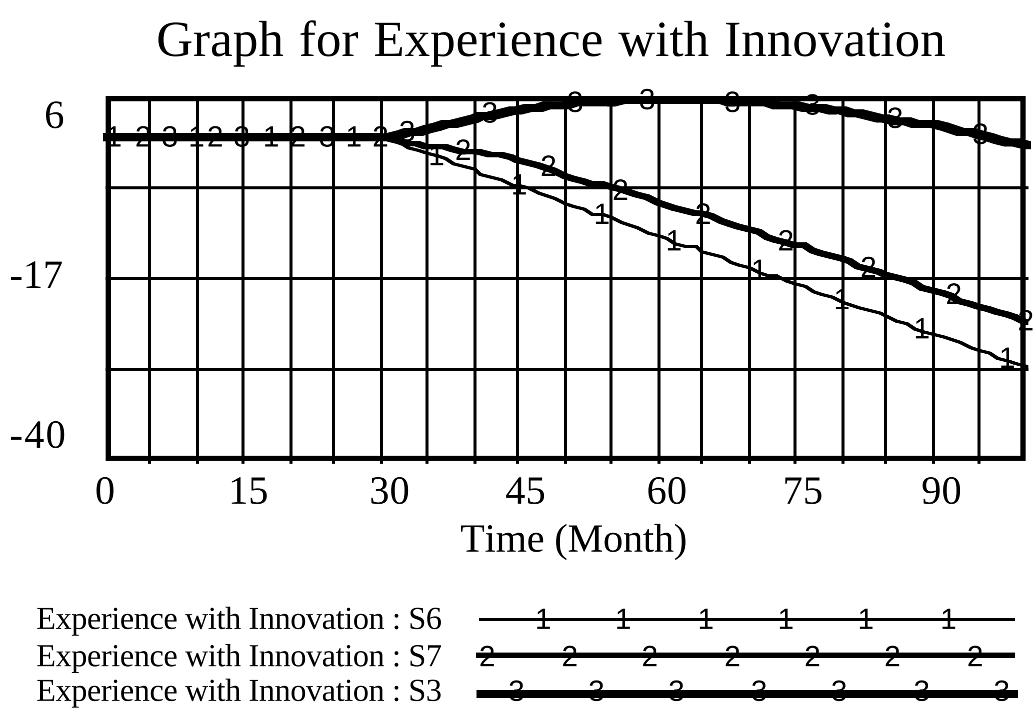

Figure 19: Results with Additional Time Allocated to Professional Development

Results shown in the graphs in Figure 19 provide a good example of how a basically sound intervention can have unanticipated consequences that produce worse results than those achieved without it. Figure 19 displays Experience with Innovation for the three simulations. (The vertical scale on the graph ranges from a slightly positive +6 to a disastrously bad -40.) In simulations (S6) and (S7), time invested in Professional Development has some desired results in terms of increasing the staff's Ability to Tailor Innovations to Students Learning Styles, as shown in Figure 16, and raising Awareness of Innovation Elsewhere, a determinant of Teacher Motivation. However, Professional Development activities also take time away from curriculum innovation and keep it from succeeding. The result is very negative Experience with Innovation for both (S6) and (S7).

The simulation in which the larger amount of time is allocated to Professional Development (S6) produces the worst result because time shifted to this activity is not available for adopting the innovation and making other changes (in Mode of Student Evaluation and Structural Flexibility) necessary to support it. There are too few Hours Available for Innovative Activity to even change the Mode of Student Evaluation. When the curriculum project is launched, it produces minimal Impact of Innovation because of a lack of teacher Hours Available for Curriculum Innovation and even that impact is not measurable. The results look very similar to those in the earlier simulation where curriculum innovation occurred in isolation from any other changes. The results with the smaller amount of time added to Professional Development (S7) are only a little better since less time is shifted away from curriculum innovation and the other changes being undertaken.

Dr. Garvin pointed out that it is important to interpret these results correctly. They do not call the value of professional development into question. Instead, they indicate that professional development, or any other intervention, needs to be considered carefully in the context of the system in which it is being implemented. (A simulation described later will show how increased Hours Devoted to Professional Development can have a beneficial effect when it is coordinated with other changes that make more time available and improve the ability of teachers to use what they learn.)

4.2.2 Increased Flexibility Given Teachers Re: Innovation

Flexibility Given Teachers Re: Innovation is the next element the group considered adding. As suggested in Figure 16, increased flexibility should improve teachers Ability to Tailor Innovations to Students Learning Styles. This can, in turn, improve the Impact of Innovation. Figure 20 shows the results of a simulation (S8) including a decision to expand Flexibility Given Teachers Re Innovation in addition to the other changes described above and included in simulation (S3). (S3) is used as a basis for comparison in the second graph that contrasts Experience with Innovation in the two simulations.

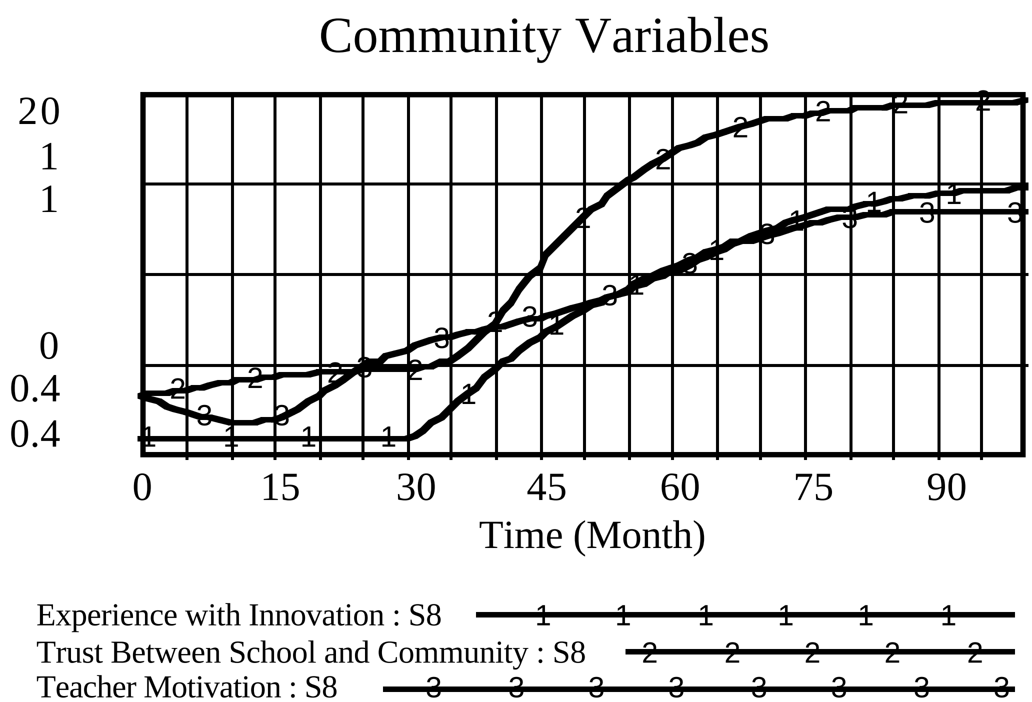

Figure 20A: Effects of Increasing Flexibility Given Teachers Re: Innovation -- Community Variables

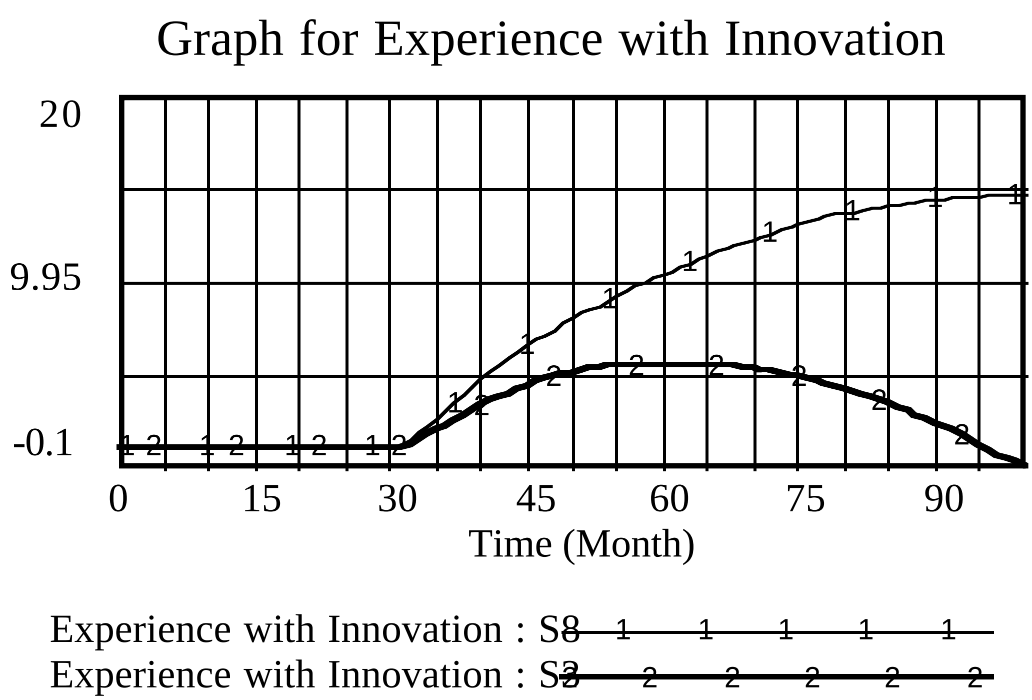

Figure 20B: Effects of Increasing Flexibility Given Teachers Re: Innovation -- Comparison of Experience with Innovation to Simulation Without Increased Flexibility

The results were significantly better and suggested that this variable can be an additional leverage point. As shown in the first graph in Figure 20A, Trust Between School and Community and Experience with Innovation both achieve high levels and appear that they will remain at those levels. Trust Between School and Community and Teacher Motivation are on scales of 0.4 to 1 while Experience with Innovation is on a scale of 0 to 20. The second graph compares Experience with Innovation achieved in this simulation (S8) with that achieved in the one without increased flexibility for teachers (S3). In the second graph, Experience with Innovation is also on a scale of (essentially) 0 to 20. It shows that, instead of dropping off as it did in the earlier simulation (S3), Experience with Innovation achieves a considerably higher level in (S8) (about 15 by the end of the simulation) and remains there. Experience with Innovation persists at that level because the Measured Impact of Innovation has exceeded and remains above 70% of the Level of Expected Impact.

Increased Flexibility Given Teachers Re: Innovation has its effect directly on Impact of Innovation and through two reinforcing loops, shown in Figures 11 and 13. One of these loops, in Figure 11, involves Impact of Innovation and Experience with Innovation. Increased Flexibility Given Teachers Re: Innovation and the resultant effect on Ability to Tailor Innovations to Students Learning Styles increases the Impact of Innovation. Impact of Innovation becomes sufficiently high that Experience with Innovation continues growing and then remains constant as the community's Level of Expectations grows to its maximum value. Improved Experience with Innovation produces increased Teacher Motivation which feeds back to create the potential for more Curriculum Innovations Adopted and greater Impact of Innovation.

The other loop, shown in Figure 13, builds in improvements in Students Capacity for Learning. Increases in Students Capacity for Learning reduce Hours Required for the Traditional Curriculum and releases additional Hours Available for Curriculum Innovation that can lead to more Curriculum Innovations Adopted. While this loop plays only a small role in creating the favorable results shown in Figure 20, it produces the capacity for significant additional curriculum innovation..

4.2.4 Combined Strategies

Now that the group had identified an effective set of interventions, it was appropriate to ask whether combinations of these could produce even better results. Figure 21 displays the results of two simulations with combined strategies compared to results of the one just described above (S8). One of the new simulations (S9) combines increased Flexibility Given Teachers Re: Innovation with a 20% reduction in Tasks in Traditional Curriculum. The other simulation (S10) further adds an increase in Hours Devoted to Professional Development from 12 to 18 hours per month to the 20% reduction in Tasks in Traditional Curriculum and increase in Flexibility Given Teachers Re Innovation. The graph in Figure 21 covers a range of 0 to 40 for Experience with Innovation.

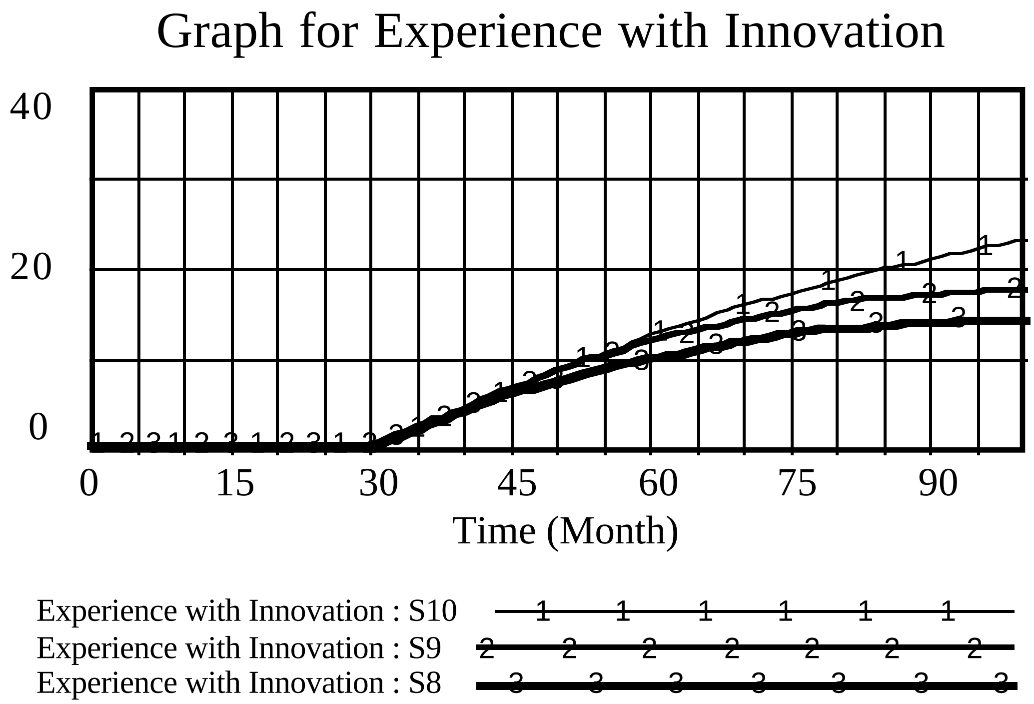

Figure 21: Results with Combined Strategies

The results indicate that combining two of these produces somewhat better results (S9) and combining all three does even better (S10). Each combination yields successively higher levels of Experience with Innovation by the end of the simulation. Both simulations benefit from the reinforcing loops described above, especially the one through Teacher Motivation. In (S9), making more Hours Available for Curriculum Innovation by cutting down on Hours Required for the Traditional Curriculum accelerates the Rate of Adoption and produces Impact of Innovation sooner (than in (S8)), well above the Level of Expected Impact. Experience with Innovation grows faster and reaches a higher level as a result. Again, higher Teacher Motivation results and helps to produce an even higher Fraction Adopted and level of Curriculum Innovations Adopted.

In (S10), allocating increased Hours Devoted to Professional Development now appears productive where it was a disaster in the earlier simulations (S6 and S7). The reduction in the Tasks in Traditional Curriculum makes enough time available for Professional Development. Hours Available for Curriculum Development are reduced somewhat (compared to (S9), but not enough to limit the Rate of Adoption. More Hours Devoted to Professional Development increases teachers Ability to Tailor Innovations to Students Learning Styles and also helps to raise Teacher Motivation by increasing their Awareness of Innovation Elsewhere. Increased Flexibility Given Teachers Re: Innovation also allows teachers to make good use of the benefits of professional development in tailoring innovations to meet individual students' needs. Increased Impact of Innovation is the result.

5. Insights from Modeling

5.1 "Rules of Thumb" for Implementing Innovations

After reviewing the simulation results, the group spent some time thinking about the implications for the major curriculum project their school system was about to undertake. While they realized the model still needed refinement, they developed some "rules of thumb" that could guide planning. These were:

- **Curriculum innovations, especially in the form of large projects, are likely to fail unless they are undertaken in the context of a larger set of changes** needed to help innovation succeed. Combinations of strategies, executed in the right sequence tend to produce the best results. For example, the combination of strategies in (S10) worked well because reducing Tasks in Traditional Curriculum allowed Hours Devoted to Professional Development to increase without taking too much time away from curriculum innovation. Where expanding Hours Devoted to Professional Development had been a problem in earlier simulations in which Tasks in Traditional Curriculum had remained constant (S6 and S7), it could make a positive contribution in (S10).

- **Strategies also work best when they focus on leverage points in the system**. Leverage points are often found on reinforcing loops that sustain growth. Leverage can also be achieved by reducing the "push back" of balancing loops. These leverage points are often not apparent and can only be understood in the context of the larger system. For example, increased Flexibility Given Teachers Re Innovation might not seem very important if simply encountered on a list of factors relevant to innovation. However, through its effect on Impact of Innovation as demonstrated in simulation (S8), it has the potential for creating leverage through a set of reinforcing loops and can therefore have a critical role in creating sustainable innovation..

- **Curriculum innovations should be considered in relation to the "traditional curriculum"** that makes up most of what is being taught in schools. If innovative curricula are to be added, what will be taken away? If additional teacher hours are required to implement new curricula, what will not be taught to make the necessary time available? How should the new and traditional curricula be integrated to provide the best results for both? Other trends affecting the traditional curriculum such as proposals for "higher standards" should be watched closely and considered when planning innovations. Will such trends create unintended impediments for locally developed innovations? Are there kinds of standards (i.e., ones that define higher quality without prescribing particular content) that can support locally developed innovation?

- It is important to produce some **early victories to build confidence** in an innovation among teachers, students, and the community at large. Positive early experiences are likely improve motivation for further work with the innovation that is essential for its ultimate success. How the innovation is perceived by the community is especially important. Keeping the community well informed can help to maintain its trust with regard to curriculum innovation and to other types of innovations such as structural changes needed to assure that a curriculum innovation will succeed.

- Successful innovation also requires **sustained effort**. Results of several simulations presented in this paper displayed "better before worse" behavior in which variables such as Experience with Innovation seemed to improve for a while, but ultimately dropped off after several years. Sustained effort is necessary to reach a threshold at which the reinforcing loops in the system take over and help to assure a permanent place for innovative curricula.

- **Problems or obstacles encountered by innovation need to be responded to in a timely manner**. The reinforcing loops, such as those shown in Figure 11, that produce growth and other desirable behavior in the system will also accelerate decline once it begins. Waiting too long to respond to problems may result in a downward spiral in which declines in Teacher Motivation and other variables become problems themselves make it difficult to reverse direction.

- It is **important for a school or school system to know its strengths and weaknesses** as it plans curriculum innovations. Low levels of variables such as Trust Between School and Community and Teacher Motivation due to past events must be dealt with honestly and factored into planning for innovative programs. For example, a simulation was done using lower initial values of Teacher Motivation and Trust Between School and Community (0.25 for both rather than 0.5 as in the simulations reported in this paper) and the set of interventions in simulation (S8) which had produced relatively good performance. The results were much poorer than those obtained in (S8) and suggested that a school with these low levels might be better off avoiding a large, ambitious curriculum project before building more support. As confirmed by another simulation, a gradual approach emphasizing teacher-initiated innovations and schoolwide programs that start small and grow in size over time will help to increase receptivity to innovation and produce moderately good results..

- **Perceived need for innovation is an important influence** on teachers' motivation since innovation usually means more work for teachers. Developing more elaborate forms of student evaluation can help to identify needs for innovation that were not evident with more traditional testing. Being a "good" school system is not the same as being an innovative one. In fact, the perception that a school system is already a good one may serve as a barrier if people see a need for innovation or see it as a risk to the school's status. To maintain a climate favorable to innovation, schools must consciously raise their expectations. Otherwise, achieving some measure of success with innovation may reduce motivation to do more.

- With any change, it is **essential to understand the systemic effects** rather than simply focusing on direct impacts of that change.

5.2 Benefits from Using System Dynamics

The group also reflected on the benefits it had derived from using the System Dynamics approach rather than a more traditional methodology for planning. These benefits included:

- As they worked on the innovation model, people had to be **explicit about their mental models about innovation** and the context within which innovation takes place. In the process, they discovered differences in their mental models that had led to misunderstandings in the past and to people "talking past each other". The common model they arrived at helped to provide a consistent framework for examining different strategies for dealing with innovation. By sharing their thinking, conversations people had in developing the model were as valuable as the product they produced.

- The System Dynamics approach enabled the group's **understanding of innovation in schools to evolve organically**. They were able to go from a simple picture of innovation to one that was much more complex and embodied a lot more insight. This evolution went through several cycles. At each stage, the model served as framework for incorporating new ideas and examining how they related to concepts that had already been included. Simulation aided this process by helping the group understand the implications of the structure they had developed and identify gaps and inconsistencies that were present. The organic nature of the model allows it to continue to be used as an interactive **communications tool** for presenting ideas to other people, eliciting additional thoughts, and incorporating them in the evolving framework.

- Working with the model prompted the group to **think about unintended consequences** of various strategies. In planning innovation and change, groups typically focus on desired outcomes and ignore new problems that can be created. Having a model that reflects some of the indirect effects of change alerted the group to particular unintended consequences and to be aware of these in general when considering change.

- The model and the simulations done with it helped give the group an **understanding of behavior over time in relation to causal structure**. It helped them, for example, understand the necessity of carrying out changes in an appropriate sequence. Many organizations approach change with a "laundry list" mentality, making lists of things to do, assigning them to committees, and letting the tasks all go on at once. The group saw that certain tasks must occur first (e.g., developing a new Mode of Student Evaluation) to prepare the way for other innovations. They also came to appreciate the importance of anticipating delays in systems and allowing for those in planning.

- Having the model would permit the group to do some **"sensitivity analysis"** and determine key areas for further concentration. In complex systems, the behavior that is of critical importance is usually influenced by a relatively small number of relationships. Unfortunately, it is not at all clear which these relationships are. Much effort is often spent on collecting data on and arguing about things that turn out to not make much difference. Important relationships may simply be overlooked in the confusion. Sensitivity analysis with the model would enable the group to focus on a small number of areas for deeper understanding.

6. Next Steps for the Reader

The next steps discussed below include:

- How you the reader might use the ideas in this paper
- How to make further use of the model itself
- Questions we would like you to help us answer
- Going further with System Dynamics

6.1 Using the Ideas in This Paper

Hopefully, reading this paper itself will have given you some new ideas about implementing innovations being contemplated in your own school or school system. There are several questions suggested by the paper that you and your colleagues might ask as you contemplate a particular curriculum innovation or any other change.

- What resources, especially teacher time, are required to successfully implement this innovation? If the necessary time and other resources are not currently available (something that is generally true in most school systems), where will they come from? What else is of a lower priority and will not get done as a result of shifting resources to the innovation?

- How much contact time with students is required to implement the innovation? Where will this time come from? What will not be taught in order to create the necessary class time? What are the benefits we expect for students? How can these be measured?

- How long will it take to produce results? What is the earliest point at which results will become apparent? How about the bulk of the results? How can we make certain the expectations of the teachers, students, and community are realistic?

- What other pieces must be in place to assure that the innovation will succeed? For example, can existing measurement systems reflect the benefits that the innovation will produce? If not, what is needed to make the results measurable? Do existing schedules permit appropriate blocks of time for teaching the innovative curriculum? If not, what are some of the options (e.g., double periods, supplementary after school time)? What are the other “regularities” that will affect the innovation and must be taken into account in planning?

- What are potential unintended consequences that might arise from the innovation? How might teachers, students, and the community at-large react in ways that undermine the potential impact of the innovation and/or create new problems?

- Do teachers have what they need to effectively implement the innovation? Do they have the capabilities and confidence to adapt the material to students individual needs? Have they been given the flexibility to do so?

6.2 Using the Model

Appendix A describes how to obtain and use the simulation model describe in this paper. There are two ways in which you might want to use such a model. One is as a personal learning experience, allowing you to get deeper into the work than is possible in a paper. Exploring the model will help you better understand how a group conceptualized a difficult problem characterized largely by “soft” variables and quantified the model using some imagination and intuition. Doing simulations with the model will also let you do your own sensitivity analyses to better understand the system, answer “What if?” questions, and craft and test your own strategies. If you have developed some modeling skills, you may want to try adding variables that you think are important and observing the results.

Once you become comfortable with the model, you might also want to use it as a framework for working with small groups of people in your own school or school system. Getting them to discuss what aspects of the model are applicable to your situation and where additional variables are needed could stimulate a rich conversation about people’s mental models about innovation. Doing simulations with the model and getting the group to anticipate and understand the results can also help them think about characteristics of effective strategies for implementing innovations in schools.

6.3 Questions We Would Like You to Help Us Answer

The work so far has raised some important questions that you the reader can help us begin to answer. These include:

- What are the major factors that affect the response of key participants -- teachers, administrators, parents, other community members -- to innovations? Which of these factors are not currently in and should be added to the model?

- The model at this point does not say anything specific about students’ roles in innovation. What are the important variables that affect how students respond to innovative programs and whether those programs succeed in achieving their objectives?

- How do curriculum innovations and other changes described in the model (e.g., in Mode of Student Evaluation) interact with other things going on in schools? How do increasing demands on schools together with fixed resources, for example, affect schools’ ability to innovate? How do these things going on in schools affect the choice of strategies and of innovations themselves? How do important trends in education such as the adoption of “high stakes” testing affect the local climate for innovation? How should the impact of these trends be reflected?

- Are there other conditions that affect the successful adoption of innovations that should be included in the model?

6.4 Finding Out More About System Dynamics

The best starting point for learning more about System Dynamics and its application to education is through the web page of the System Dynamics in Education Project (SDEP) at MIT (http://sysdyn.mit.edu). That web page provides access to a number of relevant materials including a series of papers called “Roadmaps” for independent learning in

System Dynamics. There is also an internet discussion group for K-12 educators interested in System Dynamics. Another important resource is the Creative Learning Exchange (CLE) (http://sysdyn.mit.edu/cle) that distributes many papers and curriculum materials relevant to System Dynamics in K-12 education. The MIT SDEP site also has links to many other relevant sites including the System Dynamics Society. Links also include developers of software packages used for System Dynamics modeling. The model described in this paper was developed with a package called Vensim available from Ventana Systems. You can get more information on the package and download a version called the Personal Learning Edition (free for personal use) at http://news.std.com/vensim. Another package that is popular for educational use is Stella, available from High Performance Systems (http://www.hps-inc.com). A third package is Powersim (http://www.powersim.no).

Appendix A
Using the Model of Educational Innovation

A.1. Obtaining the Software

Download the model from the Creative Learning Exchange at http://sysdyn.mit.edu/cle The file is called educinno.mdl

If you don't have a copy of the Vensim package, you can download the Vensim Personal Learning Edition (free for personal use) from Ventana systems at http://news.std.com/vensim

A.2. Examining the Model

Open Vensim or Vensim PLE and then open the model using the Open command under the File menu. The first "view" that appears will be the Control Panel which you will be using to change key parameters for simulations. If you want to examine other parts of the model, click on the words Control Panel at the bottom of the screen and you will see a list of the other views. Click on any of these to get access to various parts of the model. (Click on the same area at the bottom of the screen to move among views. You can find specific variables by inspecting the different views or by using the Find command under the Edit menu.

To examine equations and numerical values, click on the equation icon ($Y=x^2$) and then on the variable you want to examine. A dialog box will appear that displays the equation. It will also permit you to make changes if you choose to. (It might be a good idea to save a version of the model with changes under a new name if you want to be able to get back to the original model.)

You can get other information on each variable by clicking on the arrow icon at the top of the screen (if it isn't already highlighted) and then double-clicking on a variable to select it. Once a variable is selected, its name will appear at the top of the screen (after the model name). The top two buttons on the left side of the screen will produce causal chains into and out of the selected variables. The bottom four buttons on the left side will provide output for each variable for selected simulations (see "Looking at Output" below).

A.3. Running a Simulation

Choose the values of key parameters for each simulation from the Control Panel. There are two ways to make changes.

- If you want a change to "stick" for several simulations, click on the equation icon at the top of the screen and then on any parameter you want to change. Use the backspace key to eliminate the default or current value, type in the new value in the same space, and then click on OK. Do this for as many parameters as you want to change. (See A.4 Changing Parameters.) Any value you input will remain until it is changed again. If you Close the model without "Saving" it first, values of all parameters will revert to their values when the model was first opened. Doing a Save before closing, however, will make the changes you have made "permanent".

- If you only want changes to last for a single simulation at a time, click on the “Set up a Simulation” button (icon with person leaning forward that says “Set”) and the parameters on the Control Panel view will all be highlighted. Click on any you want to change. The current value will be displayed. It can be erased using the backspace key and a new value typed in. Make as many changes as you want. After the simulation, the parameters you have changed will revert to their values in the model.

Once you have set parameters to the values you want, run a simulation by clicking on the person running icon (Run a Simulation) at the top of the screen after typing in a name for the simulation in the box next to it. Naming simulations is useful when there are several to be compared to each other. The simulation will then run. To view a simulation’s results, click on the gauge icon at the top of the screen (Control Panel) and then select the Datasets tab. Click on the name of the simulation you just ran (or any other one that is loaded) and that simulation will move to the top of the list. The simulation at the top of the list will be available for viewing with the Custom Graphs feature (See A.5 Looking at Output).

A.4. Changing Parameters

To begin with, users can decide whether to initiate the following innovations and can also decide on their timing. (Names of actual model parameters are highlighted in boldface.)

- Systemwide Innovations in curriculum
- Teacher Initiated Innovations in curriculum
- Innovations in the Mode of Student Evaluation (e.g., moving from tests to a portfolio approach)
- Innovations that increase Structural Flexibility

Users can decide on the magnitudes of Systemwide Innovations by setting parameters that affect both the potential impact and resources required:

- **Breadth of Impact**
- **Rote Memorization vs Deeper Understanding**
- **Generality of Applicability**
- **Distance from Current Practice**

Each of these dimensions is scaled 0 to 2. Their default values are all 2. The overall impact of a curriculum innovation is calculated by multiplying the first three together to get a number from 0 to 8 (with an 8 being a large, elaborate project). Parameters derived from the first two of these together with the value assigned to Distance from Current Practice determine the amount of effort (number of hours) required to fully adopt an innovative program. Resources Required for Innovation, calculated in this manner, can vary from 0 to 3.75. 90 hours are assumed to be required of each teacher per unit of resource requirement. Thus a large project might require 337.5 hours (spread over several of years) to be fully adopted. Setting all four of the parameters listed above to 0 will eliminate the Systemwide Innovations entirely, which you may want to do if concentrating on Teacher Initiated Innovations.

The starting point for the Systemwide Innovation can be selected with the parameter **Systemwide Innovations Start** (i.e., set equal to 24 to start in month 24). The default value of Systemwide Project Start is 1 (start in first month of simulation)

Choosing Teacher Initiated Innovation will create a steady stream of small projects that each have a limited impact, but can cumulatively produce a large Impact of Innovation. that affects both Students Capacity for Learning and Experience with Innovation. Levels of Teacher Motivation and Flexibility Given Teachers Re: Innovation must be high enough for Teacher Initiated Innovation to take place. To select Teacher Initiated Innovations, set **Average Magnitude of Teacher Initiated Innovations** to a value other than its default value of 0 (e.g., 1). Set the time at which they start with **Teacher Initiated Innovations Start,** setting it to the starting month (for which the default is 1).

Decisions concerning the Mode of Student Evaluation and Structural Flexibility are expressed as "targets" for the desired levels of those two variables, from 0 to 1. The actual level achieved will depend on Trust Between School and Community and Hours Available for Innovative Activity relative to Hours Required for Innovative Activity.
The Mode of Student Evaluation and Structural Flexibility are both scaled 0 to 1 and require a significant investment of effort as well as the Trust Between School and Community to move upward (e.g., to greater flexibility of scheduling, more elaborate forms of evaluation than tests). A drop in Trust Between School and Community during a simulation can actually result in a decline in these variables. Hours devoted to these kinds of innovations are added to teachers' total load and are unavailable for curriculum innovation. Mode of Student Evaluation and Structural Flexibility are selected and initiated with the following parameters:

Decision to Change Mode of Student Evaluation
Mode of Student Evaluation Start

Decision to Change Structural Flexibility
Structural Flexibility Start

Both "Decision" parameters have a range of 0 to 1. Their default values are 0. Default values of the "Start" parameters are 1 (i.e., starting in month 1).

Users can also set:

- A number of **Hours Devoted to Professional Development**. This affects the Level of Professional Development over time and Awareness of Innovations Elsewhere and Ability to Tailor Innovations to Students Learning Styles. Initially, 12 hours per month are scheduled for Professional Development.

- A **Decision to Eliminate Traditional Curriculum** which will allow them to decrease the number of tasks that make up the traditional curriculum. This decision is expressed as a fraction (e.g., 0.2) of the Tasks in the Traditional Curriculum to be eliminated. However, this can only happen if the Trust Between School and Community is sufficiently high. The default value of this parameter is 0.

- A **Decision to Change Flexibility Given Teachers Re Innovations** which will enhance their Ability to Tailor Innovation to Students Learning Styles as well as being able to undertake Teacher Initiated Innovations. The decision is expressed as a "target" for the level of Flexibility Given Teachers Re: Innovations desired, a number from 0 to 1. The default is 0.1.

- An **Effect of External Standards**. This is expressed as a fraction of Tasks in Traditional Curriculum and will increase the number of tasks by the fraction specified (i.e., a value of 0.2 will increase the number of tasks by 20%). The default value is 0.

Users can also specify different initial values of variables that describe a school and its community:

- **Initial Teacher Motivation** (0.5)
- **Initial Trust Between School and Community** (0.5)
- **Initial Mode of Student Evaluation** (0)
- **Initial Structural Flexibility** (0.1)
- **Initial Flexibility Given Teachers Re Innovation** (0.1)

All of these parameters can range from 0 to 1. Default values are shown in parentheses.

A.5. Looking at Output

There are two ways of looking at the results of a particular simulation. One is through Vensim's Custom Graphs feature. For a simulation that is loaded in the top position (top of the Datasets list as described above), click on the gauge (Control Panel) icon and then on the Graphs tab. A list of graphs associated with this model will appear. Click on any one of them and then on Display to see the graph. Click on New to create a new graph or Modify to change the format of an existing graph (e.g., changing scales, dropping or adding variables). Selecting New or Modify will cause a dialog box to appear with graph information that is self-explanatory.

The other way to view output is to click on the arrow icon at the top left (if it is not already highlighted) and then double click on a particular variable on any of the views to select it. Then click on any of the bottom four buttons on the left-hand side of the screen to display that variable's results in graphical or tabular form. Clicking on the top button of the four will display graphs of the variables affecting the selected variable (Causes Strip) in addition to the variable itself. The other buttons will produce graphs of the variable itself, data on the variable and its causal factors in tabular form, and comparisons of parameter changes between simulations. Selecting these buttons will provide data for each of the simulations that is loaded and will therefore permit comparisons, variable by variable, among simulations To load or unload simulations for comparisons, click on the gauge (Control Panel) icon and select the Dataset tab. Use the double-arrow buttons to move simulations to and from the list on the right that represents the "loaded" simulations. The list on the left is the set of simulations that are available for viewing, but not loaded.

A.6. Sensitivity Analysis

It is possible to change a large number of other parameters and graphical functions in the model. One reason for this might be to perform sensitivity analyses to see which parameter changes yield the largest impact on the behavior of the system as a whole. Another might be to make the model conform more to your own mental model. A third reason might be to make the model "look like" your own school or school system. Explore the model and decide which ones you would like to change. Vensim helps by highlighting the parameters and graphical functions in each view when you click on "Set up a Simulation" (the "Set" button at the top with icon of person leaning forward).) Click on each parameter and/or graphical function in turn. Graphical functions are usually located next to the variables whose values they help to determine (and typically take on an abbreviated version of the same name). These can be changed by typing in new numbers or, more easily, by simply bending the curve to a new shape.

When you have made all of the changes you want to, run the simulation by clicking on the "Run a Simulation" button (person running icon). Be sure to name the simulation if you are planning to do several. The simulation will run and you can then look at output and compare the results to those of other simulations. Parameters you set for that simulation will revert to their values in the model. Remember to reset them if you want to make the same change in the next simulation.

If you would like to make a more permanent change (one that remains over a number of simulations), click on the equation icon ($Y=x^2$). Then click on each parameter and graphical function in turn and use the dialog box that pops up to change the values. Simply "erase" the old value with the backspace key and type in the new one. Graphical functions will be easier to change if you click on the "As Graph" button in the dialog box and then can bend the curve to the desired shape. Changes will remain until you change them again. If you "Save" the model with these changes, they will become a permanent part of the model (though they can, of course, be changed the next time you open the model). If you don't save the changes, the model will revert to its original values.

Appendix B
Parameter Values Used in Reported Simulations

(S1) Curriculum Innovation Only

Default values for all parameters (see Section A.4).

For the following simulations, only parameters different from default values are shown.

(S2) Curriculum Innovation and Changes in Mode of Student Evaluation and Structural Flexibility

Decision to Change Structural Flexibility=1
Decision to Change Mode of Student Evaluation=1

(S3) Curriculum Innovation (Starting After Two Years) Together with Changes in Mode of Student Evaluation and Structural Flexibility

Decision to Change Structural Flexibility=1
Decision to Change Mode of Student Evaluation=1
Systemwide Innovation Start=24

(S4) Curriculum Innovation with Changes in Mode of Student Evaluation and Structural Flexibility and 20% Reduction in Traditional Curriculum

Decision to Change Structural Flexibility=1
Decision to Change Mode of Student Evaluation=1
Systemwide Innovation Start=24
Decision to Eliminate Traditional Curriculum=0.2

(S5) Curriculum Innovation with Changes in Mode of Student Evaluation and Structural Flexibility and 20% Increase in Tasks in Traditional Curriculum in Response to External Standards

Decision to Change Structural Flexibility=1
Decision to Change Mode of Student Evaluation=1
Systemwide Innovation Start=24
Effect of External Standards=0.2

(S6) Additional Time Allocated to Professional Development (24 Hours)

Decision to Change Structural Flexibility=1
Decision to Change Mode of Student Evaluation=1
Systemwide Innovation Start=24
Hours Devoted to Professional Development=24

(S7) Additional Time Allocated to Professional Development (18 Hours)

Decision to Change Structural Flexibility=1
Decision to Change Mode of Student Evaluation=1
Systemwide Innovation Start=24
Hours Devoted to Professional Development=18

(S8) Effects of Increasing Flexibility Given Teachers Re: Innovation

Decision to Change Structural Flexibility=1
Decision to Change Mode of Student Evaluation=1
Systemwide Innovation Start=24
Decision to Change Flexibility Given Teachers Re Innovation=1

(S9) Combined Strategy Including Increase in Flexibility Given Teachers Re Innovation and 20% Reduction in Traditional Curriculum

Decision to Change Structural Flexibility=1
Decision to Change Mode of Student Evaluation=1
Systemwide Innovation Start=24
Decision to Change Flexibility Given Teachers Re Innovation=1
Decision to Eliminate Traditional Curriculum=0.2

(S10) Combined Strategy Including Increase in Flexibility Given Teachers Re Innovation and 20% Reduction in Traditional Curriculum Plus Additional Time Allocated to Professional Development (18 Hours)

Decision to Change Structural Flexibility=1
Decision to Change Mode of Student Evaluation=1
Systemwide Innovation Start=24
Decision to Change Flexibility Given Teachers Re Innovation=1
Decision to Eliminate Traditional Curriculum=0.2
Hours Devoted to Professional Development=18