Supporting Material is available for this work. For more information, follow the link from the Table of Contents to "Accessing Supporting Material".

System Dynamics Adoption at Enterprise Locations[1]

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Anecdotal evidence indicates that efforts to acculturate enterprise locations to **system dynamics (SD)** *are often less successful than anticipated. Experience teaching SD in Door County, Wisconsin suggests a process that holds promise to significantly increase the probability of SD acculturation in any community of adults. This paper translates this process to the context of a location within an enterprise, whether the enterprise is for-profit, non-profit, or government.*[1]

Prescriptions for Successful SD Adoption Dynamics:

During the 1999-2000 academic year in Door County, Wisconsin, four high school teachers and four other adults, along with five high school sophomores, took an SD course. Classes met one weekday evening and Saturday mornings from September through April (eight months). Now, almost three years after the start of the course, seven of the eight adults continue to think about problems in stock/flow and feedback terms, and to either teach, or encourage SD use, in their schools, community, and work. This adoption fraction seems much higher than is achieved in most SD training efforts. Recently, the adult SD students and the course instructor hypothesized six reasons for their high adoption fraction. Their conclusions should be useful as a set of prescriptions to achieve similar SD adoption rates at enterprise locations.

Prescriptions (See Appendices 2 & 3 for more detail.)

1) Ensure self selection into the program
2) Customize and re-tailor the curriculum as necessary during the program, both in pace and content, to maintain student interest
3) Sustain learning focused on problems compelling to individual students
4) Focus the program curriculum on the SD paradigm and process
5) Ensure collaboration among students
6) Ensure sharing of applications and perspectives among a mix of students at the same learning stage who are using SD for very diverse applications and for very different purposes.

[1] The **audience for this paper** is enterprise people familiar with **system dynamics (SD)** and interested in its adoption at their own, a client's, or a supplier's enterprise location. If you are unfamiliar with SD, see the sections entitled, "*What is system dynamics*," "*System dynamics applications in business*," " *System dynamics and management*" and "*System dynamics and leadership*," at www.StewardshipModeling.com.

The Door County SD experience indicates that following these prescriptions can significantly improve SD adoption dynamics. In particular, the number of people who decide to continue to use SD after completing their first SD project increases, and the time required for people to become acculturated to SD decreases. See Appendix 1.

Proposed Process:

At many enterprise locations SD instructors will not be locally available who can spend eight months teaching a class twice each week as was done in Door County. And with as much travel and other interferences as there are in many enterprise settings, it often will be difficult to hold classes over eight months as in Door County. But, the curriculum can be covered in two one-week workshops. In order not to violate prescriptions 2 and 3 above, this necessitates individual coaching of students by the instructor, after each workshop, as the students apply what they learned in the workshops to their individually compelling enterprise problems. Students don't take the second workshop until they have applied what they learned in the first workshop to their enterprise problems. Such compression of the curriculum into one-week workshops, with follow-up coaching, has worked well in practice for an SD course at Cornell University. It is a three-step process:

1) Identification and self-selection of a cohort of students, probably via one or more on-site seminars on both SD and on what the program would entail were one to choose to participate. Part of this step includes preliminary selection of the set of enterprise problems that this the cohort of students will address. These need to be important enterprise problems that are individually compelling to the students. Students will work in pairs on problems, and are given a preparatory reading assignment.

2) Learning stage 1 consists of two parts. First, a one-week workshop (a few weeks after cohort selection) that focuses on the SD paradigm, process, tools, and basic dynamic behaviors and the structures that cause them, enabling students to articulate problems, select boundaries, and formulate dynamic hypotheses. Note that each student team will spend a significant part of the workshop (one to two days) applying what they are learning to their compelling enterprise problem. Second, after the workshop, each team continues to apply what they learned in the first workshop to their compelling enterprise problem, thereby significantly improving their thinking about the problem. The entire cohort meets weekly to share their work and perspectives with one another (prescription #5 above).

3) Learning stage 2 also consists of two parts. First, there is a second one-week workshop in which the two-person student teams begin building a simulation model that replicates some of the behavior modes that describe their compelling enterprise problem, thereby developing an appreciation for the necessity of simulation modeling in understanding dynamically complex problems. The second workshop should be held after most students have gone as far as they can on their compelling enterprise problems using what they learned in the first workshop; this could be as long as six months after the first workshop. Second, still working in two person teams after the workshop, students continue to develop their models, thereby dramatically improving

their thinking about their compelling enterprise problems. The entire cohort meets weekly to share their work and perspectives with one another (prescription #5 above).

The workshop instructor coaches the cohort, both collectively in the cohort's weekly meetings (via teleconference), and individually outside these meetings (via phone and email, or better via internet conferencing and application sharing), answering individual team questions and reviewing their work, thus meeting prescriptions 2, 3, and 4 above.

As more people at the enterprise location become interested in SD, these three steps are repeated with each additional cohort (see Appendix 1 for adoption dynamics). Meanwhile, student teams in the first cohort complete their application of SD to their 1st enterprise problem, and most of them continue to use SD on more problems. As they work on more problems, they continue to need coaching (prescription #s 2, 3, & 4) collaboration (prescription #5), and sharing (prescription #6 above, and next paragraph) until they are acculturated to SD. Over time, the enterprise develops internal SD training capacity, and no longer needs to rely on outside training resources.

Meeting Prescription #6: SD learners who observe the work and questions of other SD learners at their same skill level who are using SD for diverse purposes and applications, more quickly grasp the SD paradigm, process, and tools. In universities, multiple disciplines in each cohort can provide the required diversity. Other enterprises will find that local K-12 teachers provide the best source of diversity of purpose and application. Enterprises use SD to address dynamic enterprise problems; whereas, K-12 teachers use SD for a very different purpose – to help students retain or increase their natural curiosity, love of learning, and ability to learn on their own. K-12 teachers' curriculum applications of SD are very diverse and interdisciplinary, including history, literature, current events, ecology, civics, economics, physical science, mathematics, etc. For most enterprises, there is no better way to meet prescription #6 above, than to enlist local K-12 teachers in a parallel learning process, and to arrange for sharing of SD applications and perspectives, in the weekly cohort meetings, between parallel cohorts of enterprise people and K-12 teachers learning SD. Of the six prescriptions, #6 is probably the most vital to success. Of course, choosing to teach SD to local K-12 teachers not only improves SD adoption dynamics at the enterprise location, but also creates enterprise image, future workforce, and community and societal benefit (see Figure 3 in Appendix 4).

The End Result: Categories of SD Skill at a Enterprise Location

The two workshops will satisfy most students; however, a few students will want to continue their learning. They may want to improve their simulation modeling ability, to study the structure and dynamics of generic enterprise problems as a springboard to working on similar problems in their enterprise, or to learn how to use SD tools to facilitate team problem solving. This is only natural as there are three broad categories of SD skill that should naturally develop at an enterprise location: qualitative skills (everybody), modeling skills (a few people), and facilitation skills (a few people).

Qualitative skills: Students finish the two workshops with an excellent start on becoming acculturated to qualitative SD. People with qualitative SD skills can see change in the world as being caused by feedback among states of the world and rates of change of those states; that is, they appreciate stock-flow and feedback dynamics. They are able to use behavior-over-time-graphs, causal loop diagrams, and stock-flow diagrams to describe dynamic problems and to hypothesize structures, with appropriate boundaries, that create those dynamics. They appreciate how stock-flow and feedback structures containing delays and non-linear relationships can create non-intuitive behaviors-over-time, and therefore demand simulation for better thinking about, and solutions to, dynamically complex problems. Finally, they can effectively participate in a group that is using system dynamics, whether qualitative or quantitative, to address dynamically complex problems. The two-workshop program is designed to develop these qualitative skills.

Facilitation skills: There are people at most enterprise locations who are considered by their peers to be good facilitators. Hopefully some of these people will become interested in learning to use the basic system dynamic tools (behavior-over-time graphs, stock-flow diagrams, and causal loop diagrams, among others) as they facilitate groups of people in addressing enterprise problems. SD facilitators know the types of problems for which system dynamics is suitable, and even though they don't necessarily have significant simulation modeling skill themselves, they know when a team's problem demands the services of a simulation modeler.

Simulation Modeling skills: A few of the people who take the first two workshops will be very intrigued by SD simulation models and will want to become better simulation modelers. SD simulation modelers are the people that the facilitators will call on to help teams who are working on specific dynamic problems. Also, these are the people who will become the in-house trainers, eventually taking over the teaching of the two workshops, including follow-up coaching, from the outsider trainers. Additional simulation modeling workshops should be offered to people who want to become better simulation modelers, and these workshops, like the first two, should use compelling enterprise problems as the learning mechanism.

Again, following prescription #1, people should be allowed to self-select into these three skill categories. The two-workshop program is designed to provide an excellent start on becoming acculturated to qualitative SD; everyone at the enterprise location who is interested should be given the opportunity to take these two workshops. A few of those who complete the two workshops (probably well under 10%, but possibly significantly higher for the first few cohorts) will desire to enhance their skills, some taking the simulation modeling track, and others taking the facilitation track. The enterprise location should provide the resources required for people desiring to follow either track.

More Experiments Needed

The Door County SD experience is one experiment in one place. Although compression of the Door County curriculum into one-week workshops, with follow-up coaching, has worked well in practice for an SD course at Cornell University, more experiments are

required to confirm that this approach can consistently improve SD adoption dynamics. Candidates include enterprise locations of manufacturing, service and consulting firms; local, state, and national government; NGOs and charitable organizations; and higher education, including universities, colleges, and technical colleges. A reasonable goal for any multi-location firm now engaged in system dynamics might be to start a SD initiative at one new location per year.

Appendix 1: SD Adoption Dynamics at an Enterprise Location

Figure 1 is a sketch of a small system dynamics model of innovation diffusion designed to study the dynamics of SD adoption at a generic business location. The model assumes the business location employs 1000 people. Although this model describes a business location, it could as well represent other types of enterprise such as a federal or state government agency, or a college at a university.

If you have difficulty understanding the structure of the model, both the documented model equations, and a PowerPoint presentation that gradually exposes and explains the model's structure, are available on request.

For most SD training efforts, the value of *2nd project start fraction* is probably between 0.3 and 0.5, say 0.4; and the value of *acculturation time* is probably between 30 and 42 months, say 36 months.

On the other hand, if the six prescriptions above are well followed, the Door County experience suggests that *2nd project start fraction* can be increased to between 0.7 and 0.9, say 0.8; and that *acculturation time* can be decreased to the 12 to 24 month range, say 18 months.

For these values, what are the behavior-over-time over five years of the following four measures of adoption success?

1) elapsed time until the 2nd cohort starts (can be seen on a graph of *People awaiting a quorum to form a second class* circled in Figure 1)
2) people using SD on business problems (sum of the three stocks in the upper large rectangle in Figure 1)
3) *people acculturated to SD* (circled in Figure 1) and
4) people who discontinued SD use (sum of the two stocks in the lower large rectangle in Figure 1)

See Figure 2 for a comparison. It's obvious that, over five years, which is about the maximum time that any business would allow to decide the success or failure of an initiative, the first graph indicates a failure (even though an epidemic is started), and the second graph indicates a success.

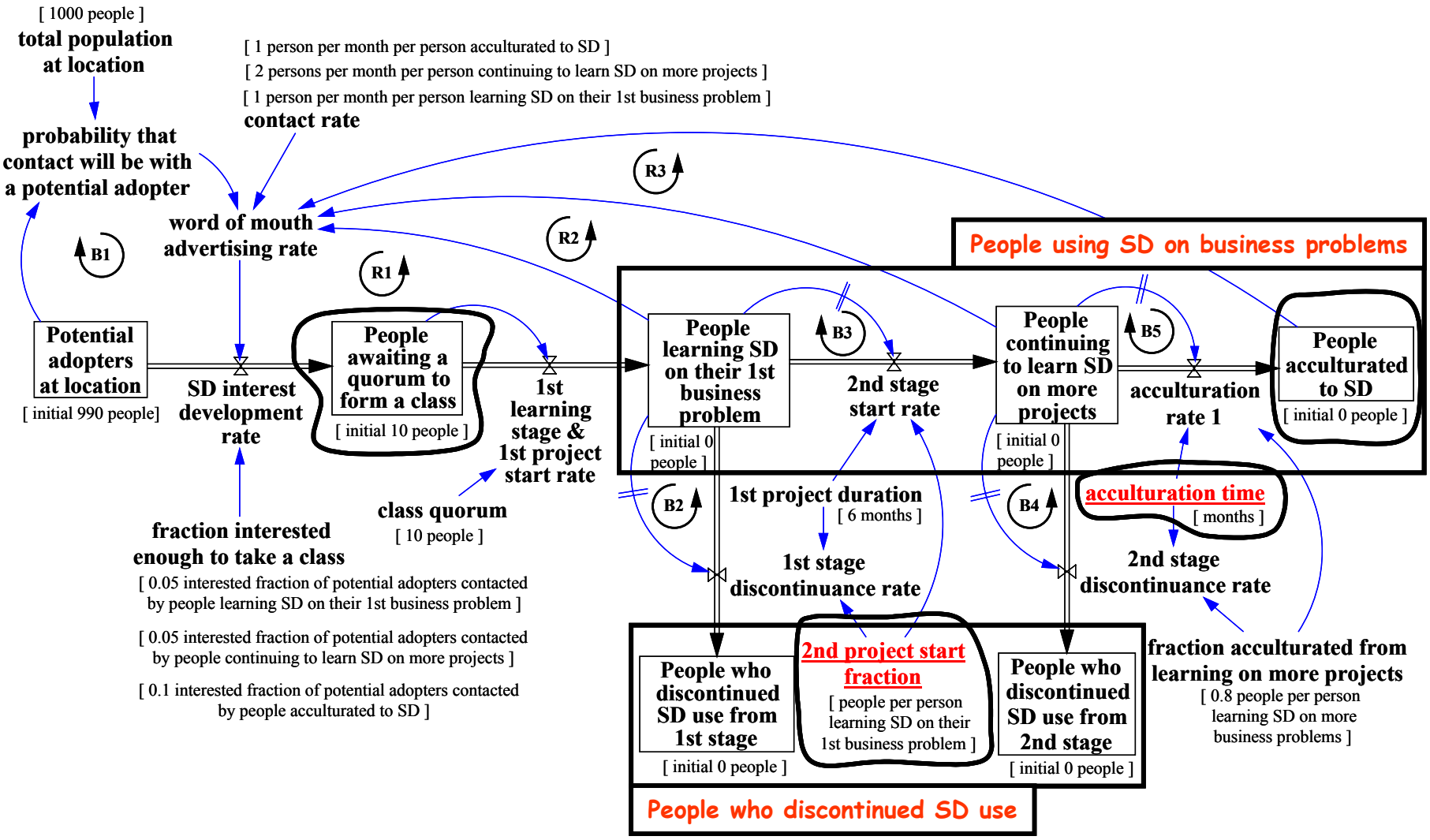
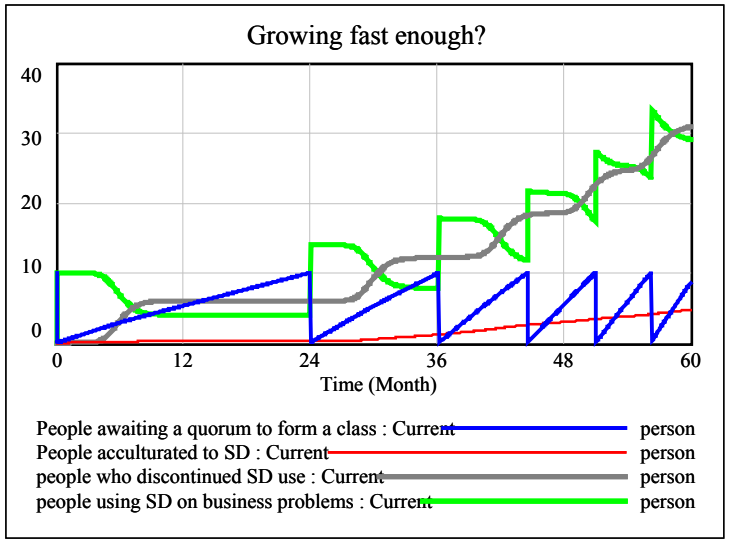
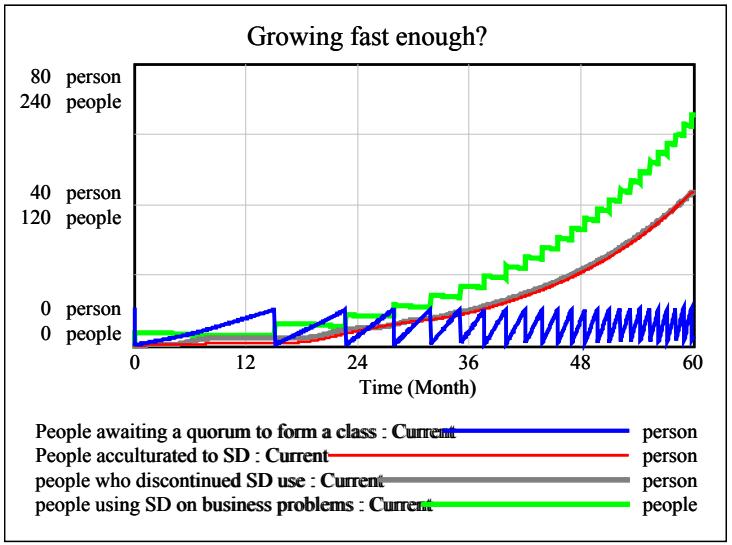


Figure 1: Model sketch of SD adoption at an enterprise location (equations available on request)





(1000 people at business location)

2nd project start fraction = 0.4
acculturation time = 36 months

Time until quorum reached for 2nd class = 24 months

29 people using SD on business problems after five years

5 people acculturated to SD after five years

31 people discontinued SD use in first five years

Applying the six prescriptions:

- *2nd project start fraction* may be increased to the 0.7 to 0.9 range, say 0.8 , and
- *acculturation time* may be decreased to the 24 to 12 month range, say 18 months

producing the behavior at bottom left and below.

(1000 people at business location)

2nd project start fraction = 0.8
Acculturation time = 18 months

Time until quorum reached for 2nd class = 15 months

196 people using SD on business problems after five years

44 persons acculturated to SD after five years

44 persons who discontinued SD use in first five years

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Figure 2: Behavior-over-time of the enterprise location model sketched in Figure 1

Appendix 2: Description of the six prescriptions as applied in Door County, WI

1) *Self selection*: Teachers and community members chose to take the course; it was not mandated (however, it was necessary that the teachers obtain graduate hours for the course)

2) *Customized and re-tailored curriculum*: In the fall session, a separate curriculum was used for adults and sophomores; adults used Trinity College Course 1, and sophomores started with Diana Fisher's curriculum and changed to Forrester's *Principles of Systems*. In the spring session, teachers and other adults had separate curricula. Teachers used Trinity College's self-paced Course 2, and the other adults used Alfeld and Graham's *Introduction to Urban Dynamics*. During both courses, all classes used portions of the first draft of Sterman's *Enterprise Dynamics*.

3) *Compelling problems*: The curriculum must use problems that are compelling to students. The teachers were interested in curriculum improvement, and so used the Trinity College courses for teachers, and spent as much time as possible exploring ways they could use what they were learning to improve their classroom curriculum. Community members were interested in community sustainability issues, and so used Alfeld and Graham's *Introduction to Urban Dynamics* book for the spring curriculum, and throughout spent a lot of time exploring how SD could be used on Door County and Sturgeon Bay community issues.

4) *Focus on SD paradigm and process*: Shared readings were selected to emphasize paradigm and process. They were read as homework and discussed in shared reading circles between the two classes. Sometimes, the discussion circle was turned into a reading circle, in which meaningful passages were read aloud by participants and then discussed.

5) *Continued collaboration during self-study course*: Although the spring course for the teachers was self-study, the teachers met regularly each week to ask each other questions and share their work with one another.

6) *Sharing between teachers and non-teachers*: Reading and discussion circles across both classes created an environment for the teachers and other adults to share perspectives on SD. Often, the discussions led to introduction of specific applications, sometimes community applications, and sometimes curriculum applications. In the spring, the teachers shared their modeling work from the Trinity course with the community adults, and the community adults shared their modeling work with the teachers.

Appendix 3: Adapting the Six Prescriptions to an Enterprise Location

1) *Ensure self-selection.* Don't mandate that people learn SD. Inform them about SD and the kinds of enterprise problems for which it is appropriate, and let them self-select into the SD training program. Likewise, if K-12 teachers are part of the program, the school administration should not mandate specific teachers' participation; instead, figure out a way that teachers can self-select into the program.

2) *Customize the curriculum, and re-tailor it during the course as necessary.* If you engage local K-12 teachers in the enterprise peoples' learning process, don't use the same curriculum for the teachers and enterprise people. Use examples that relate to the individual students' compelling problems. Keep the students' interest.

3) *Sustain compelling-problem-focused learning.* At most enterprise locations SD instructors will not be locally available who can spend eight months teaching a class twice each week. And with as much travel and other interferences as there are in most enterprise settings, it typically would be difficult to hold classes over eight months as was done in Door County. To sustain the learning in a different way, divide the learning into stages, each stage consisting of a one-week workshop and follow-up work. During the several weeks of follow-up work have the student teams continue to apply what they learned in the workshop to their compelling problem (an enterprise problem for the enterprise people, and a curriculum improvement problem for K12 teachers), and ensure that the course instructor is available for distance collaboration with the students and teams, and for review of the students' work. It is best to have at least two learning stages (see the learning stage descriptions in Steps 3 and 4 in the "Proposed Process" section above).

4) *Focus on the SD paradigm and process.* Ensure that the curriculum emphasizes the SD paradigm and process. If students study the SD tools, including simulation, without learning the SD paradigm and process, they will fail in their attempts at using SD to address enterprise and curriculum problems.

5) *Ensure continuing collaboration.* Have students work in two person teams on each enterprise problem. After each workshop, ensure weekly meetings of the entire cohort to share progress. Each team in a cohort might present every other week, thus allowing adequate calendar time for meaningful work between presentations, yet minimizing meeting time.

6) *Ensure sharing of a broad array of SD applications and perspectives.* SD learners, by observing the work and questions of other SD learners who are at the same skill level, and who are using SD for diverse purposes in diverse applications, more quickly grasp the SD paradigm, process, and tools. Local K-12 teachers can provide this diversity of purpose, application, and perspective. Schedule regular sessions for perspective and application sharing between the K-12 teachers and enterprise people. These meetings should be held weekly, and can be part of the regular collaboration meetings (prescription #5).

Appendix 4: Additional community, enterprise, & societal benefits of involving K-12 teachers

Figure 3, drawn in the context of a business enterprise, is a causal loop diagram that illustrates the additional community, business, and societal benefits of involving K-12 teachers. Study each numbered loop in turn to get a sense of this dynamic hypothesis for development of these benefits. A PowerPoint presentation that progressively exposes and explains this structure is available.

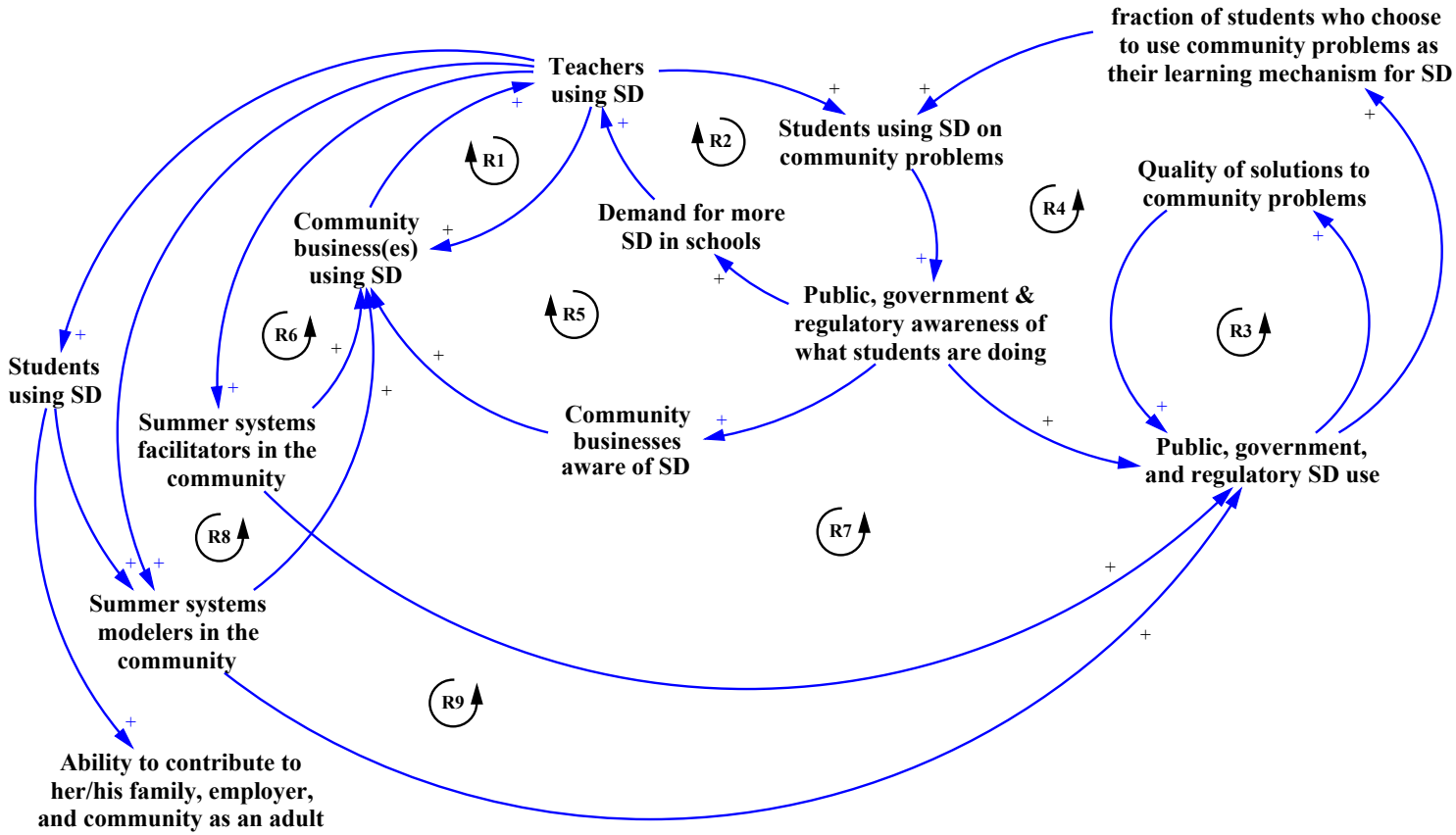

Figure 3: Additional community, enterprise and societal benefits of involving K-12 teachers

Back to the Top