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Peer Influence in Educational Reform
A System Dynamics Approach

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The concept of peer influence in public education is examined in the context of its effect on student achievement. A system dynamics model based on a positive feedback interpretation of peer influence has been developed, and applied to gain insight into claims that the concept can be employed in efforts to raise the academic performance of disadvantaged students. Aggregated model results are placed in context of achievement data for a large school district and used to investigate certain of the assumptions of an educational reform that is currently gaining popularity—the Economic Integration of Schools.

Keywords: Peer influence; Positive feedback; Economic integration of schools; Educational reform

The past few years have seen a substantial escalation of the debate over the quality and usefulness of educational research. The ever-increasing pressure on the public schools to show results has increased the demand for research that will produce policies and practices that produce those results. The Bush administration and the Congress have joined in that demand. Last year, *Education Week* reported that "The phrase . . . 'scientifically based research' . . . . appear[s] more than 100 times in the reauthorization of the Elementary and Secondary Education Act, which requires practices based on research for everything from the provision of technical assistance to schools to the selection of anti-drug-abuse programs" (Olson & Viadero, 2002).

In all this clamor for "scientifically based research" it should surprise no one that there is no mention of feedback or any kind of dynamic analysis. The idea of feedback is not unknown in educational research, but researchers have by and large given it wide berth. Some years ago, the authors of a popular text on alternative educational research methodologies, in advising their readers on the use of causal diagrams, had this to say:

> There is usually a temptation to add reciprocal or back-effect arrows [to the diagram]. . . . We do not advise such causal flows. . . . They can be modeled by computer (see Gaynor, 1980 and Forrester, 1973, for good examples), but they rapidly bewilder the human brain ("after all, everything affects everything else"). (Miles & Huberman, 1984, p. 150 [note 7])

This passage tells us that educational researchers are not unaware of the concept of feedback—some have even heard of system dynamics—but most are far from comfortable with the idea. Nevertheless, feedback is given lip service (one not infrequently sees references to "snowballing" and "multipliers") even while being sidestepped methodologically.

In this paper I examine an element of student interaction that is often considered instrumental in the quest for educational improvement, and that is arguably best understood as a function of feedback. I apply a simple positive feedback model to a concept both old and (coming around again) "new"—that of peer influence as a means of raising the academic performance of disadvantaged students—and examine the results in the context of the achievement data of a large school district. Some of the assumptions of an up and coming educational reform—the movement for the Educational Integration of Schools (EIS)—are critiqued in light of the model results.

Peer Influence as a Vehicle for Improving Student Achievement

Achievement, poverty, and the ubiquity of reform

The display in Figure 1 reveals the relationship between academic achievement and poverty in a large urban Florida school district over a 10-year period.[1] The measures of achievement are the standardized (z scored) seventh-grade math results by school by year. The measure of poverty is the percent of students eligible for Free and Reduced-price Lunch (FRL). FRL is a measure available to every school system, and in common use by educational researchers both as a measure of the degree of poverty and as an indicator for SES. The clearly linear shape of the descent of the scores as FRL increases is striking. This pattern is representative of all grades in the district, and nationally. The prevalence and persistence of this condition is what the demand for "scientifically based research" is about.

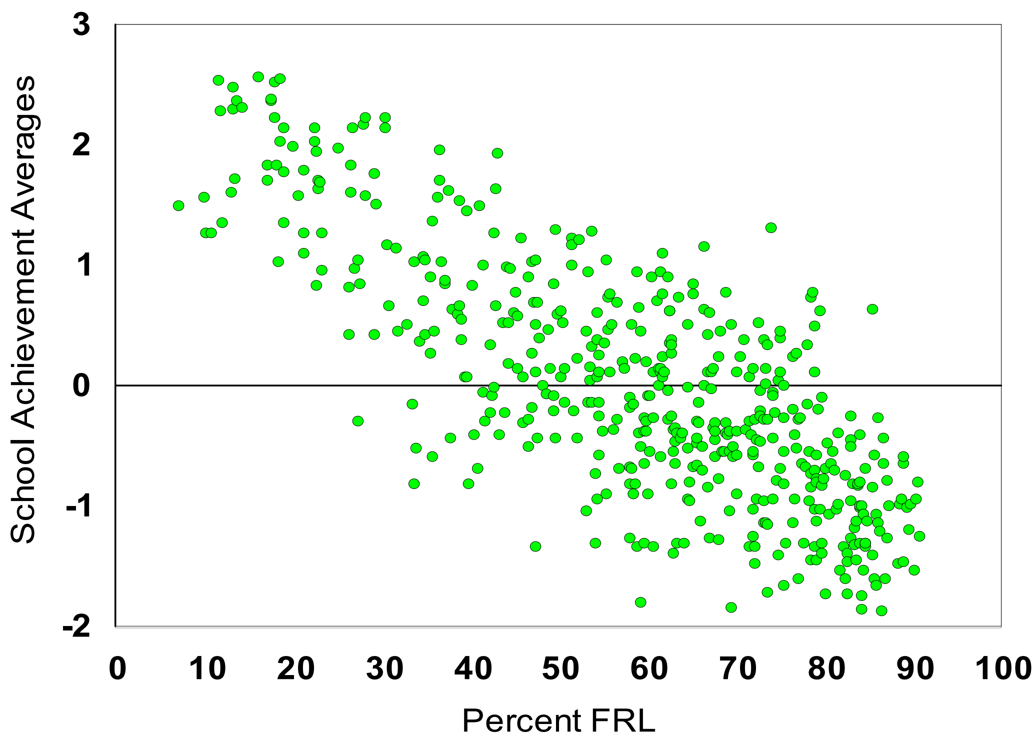

Figure 1 The distribution of seventh grade math scores by school by year for the Miami-Dade school district over the period 1990-2000. Each symbol indicates an annual aggregate test score for a middle school seventh grade. The scores have been standardized to combine the results of approximately 48 schools across 10 years and two versions of the test. Source: Compiled from the *District and School Profiles*, Office of Educational Planning, Miami-Dade County Public Schools, Miami, Florida.

There has been an unbroken stream of reform movements over the past 40 years, all proposing to remedy the situation reflected in Figure 1. Among the most recent of these reforms is the drive for the Economic Integration of Schools. I single it out here because it names peer influence as one of the major forces of potential change. A direct descendant of the movement for racial integration, EIS advocates that all of the nation's public school students attend middle class schools. The number of students in districts that have adopted the approach has grown from approximately 20,000 students in 1999 to more than 400,000 in 2002 (Kahlenberg, 2002). In a succinct description of the concept, Weicker & Kahlenberg (2002) write:

> Studies find that a child growing up in a poor family has reduced life chances, but attending a school with large numbers of low-income classmates poses a second, independent strike against him or her. All students—middle class and poor—perform worse in high-poverty schools. According to Department of Education statistics, low-income children attending middle-class schools perform better, on average, than middle-class children attending high-poverty schools. . . . virtually all of the essential features that educators identify as markers of good schools are much more likely to be found in middle-class than in high-poverty schools. (p. 9)

The key assumption of EIS is that low-income students will improve in academic achievement when placed in schools where a majority of students are middle class. One of the proposition's most ardent proponents, Richard Kahlenberg (2000), states it as an obligation:

> To better promote genuinely equal educational opportunity, every schoolchild in America should have the right to attend a middle-class school. Using a system of public school choice, school officials should ensure that in all public schools, a majority of students come from middle-class households. (p. 1)

A second major assumption, a supplement to the first, is that there is an asymmetry of effect that will protect middle-class students from adverse reactions so long as they constitute the majority of the school's students. That is, adding low-income students to a middle-class student body will not affect the academic performance of middle-class students, so long as the school's FRL percentage does not rise above 50 percent. Kahlenberg states this flatly: "At the same time [that low-income children are benefiting academically], middle-class kids are not hurt academically, so long as schools remain majority middle class" (2000, p. 4).

It is well to note that if and to the extent that EIS realizes its goals, the result *must* be that all schools in a district will gravitate toward the district's mean FRL percentage. The best that a school district can hope to do in meeting the EIS goals is to have each school have the same mix of low-income and middle-class students as the district mean. For many districts, this will mean that all schools in the district will place somewhere near the middle of the FRL range.

Assuming that they are moved to middle-class schools, how will this improvement in the performance of low-income students come about? Kahlenberg identifies three variables as the keys to the success of middle-class schools. Those schools have "more motivated and well behaved peers, more active and influential parents, and . . . the very best qualified teachers" (2002). It is the emphasis on peers that is the focus here. Elsewhere he has elaborated on the role of peers:

> Classmates provide students with what has been called a "hidden curriculum." Children teach each other things all day long. In high-poverty schools, students have lower aspirations and academic

> achievement may be looked down on. Low-income kids are three times as likely to be disruptive and twice as likely to cut class as middle class kids. . . . By contrast, students in middle-class schools are much more likely to be exposed to peers with high aspirations (2000, p. 4).

Two of the named major variables, parent support and teacher quality, have received ample attention. The association of parent activism with SES is well documented. A recent study has reemphasized the difficulties of poor schools in finding and keeping experienced and capable teachers (Olson, 2002). These variables, and the more general topic of reform, have also been addressed within the field of system dynamics (see Roberts 1974, 1975; Clauset & Gaynor 1984, 1985). The research would appear to be consistent with the key EIS assumptions stated above. Questions arise, however, with respect to the third—peer influence. At the elementary level, where peer influence is subordinate to parent and teacher influences, this may be a negligible concern, but there is a general consensus that peer influence plays a significant role in the educational experience of middle and high school students. I now turn to an examination of the research concerning the effect of peer influence on achievement.

Early optimism

The EIS assumptions reflect early ideas about the positive effects of peer influence. It has long been known that socioeconomic status (SES) is very strongly associated with student aspirations and achievement. Studies from the 1950s and 1960s showed also that students of lower SES have higher grades and are more likely to aspire to college, if they attend schools where there are large proportions of high-SES students (e.g., Boyle 1966; Haller & Butterworth 1960; Krauss 1964). In 1965 Campbell and Alexander proposed a statistical model in which they identified the mechanism of peer influence with the probability of acquaintance with students who were highly motivated to achieve. They did not attempt to describe in detail how friendships among students of different backgrounds came about.

> [I]t is necessary to assume only that friendship choices are randomly distributed in the system. As the average socioeconomic status in a school rises, the more often will individuals at each status level choose friends of high status—simply because there are proportionately more of them available to be chosen. We can then explain the observed association between the average status of a school and the educational aspirations of its students in terms of the intervening variable of interpersonal influence by an individual's friends. (1977, p. 20)

Campbell and Alexander found that friendships with high-SES students accounted for virtually all the independent statistical influence of school SES in their study.

In these early aggregate models of peer influence—which focused mainly on high school students and their college aspirations—the dominance (in a school) of one set of values, consistent with high achievement and the behavior that supported it, is assumed. There is a subset of students in the school who are exceptionally high achievers, who personify these values and set an example with their behavior. The prestige of these high-achieving students (call them the *core*) inspires others to emulate them and adopt those values. While not a great many students are members of this core, the goal of achievement is a value of all, and low achievement (i.e., failure) is rare. Other students and new students who come to the school are likely to be drawn into high achievement by contact with this core of leaders. As long as students come to the school voluntarily as individuals, there will remain only one dominant set of values, unchallenged among the student body. Private schools and boarding schools fit the description well.

In the wake of the Coleman Report (1966), peer relationships came to be considered particularly important as a way of improving achievement, and served as one of the cornerstones of the rationalization for the racial integration of schools. As Harold Howe, Commissioner of Education from 1966 to 1968, explained it, one of the conclusions that belatedly emerged from the Coleman Report's confusion of findings was that "who one went to school with was important" (interview from the video *Against All Odds,* 1989).

In the earlier research, the concept of peer influence had been applied in a context of young adults and near-adults. After Coleman, with the introduction of racial integration, the concept was pushed down the grades to apply to children of earlier ages. Whether the behavior of younger children is so greatly influenced by peer opinions is open to question. In 1977 Erickson warned that much of what is studied as peer influence may actually be parent manipulation.

> What often appear to be consequences of social relationships in schools could conceivably result from the tendency of more concerned parents within a given SES stratum to find ways of placing their children in schools that look superior, schools that are most commonly found in high-SES neighborhoods. Because of the support and advantages provided by such parents, these same children will perform at and aspire to higher levels than will their peers (from the same SES strata) in "inferior" schools. But it will seem that the superior achievement and aspiration result from the influence of the high-SES youngsters who predominate in the "superior" schools or the "better" programs found in these schools. To extend the argument, children of exceptionally concerned, supportive parents may not only be placed in "better" schools, but may seek the friendship of students in these schools who seem likely to help them do well in their studies. Since the latter youngsters will be drawn for the most part from high-SES backgrounds, it will appear that the high attainment of the children of uncommonly supportive parents is a result of friendship links with high-SES children, whereas its real source is the home. (Erickson, 1977, pp. 6-7)

Behavior and achievement

As the racial integration issue faded, and the difficulties of raising achievement remained, there were many attempts to reexamine the function of peer influence. There was a renewed emphasis on behavior, and a new perception of the connection between the changes in behavior and the interaction with peers. One of these reexaminations was a reassessment of the middle grades and their characteristics. Middle schools differ sharply from elementary schools in a number of ways. Departmentalized instruction replaces the single classroom teacher with a number of subject specialists less likely to be familiar with individual students. It is a different and unfamiliar environment also for parents, who are less likely to be acquainted with all their children's teachers and the expectations of secondary education. The transition to the middle level of education is also marked by a number of abrupt changes in the students: in achievement and motivation to achieve, in behavior, and in self-esteem. Anderman and Maehr (1994) have noted that "motivation, self-concept of ability, and positive attitudes toward school decrease, particularly during grades six and seven" (p. 288). As parent and teacher influences weaken, peer relationships become dominant and behavioral problems accelerate (Urdan & Maehr, 1995). Thus middle schools are marked by abrupt changes in the roles and relationships, a lack of familiarity among teachers, students and parents, and—partly as a consequence of these things—misbehavior well in excess of elementary school averages, whatever the FRL percentage.[2]

Especially since the 1980s, there has been a reemphasis on the relationship between behavior and achievement in the middle grades, and in the 1990s the characteristics of middle-school behavior formed the basis of an alternative interpretation of the role of peer influence. Some research has emphasized the feedback loop of reciprocal causation among a selected group of variables in producing and sustaining student failure. Straits (1987), for example, cites several studies which show that "age-grade retardation is a cumulative or snowballing process" (p. 40). Weishaw and Peng (1993) list a dozen references of research between 1960 and 1990 that "suggest a reciprocal causal relationship between achievement and behavior" (p. 5). Kohn (1994) has noted that "Some [researchers] say that self-esteem and achievement are causally related. . . . [And] some writers insist that the relationship is reciprocal, with self-esteem and academic achievement each affecting the other" (p. 275). Kaplan, Peck, and Kaplan (1994) constructed a structural model and reported that "The causal chain whereby early school failure leads to feelings of self-rejection in the school environment . . . which in turn influence disposition to deviance . . . which itself influences academic failure . . . found strong support in this analysis" (p. 169).

Tying these student-level studies inferring reciprocal causation to group-level peer interaction patterns is a logical next step. Peer influence became a critical variable in explaining chronic student under-performance, particularly in the middle grades. Urdan and Maehr (1995) described the reciprocal interaction of many of the variables related to academic failure in a dynamic scenario. They wrote:

> [A] student that begins to experience failure in school . . . may begin to develop negative attitudes about schoolwork and exert less effort in school. On the basis of these attitudes, the student may select a friend with similarly negative feelings and attitudes toward school, and these two students can reinforce and strengthen each other's negative orientations toward academic achievement. . . . Over time, these attitudes may lead to sustained underachieving behavior, which in turn might cause these students to be placed in a low-ability track with other peers who have negative orientations toward school and school work. In this case, academic failure (an antecedent) leads to the social goal of seeking approval from a negatively oriented peer, which leads to increased negativity toward school and even lower achievement (a consequence). This consequence, in turn, leads to the additional antecedent of being surrounded by negatively oriented peers, and a cyclical pattern of causes and effects is created. (p. 231)

Here we have the classic peer influence model from the 1950s "in reverse," so to speak. Rather than leading to greater achievement, it de-emphasizes achievement while encouraging other interests. The model identifies one group, one dominant core of leaders, and one set of values. Membership is voluntary, and by deduction the power of the attraction to membership is proportional to the size of the core membership with respect to the entire student body.

Multiple peer groups and more complex interactions

At this point; the similarity to complementary scenarios such as that of Campbell-Alexander are all too obvious. Whereas the optimistic Campbell-Alexander interpretation seeks to utilize peer influence to explain achievement, the pessimistic Urdan-Maehr version seeks to explain declines in achievement. Peer influence is now broadened to apply not only to friends of high status, but to friends of low status, friends who frequently misbehave, and so on. Urdan and Maehr (1995) acknowledged this fact:

> Most researchers now assume that peers can have either a negative or a positive influence on adolescents' attitudes and behavior. In particular, peers can either encourage adolescents to view their school experiences positively, or encourage them to see school as an uninteresting or hostile place. The outcomes for any specific adolescent depend on the characteristics of the peers with whom the adolescent spends most of his or her time. (Berndt & Keefe, quoted in Urdan & Maehr, 1995, p. 220)

Thus there are two core groups—high achievers and counter-achievers—with very different attitudes and behaviors, occurring together in varying proportions in every school where peer influence is a dominant force. Peer influence as a factor to take into account is not expected to appear until the middle grades. The influence of low-income core groups is expected to be more pronounced in middle school than in high school. Not only does peer influence emerge there, but the core of the low-income group of students is most likely to be intact and most vocal during those years. In high school, as Bidwell and Friedkin (1989) point out, "if a student has strong ties to school friends who themselves do not value educational attainment, the student may stay in school for a time to enjoy the friendship, but student and friends alike will probably leave school as soon as it is practicable to do so" (p. 463).

Like attracts like. Applying simultaneous dual models of discrete groups, as discussed earlier, we find that intra-actions among members of these groups generate positive feedback loops that produce changes in the group achievement level, separately within each group. There is not much useful research on the process of the cross-interactions of two groups, although there is a literature from the heyday of racial integration on the difficulties of cross-interaction.

With the idea of two separate groups together, vying for dominance on the basis of core-prestige attraction, we begin to think of two different cultures or backgrounds that coexist. Each student has a family and neighborhood where he/she has grown up, learned to behave, formed basic habits and outlook, and—even during the school year—spends most of his/her time. When some students are poor (or otherwise set apart) and others are affluent, those formative habits and behaviors are apt to be mutually antagonistic. There is an inclination to remain apart, even when thrown together in the same school environment. Efforts to bring them together may sometimes result in hostility rather than friendships, as the racial integration experience revealed (e.g., Amir, 1969; Eisenman, 1969). In other cases, special efforts may be required to foster opportunities for interaction. McPartland (1969) argued that to achieve (racial) interactions, the groups had to be integrated at the classroom level. Even special efforts may not be enough to achieve the desired result. One recent report from Chicago (Banchero & Little, 2002) notes that despite great integrative efforts on the part of school administrators in affluent Chicago-area schools, the test scores of poor and minority students remained unchanged even as those of their more affluent peers increased in response to the additional efforts.

Impediments to peer influence can also occur in the form of organizational rules that make it difficult for individuals to interact. While all these impeding causes—social or organizational—are different, they all have the same effect. As they increase, the peer influence process becomes more restricted. That is, restricting individual interaction, whether by social precedent or by organizational rules, reduces the opportunities for peer influence to occur, for better or worse.

Given that cross-group interactions may face obstacles, such interactions do occur. I have found little research in this area of describing the process of cross-group interaction, and more is needed, but some conclusions follow from common sense and reason. Let us assume that there are two groups, and that there are no salient obstacles blocking interaction across the groups. What will govern that interaction—what will it look like?

Recall the process within each group. Each core consists of that sub-group of individuals that embodies and excels at those values that the group holds in common, and each core possesses those leadership qualities that encourage others to follow and emulate its examples. As a consequence, each core attracts an active following from among its own group over the course of the year. As a core group gains momentum, it not only increases its own group of active followers, it also detracts from the prestige (the "attractive force") of the other group's core, such that its followers do not find it as attractive, and may fall away from it, becoming less interested in its values and practices. This is an indirect cross-interaction effect, reducing the other core's influence over its own potential followers.

A direct effect of one group on the values and behavior of the other would seem to require some considerable dominance. If one group becomes dominant enough (beyond some threshold, say), an attraction of sorts to the non-core members of the other group can develop. Even while retaining their own values and preferences, these other-group members may find themselves persuaded to go along with the majority. These disenchanted members of the less successful group will not be drawn to embrace the values of the other group's core, but they may be persuaded to emulate the behavior of the other group's members. The main idea here is that the power of the attraction of a core leadership is much stronger for the members of their own group, who share their background and values, than it is for members of another group. For example, students who are at risk of failure may not be persuaded to excel academically when they find themselves in an overwhelmingly high achieving school, but they may be impelled to improve their work sufficiently to avoid what in that environment will be seen as the stigma of failure. The converse should hold for not-at-risk students who find themselves in a very anti-achievement environment, and their achievement level should decline. It is more a case of captivation, perhaps, than attraction.[3]

To summarize, peer influence is most likely to play a major role in determining achievement, in the secondary grades. In middle school, an adequate level of maturity (more freedom from parental supervision) coincides with less familiarity with teachers (more teachers and less time with each), and greater opportunity for broad interaction with other students (changing classes hourly, for example), to bring peer influences to a maximum. Peer influence can work either for or against academic achievement. There is the possibility of competition and uncertainty of outcomes when groups of opposing values are strongly represented in the same school. Finally, while the within-group peer influence process appears to be easy and "automatic," there are many obstacles that can slow cross-group influence and even bring it to a halt. Among these are not only social and cultural forces, but organizational and policy factors as well.

Modeling the Effects of Peer Influence

Based on the foregoing discussion, a model of the peer influence concept has been constructed. A diagram and equation list for the model are given in the appendix. The narrative will concentrate on elaborating the major aspects of the model.

In the model, an enrollment of 300 is drawn from a neighborhood or community. The interaction of a pre-determined "social climate" and the random variable Risk Determination determine whether a student entering the grade will be one who is a member of the Low Risk or the High Risk group. Each student make his/her way through the year, ending up among the High Achievers, Average Achievers, Under Achievers, or Counter Achievers.

The mark of this progression through the year is the Encounter, simulated by a second random generator. One should think of the Encounter as the determining event in a cumulative series of experiences that the student has come upon—the turning point or decision point that results in determining his/her performance level. Every student accumulates experiences as he/she progresses through the year. The Encounter is conceptualized as a culmination of these experiences that results in a choice to continue on with the performance characteristic of his/her group, or to embrace the values of its most dedicated members. Although the model is sequenced through regular iterations, it is the Encounter that should be seen—rather than "time" per se—as the major unit. As a result of this process, the student body will be redistributed by the end of the school year. This section explains the model process.

Description of the model

The basic structure There are two identical submodels. Each represents a group of students and their values or orientation. One group consists of students who are oriented to academic achievement—the Low Risk group. The Low Risk submodel is intended to correspond to the Campbell-Alexander concept discussed in the literature review. The other consists of those not oriented to academic achievement—the High Risk group, which corresponds to the Urdan-Maehr description of low achieving students reinforcing each other.

Within each group there is a subculture—called the "Core"—that represents the "values" predominant for each group, and serves as the source of behaviors that members of the group presumably desire to imitate. These Cores are initially weighted to be about a fourth of the size of each group, and are called: for the Low Risk group, High Achievement, and for the High Risk group, Counter Achievement.

Figure 2 displays the submodel for the Low Risk group.[4] When a student is identified as Not At Risk, then depending on the value of Encounter, he/she may become a High Achiever, or simply an Average Achiever. If the value of Encounter—a random variable—is greater than the HiAch Fraction, then that student will join the high achievers. This will increase the HiAch Fraction, making it slightly more likely that the next Not At Risk Student will become a High Achiever. The feedback loop is positive.

The flow equation in which this is achieved—for the submodel as diagrammed in Figure 2—is shown in equation (1).

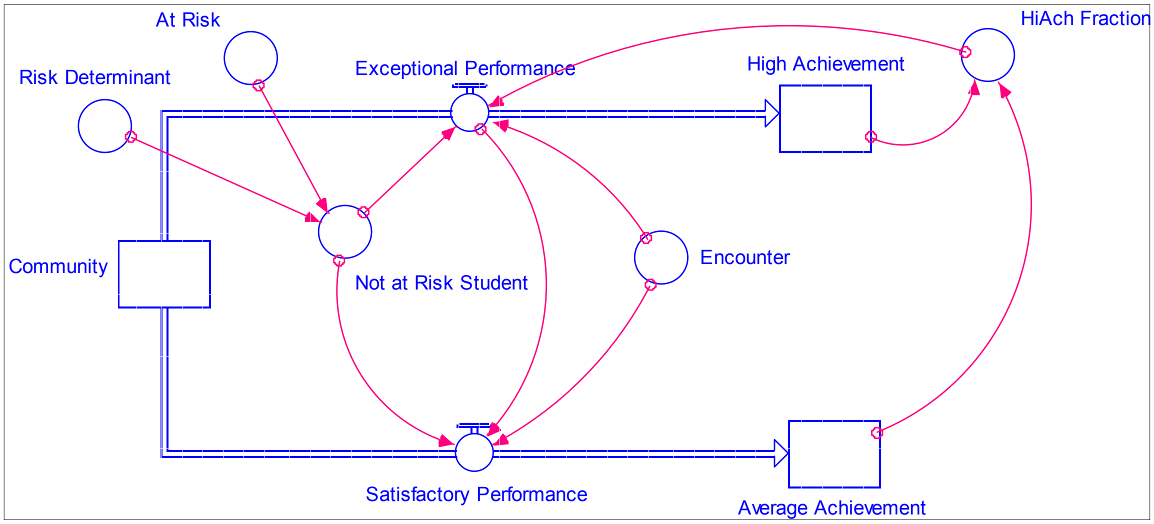

Figure 2 The Low Risk sub-group. Students who are not at risk become either high achievers or average achievers in this simplified diagram, depending on the value of Encounter.

```
Exceptional_Performance = IF (Not_At_Risk_Student=1) AND                (1)
(Encounter< HiAch_Fraction) THEN 1 ELSE 0
```

In this equation, the feedback loop depends only on the size of High Achievement relative to Average Achievement. As such, it is most effective when the sizes of both stocks are small (say, less than 10). As the structure is applied here, however, the stocks' contents become relatively large, and in fact are deliberately initialized with large numbers (a weighting by another factor, Climate, to be discussed later). When the core fraction (in this case the HiAch Fraction) is small relative to the sum of both stocks, the outcomes over a model run quickly stabilize. The same is true, of course, for the High Risk group, where the feedback is through the CntrAch Fraction. The results of a model run in which the feedback is entirely dependent upon the core fractions alone, as described for the Low Risk group here, is shown in Figure 4A, subsequent to the discussion of the attraction functions considered next.

Peer attraction The feedback loops in the model, however, are not dependent on the Core size alone. The cores (i.e., High Achievment and Counter Achievement), which exercise influence over their respective groups, are set to be in competition with each other for strength of influence. This is accomplished by adding a function to the flows of the core stocks of both submodels that has the effect of increasing or decreasing the core fraction. For the Low Risk group that function is called Ach Attraction, and the flow equation is reproduced as equation (2).

```
Exceptional_Performance = IF (Not_At_Risk_Student=1) AND                (2)
(Encounter<Ach_Attraction* HiAch_Fraction) THEN 1 ELSE 0
```

The reader should compare this to equation (1). Unlike the first equation, this one (identical in every other respect) adds Ach Attraction as the multiplier of HiAch Fraction. The Ach Attraction can double the size of HiAch Fraction, or reduce it to zero, depending on the relationship obtaining between the two cores.

Ach Attraction, the function added, is displayed as equation (3), and takes on a range of values from 0 to +2. If High Achievement is greater than Counter Achievement, the value of Ach Attraction is greater than 1, and the product of Ach Attraction and HiAch Fraction is more likely to be greater than Encounter, sending the student to the High Achievement stock. Conversely, if Counter Achievement is the larger, the value of Ach Attraction is less than 1, reducing the probability that the student will become a High Achiever.

```
Ach_Attraction = 1+(High_Achievement-Counter_Achievement)/          (3)
(Counter_Achievement+High_Achievement)
```

The counterpart of HiAch Attraction is called CntrAch Attraction, and has the same function with respect to the High Risk group. Together they link the two submodels into one peer influence system. Figure 3 shows this linking of the two submodels. The flows (Exceptional Performance and Poor Performance) are affected by changes in both cores, and feed information from both back into the flow equation. When FRL is at or near 50%, the possibility of sudden shifts in the dominance of the cores is highly probable. In the center of the FRL range, both groups start equal; neither has an advantage. At all other points, one core has at least a slight initial edge over the other. If High Achievement is larger, then each addition to it multiplies the effect by some increment

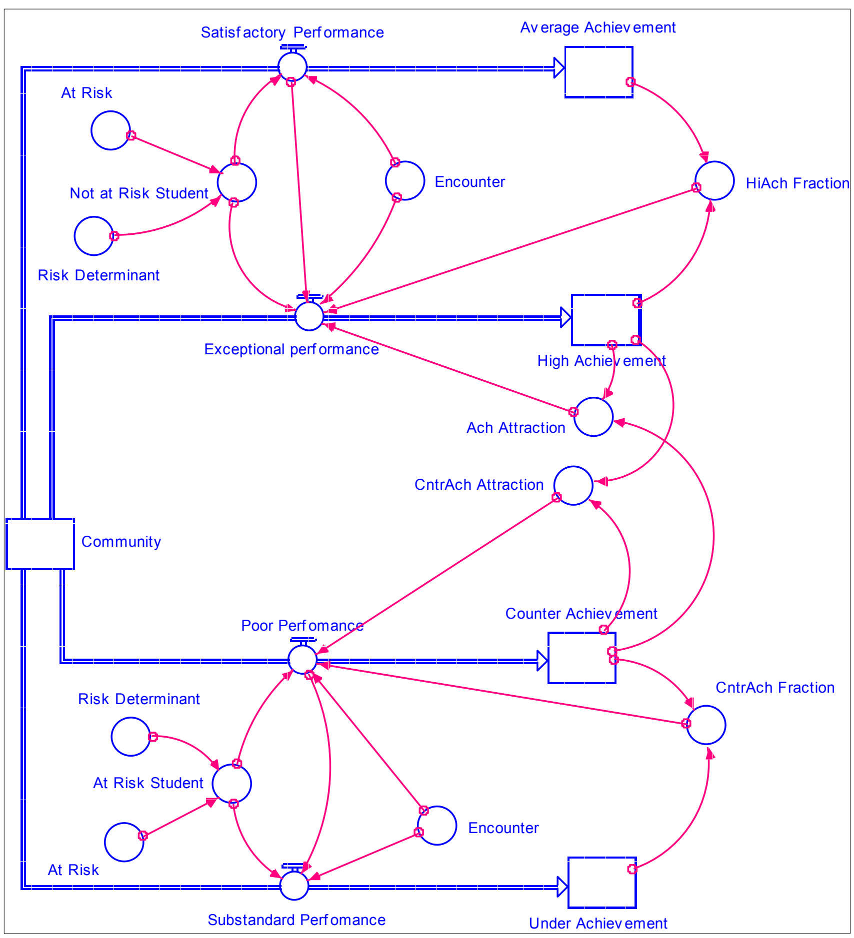

Figure 3 The peer attraction functions. The functions Ach Attraction and CntrAch Attraction enhance the feedback of their respective "fraction" functions, HiAch Fraction and CntrAch Fraction.

above unity, and there is a non-linear positive feedback. This advantage is "double-edged." Every gain of one core diminishes the position of the other. For the smaller core, the multiplier is negative, causing the core to decrease more rapidly. Away from the center (FRL = 50), there is always a smaller core that has a disadvantage to overcome, and that initial disadvantage increases with distance from the FRL center.

The effect on the behavior of the model is substantial. Panel B of Figure 4 shows the results of a run with Ach Attraction and CntrAch Attraction added to the model. This result should be compared with panel 4A, which shows an identical run but without the Attraction functions.

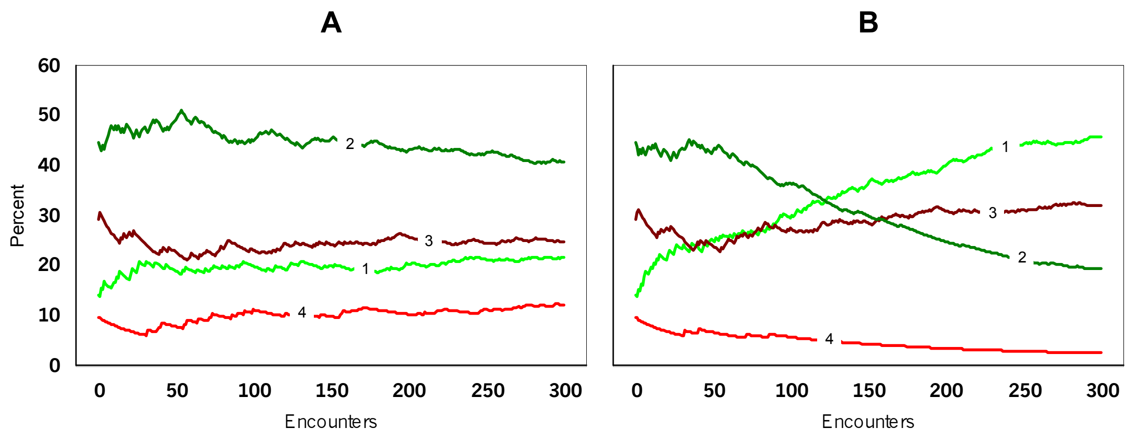

Figure 4 Model runs without and with the Attraction functions added. Two copies of the model attached to the same random generators were run simultaneously at an FRL fraction of 0.4 and Climate weighting of 50. The results permit the comparison of model performance with and without the Ach Attraction and CntrAch Attraction functions. Panel A shows the result when feedback to the Core functions High Achievement (1) and Counter Achievement (4) is only from the HiAch Fraction and CntrAch Fraction respectively. There is not a great deal of interaction with the other sub-groups—Average Achievement (2) and Under Achievement (3). Panel B shows the result when the Attraction functions are added.

"Crossovers" Finally, there is a way for a student to "cross over" and perform at the same level as an average member of the other group—though he/she cannot progress to the other group's core level. By cross over, I mean that a Not-At-Risk student, for example, will perform at the level of an At-Risk student, and vice versa. A very dominant core can attract members of the other group's non-core to its own group. If a core grows large relative to the whole student body, presumably its influence will overwhelm even the members of the other group, who will respond by imitating the behavior of the dominant group's members. Thus as the core of the High Risk group, for example, grows very large relative to the whole, some Not-At-Risk students will begin to perform in the same manner as their At-Risk cousins. That is, their achievement scores will deteriorate substantially.

In the model, this is effected by rerouting the Not-At-Risk student away from the Low Risk stocks and to the Under Achievement stock. The equation by which the Not-At-Risk student "crosses over" from the Low Risk to the High Risk group is equation (4).

```
Declining_Performance = IF (Not_At_Risk_Student=1)                    (4)
AND (Exceptional_Performance=0)
AND (Encounter<Convert_to_Hi_Risk) THEN 1 ELSE 0
```

This says that if a Not-At-Risk Student is not directed to High Achievement, then the student is tested become a member of the High Risk group. If the Counter Achievement influence is strong enough to persuade him/her to cross over, then the Under Achievement stock is incremented by one. Otherwise, the student goes to Average Achievement by default. The process is diagrammed in Figure 5.

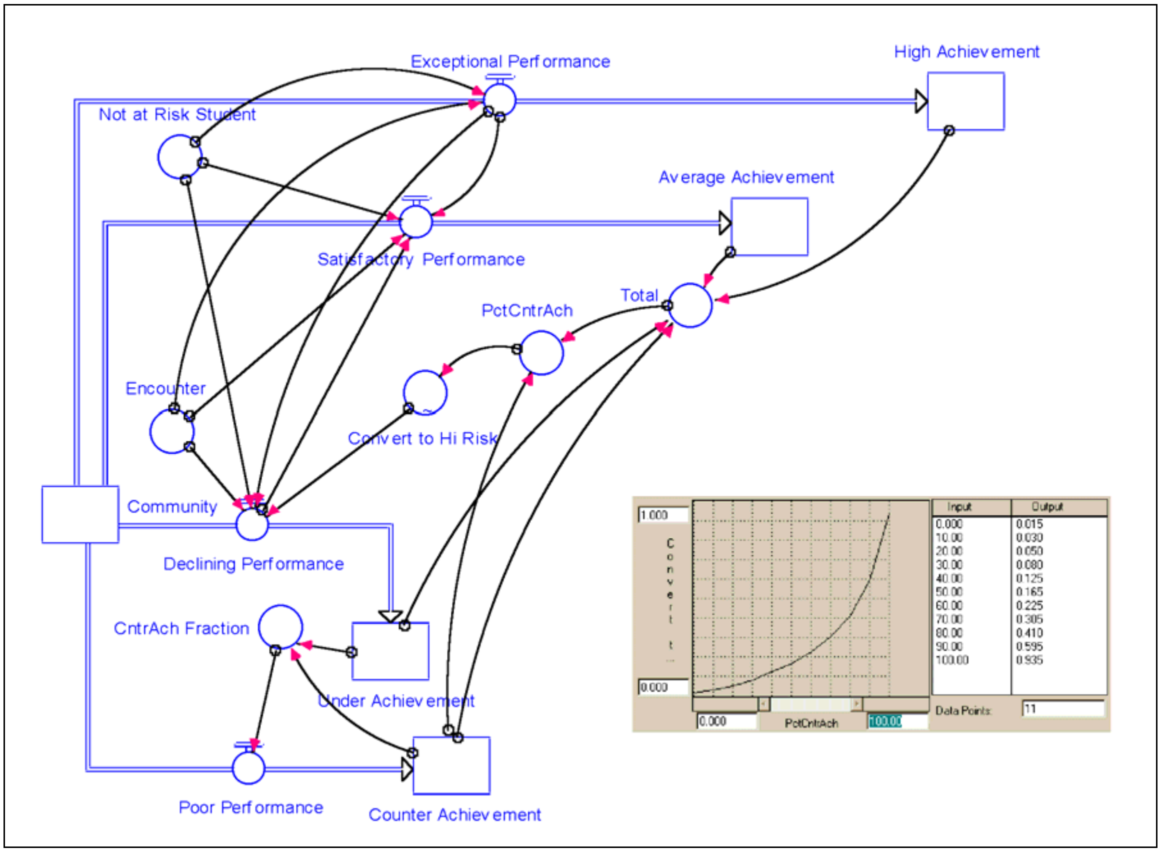

Figure 5 Possible destinations for a Not At Risk Student. This simplified diagram shows the paths for a Not At Risk Student to High Achievement, Under Achievement (as a crossover), or Average Achievement. The inset displays the graph for the connector Convert to Hi Risk.

How strong is strong enough? The Not-At-Risk student has a probability of becoming an At-Risk student based on the Counter Achievement sub-group's size relative to the sum of the contents of all four stocks. Convert-to-Hi-Risk is a graphic function that increases at a non-linear rate as the Counter Achievement core's percent of the entire student enrollment increases, equaling 0.05 when the core is 20 percent of the enrollment, 0.165 at 50 percent, and 0.595 when the core is 90 percent of the enrollment. The graph of this function is displayed as an inset of Figure 5. I have no empirical data by which to estimate the shape of the Convert-to-Hi-Risk function. The choice rests on logic and plausibility.

Within the crossover process there is a negative feedback effect that works as follows. When a Not-At-Risk student goes to the Under Achievement stock, the denominator of the CntrAch Fraction is increased slightly, in turn slightly decreasing the probability that At-Risk students will become Counter Achievers. This then inhibits the probability that the Convert-to-At-Risk value will exceed any given Encounter value, and crossovers become less likely. However, the conditions which promote such Counter Achievement dominance are most likely to occur when there is a smaller percentage of Not At Risk students in the system. As a result, the effect of the negative feedback on the behavior of the model is negligible.

The constants The social characteristics of the school for which peer influence is to be simulated are determined by three constant values chosen prior to running the model. Those constants are: the fraction of students who are At Risk (determined by selecting the FRL of the school); the Core (that initial weighting that will represent the group's values—achievement or non-achievement); and Climate (the degree of force from whatever source that inhibits student interaction and the communication of peer influence).

First, the proportion of students At Risk is determined as follows. The SES composition of a school's student body is a basic determinant of its overall achievement pattern. The concept of FRL is used in the model to represent SES. As explained earlier, FRL represents the percent of students in a school who qualify for Free or Reduced-price Lunch, and it is read as the reverse of SES. That is, where SES is inversely proportional to low academic performance and poverty, FRL is directly proportional to those variables.

Since the percent At Risk is assumed to be linearly related to FRL (and convincingly so, the relationship graphed in Figure 1 is representative of such relationships), I use a linear equation to derive the proportion of the student body that will be At Risk directly from FRL. It is:

`AT_RISK = a + b*FRL = 0.03 + 0.94*FRL` (5)

where FRL and At Risk are fractions rather than percents, and where a and b are constants that can be changed to fit the information relevant to the system to be modeled. Here I have chosen to keep At Risk very close to the value of FRL, assigning a value of 0.03 to a and 0.94 to b. This means that when FRL is zero about 3 percent of the student population will be at risk.

Second, the Core size is estimated to be initialized at one-fourth the group size (where the groups—named High Risk and Low Risk—are the proportions At Risk and Not At Risk). I have chosen 0.25 as the core size, constant for this paper. The decision is not arbitrary; it is based on observations of the example district's performance over time in the 1980s and 1990s on a criterion-referenced test for graduation given to 9th (later 10th) graders, wherein about 75 percent consistently pass. The reasoning is that the persistent 25 percent failure rate represents an unchanging core of students who are irreconcilably uninterested in academic achievement. Having no comparable measure with which to estimate the achievers, I assume that the cores are symmetric and fixed, for the purposes of this paper.

Climate is the third constant. Among sociologists, school climate usually refers to the SES makeup alone. I use the term here to name the constant indicating the strength and degree of rigidity of the structure, both social (ethnic preference and the like) and organizational (rules and policies). In the model it is a number to be chosen by the modeler. Choose a smaller number and the model behavior is more volatile (simulating greater ability of students to interact with each other). It may be assumed to represent environmental conditions, a program or policy, or a combination of the two. Choose a larger number and there is less deviation from the initial pre-determined conditions as the run progresses (students have less ability/interest in interacting, and are consequently less affected by peer influences).

A combination of these constants determines the distribution of initial values or weightings among the four stocks (High Achievement, Average Achievement, Under Achievement, Counter Achievement), according to the sub-groups they represent. If, for example, a school starts the school-year (run) with an FRL fraction of 0.4, it exists in an environment that is made up of more than half Not At Risk Students. This in turn will constitute a slight bias in favor of an exponential growth in the Low Risk Core, which with a value of 0.25 has a potential size of one-fourth the size of the Low Risk group. However, a Climate weighting of 50 will introduce a resistance to the feedback and restrain growth of the core that gains dominance .

In this example, the initialization of the High Achievement stock is given by equation (6):

```
INIT High_Achievement = (1-AT_RISK)*Core*Climate                 (6)
= 0.59*0.25*50 = 7.4
```

The other stock in the Low Risk group, Average Achievement, is initialized by equation (7):

```
INIT Average_Achievement = (1-AT_RISK)*(1-Core)*Climate          (7)
= 0.59*0.75*50 = 22.3
```

For the High Risk group, the initial values of Counter Achievement and Under Achievement are 5.1 and 15.2, respectively. Even at a modest 10 percent below the halfway point in the FRL range, the initial ratio of the cores High Achievement to Counter Achievement is about 7 to 5.

Example runs Figure 6 shows examples of model performance, with each sub-group shown as a percent of the whole, changing with respect to the others as the run progresses. The columns of panels on the left (A, C, E) display the results of runs with a Climate weighting of 50, and the column on the right (Panels B, D, and F) shows results with a Climate weighting of 100. The runs on the left show a great deal more variation from beginning to end than do those on the right.

The rows represent runs at different FRL percentages. In the top and bottom rows, the FRL percent is at an extreme end of the range and one or the other of the Cores quickly dominates, forcing the other Core to near zero. At the top, with an FRL percent of 0.1, the High Achievement Core dominates, climbing from around 20% to 70% over the course of the run. In the bottom row, it is the Counter Achievement Core that dominates. Note that in all cases, any gain in a Core is at the expense of its own non-core sub-group, and that the losing Core's non-core sub-group gains modestly in percentage as its Core falls.

In the center row of the Figure, the Cores begin equally matched. In the example shown the Counter Achievement Core gains dominance, but increases to less than 40% in Panel C, and in Panel D—where the Climate weighting is higher, it finishes at less than 30%. Two points should be noted about the model's performance at the FRL midpoint. First, both Cores have the same opportunity to gain dominance. Second, the maximum that either is likely to attain will be less than 50%.

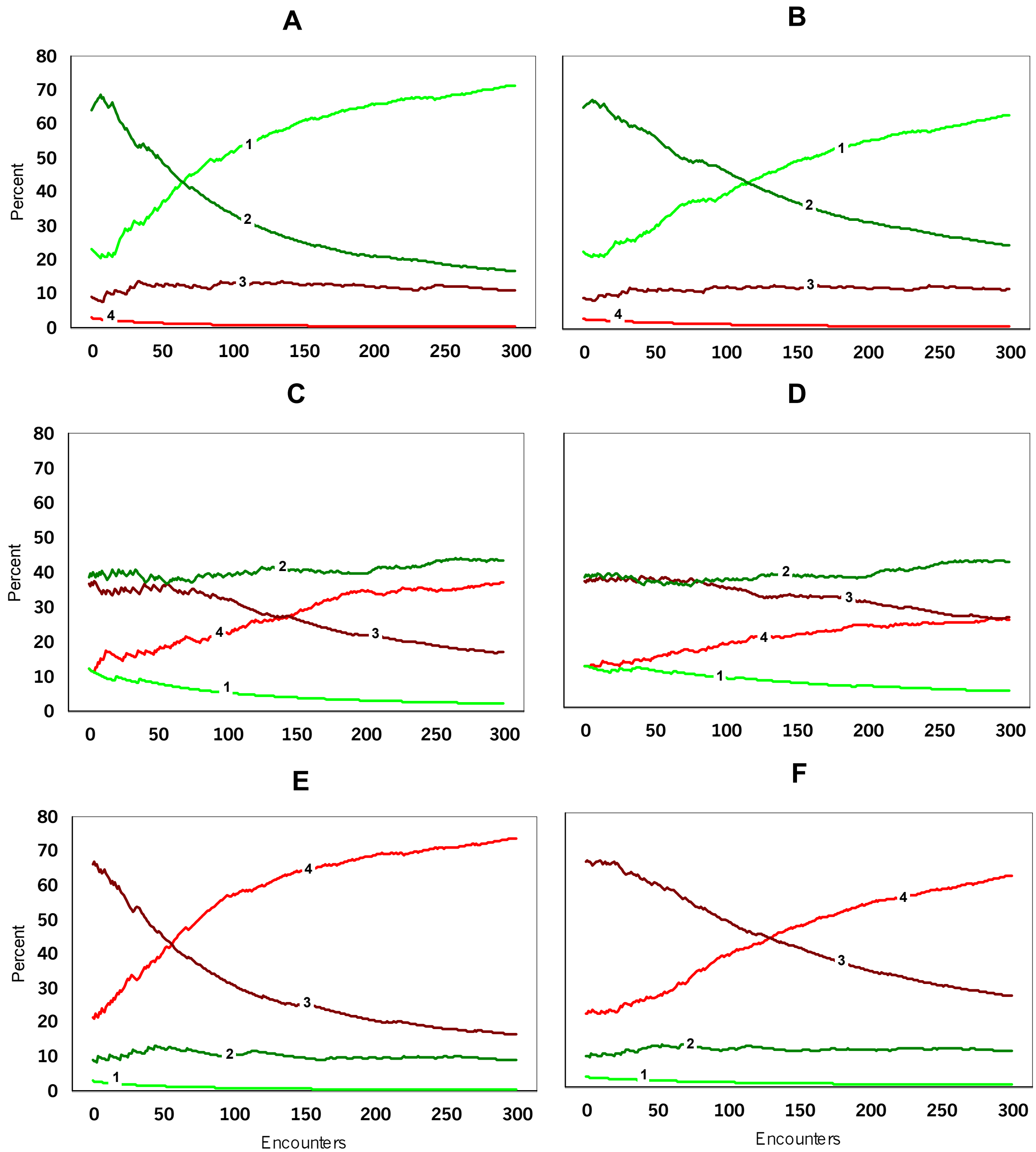

Figure 6 Example runs of the peer influence model. Each left-right pair of panels represent simultaneous runs by two models joined to the same random variables (Risk Determination and Encounter), and representing two different Climate weightings, 50 on the left and 100 on the right. The runs at the top row are at FRL=0.1, at the middle row, FRL=0.5, and at the bottom row, FRL=0.9. The lines represent the percent of the total sum across the four Achievement stocks constituted by (1) High Achievement, (2) Average Achievement, (3) Under Achievement, and (4) Counter Achievement.

Placing the model in a district context

To place the Peer Influence model in the context of the EIS reform, it will be necessary to examine it from the perspective of an analysis aggregated to the district level. The procedure by which this is done is described next.

Expressing model results as a school's "achievement score" If the model is a reasonable representation of the actual functioning of peer influence in the middle grades, then there should be some reflection of the model's outcomes in the behavior of actual systems. With some manipulation it is possible to compare the model behavior with empirical data relevant to questions raised concerning the EIS reform. Consider first that the peer influence model produces results for one grade in one school, for one year. A district is made up of many schools, which produce outcomes annually over a specified time period.

Looking back to Figure 1, the data displayed in that graph consists of 480 data points from approximately 48 middle school 7th grades (the number varied over the years) over a 10 year period. The poverty levels of the schools varied over most of the FRL range. The graph presented there is reproduced in Figure 7 as panel A. The data points plotted there are school-level achievement test scores.

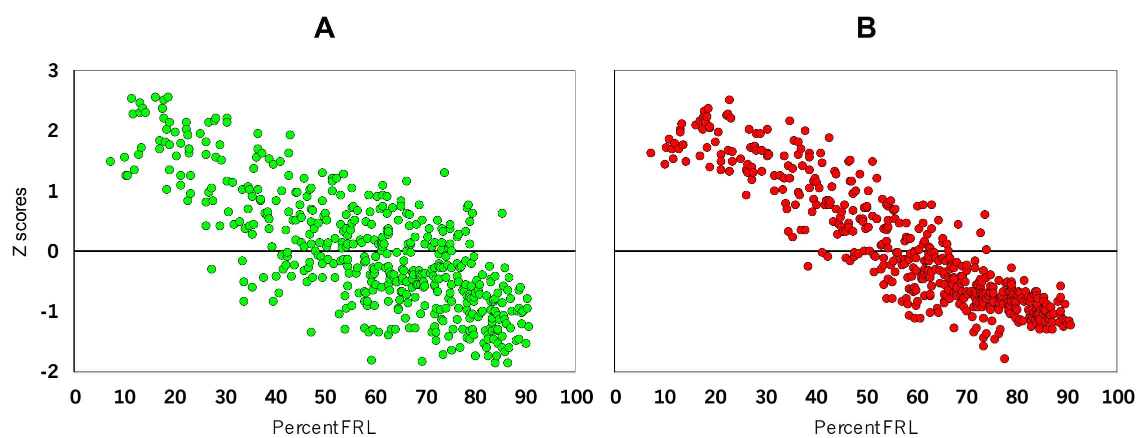

Figure 7 Seventh grade test scores by school by year, paired with peer influence model results. Panel A is a reproduction of the MDCPS seventh grade scores from Figure 1. Panel B displays the results of model runs produced by assigning the model the identical FRL percentages as each of the school scores in the data set displayed at left.

For comparison, runs from the model have been assembled in a similar manner. We can conceive of any student body as made up of the groups and sub-groups described in the Model section. We can further assume that the students in each sub-group will collectively average a score within a given percentile range on some hypothesized achievement test. First, I assigned each model sub-group an average percentile score. Students in the High Achievement sub-group were assumed to deliver an average between 85 and 95 percentile points. Next comes the Average Achievement sub-group, scoring between 55 and 65. The Under Achievement sub-group was presumed to score persistently below the 50th percentile, and was assigned the range 35-45. Finally, the Counter Achievement sub-group was assumed to average between 5 and 15 percentile points.

I then ran the model 480 times, each time assigning to the run an FRL value from the original data set. The value of Climate was held constant at 50. The result was a set of values for each model sub-group for each run, based on the poverty level (FRL percentage) given to the school.

Next, each of the sub-groups, in each of the 480 runs of the model, was given a randomly selected score within its assigned percentile range, and those scores summed across all sub-groups to yield a "school-level test score" for each of the 480 runs. These "test scores" were then divided by "year" in the same manner as the original data set, and z-scores computed.

The results of these efforts are displayed in Figure 7B. A comparison with panel A demonstrates the strong similarity of outcomes. The plot from the model run is much tighter, of course, reflecting the fact that there is only one variable acting on the model plots, peer influence. There are an unknown number of variables affecting the data plot, one of which is assumed to be peer influence.

Model outcomes and data patterns The model results are now directly comparable to the data in Figure 7A, and similar data sets, provided it is clear what is being compared. The logic of the model and experience with it indicate that outcomes—in particular which group will emerge dominant at the end of the year—become increasingly unpredictable in the middle of the range, as FRL approaches 50%. This of course follows from the fact that the groups are more evenly matched in that area.

This suggests that the *variation* in model outcomes should change in a predictable way across the range of FRL. In the model-generated data of Figure 7B, the "test scores" should show more variability from one run to the next in the middle of the FRL range than at the extremes, and—since we know that our simulated peer influence is the cause—there is no ambiguity in the interpretation of the resulting pattern.

One way to examine that variability is to take measurements of the variability of the school score—standard deviations, say—across small increments of the FRL range, and then observe the pattern that they form across that range. The expectation is that there will be less variation near the ends of the range, and more in the center.

To uncover the pattern, I divided each data set into 5 percentage point intervals of the FRL range and found the standard deviation for the group of data points within each interval.[5] These results are shown in panel A of Figure 4. The line emphasizing the patterns is a scatterplot smooth produced by a local regression program called lowess (see Cleveland, 1979).

If the model is a reasonable interpretation of peer influence, then we expect that pattern to be reproduced in similar empirical data sets where peer influence is a major variable. From the survey of the research and principles developed earlier, we expect peer influence to be at a maximum in the middle grades, and to be overshadowed by parent and teacher influences at earlier grades. Let us now examine the test data from the MDCPS seventh grade more closely, and add to that data a comparable data set from an elementary grade, in the present case, ten years of math test data from elementary 6th grade.[6] Standard deviations across the FRL range for the 7th grade data set and from the 1989-1999 annual test scores of elementary 6th grades (N = 485) were extracted using the methods described above. The results are shown in panels B and C of Figure 8, respectively.

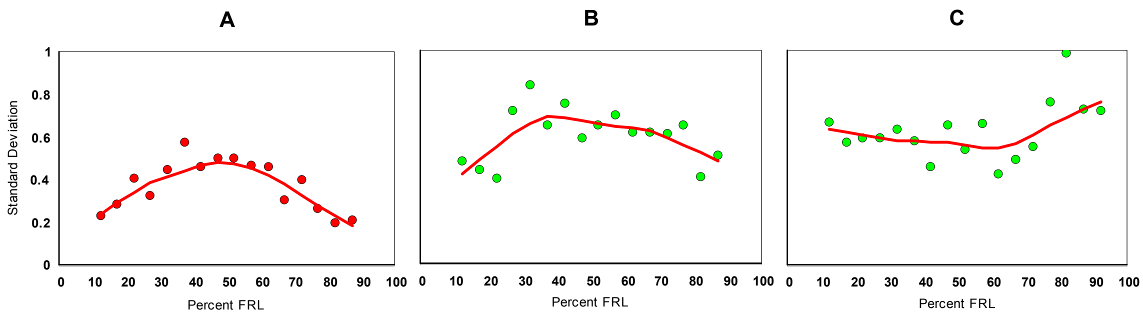

Figure 8 Patterns of variation of scores across the FRL range in three data sets. Panel A shows the variation for the model runs shown in Figure 7B. Panel B shows the variation for the seventh grade data plotted in Figure 7A. Panel C shows the variation in a data set of elementary sixth grade test scores. The scatterplot smooths tracing out the patterns are lowess lines (Cleveland, 1979).

One would expect the strength of peer influence to be inconsequential in 6^{th} and fully developed in the 7^{th} grade. If this is the case, then the pattern of variation found in the model results graphed in Figure 8 should be clearly apparent in the 7^{th} grade data and absent in the elementary 6^{th} grade data.

The patterns observed in Figure 8 are consistent with the theory, and with what one would expect given the known characteristics of the model. The 7^{th} grade pattern is very similar to the model pattern, while there is no hint of the expected shape in the 6^{th} grade graph.

The pattern associated with peer influence is not unique, and so a match of patterns will not confirm the presence of peer influence. But while it is not unique, the match of the pattern in the data to the pattern predicted by the model results—particularly as augmented by the absence of a pattern where that was predicted—adds credibility and support both the presence of peer influence in the data and the ability of the model to reflect it.

Patterns of model results across FRL A quantitative summary of the results of the 480 runs of the model, which were graphed in the preceding section, is given in Table 1. The information will be used in the ensuing discussion of the application of the model results to the EIS reform. The table displays the patterns resulting from runs of the model produced as described in the previous section, at Climate settings of 50, 100, and 500. In the table, the initial values have been subtracted from the model outcomes, so that the averages are based only on the distribution of the 300 "students." Results are presented in intervals across the FRL range, for each of the four model subgroups—that is, the final "student distributions" are shown, and how they change across the FRL range. The results are given as averages at the FRL intervals.

In addition, the crossovers have been separated out so that their average quantities and patterns may be observed. A copy of the model was modified to send them to stocks created for the purpose. For this reason, in the table, the average size of the crossovers is given by the numbers to the right of the plus sign in the columns showing the averages of

Table 1
Average Model Outcomes by FRL Intervals

FRL Avg[a]	No. in Interval	Climate weighting	High Achievement		Average Achievement plus crossovers[b]		Under Achievement plus crossovers[b]		Counter Achievement	
			Avg	StD	Avg	StD	Avg	StD	Avg	StD
12%	13	50	233.8	13.2	21.7 + 10.0	8.3	34.0 + 0.0	8.7	0.5	0.6
		100	219.1	14.8	36.5 + 6.3	10.9	37.0 + 0.0	9.6	1.2	1.1
		500	140.4	13.6	120.2 + 0.4	11.6	36.7 + 0.0	7.0	2.3	1.7
		Initial[c]	64.3		192.8		32.2		10.7	
20%	27	50	208.5	17.0	24.6 + 10.0	11.5	56.0 + 0.0	9.1	0.9	1.0
		100	187.0	21.7	46.1 + 5.7	17.8	59.4 + 0.0	8.4	1.8	1.3
		500	115.0	14.9	118.3 + 0.3	12.2	61.9 + 0.0	9.2	4.6	3.0
		Initial[c]	58.6		175.7		49.3		16.4	
30%	30	50	157.3	36.8	49.5 + 6.8	29.6	80.5 + 0.0	8.9	5.9	6.3
		100	134.7	33.5	72.1 + 3.3	27.7	82.9 + 0.0	7.9	7.0	5.6
		500	91.2	13.2	117.5 + 0.0	11.1	79.5 + 0.0	10.9	11.8	4.8
		Initial[c]	51.6		154.7		70.3		23.4	
40%	46	50	119.3	46.5	58.0 + 5.5	41.1	105.4 + 0.0	17.5	11.7	15.8
		100	93.3	31.9	84.0 + 1.1	28.3	107.7 + 0.0	15.1	13.9	10.9
		500	59.6	9.3	117.5 + 0.0	9.7	100.6 + 0.0	8.8	22.3	6.4
		Initial[c]	44.5		133.5		91.5		30.5	
50%	61	50	49.7	40.3	98.2 + 0.7	36.1	103.3 + 0.8	35.6	47.3	38.5
		100	41.8	22.8	106.8 + 0.0	20.6	111.8 + 0.1	20.7	39.6	21.8
		500	37.0	10.2	115.4 + 0.0	9.9	110.1 + 0.0	8.6	37.4	10.1
		Initial[c]	37.2		111.7		113.3		37.8	
60%	86	50	11.1	13.8	104.7 + 0.0	14.2	63.8 + 5.0	40.3	115.4	46.6
		100	13.4	9.0	106.0 + 0.0	10.9	87.3 + 1.4	29.5	91.9	33.3
		500	20.5	6.2	98.4 + 0.0	8.4	119.7 + 0.0	11.5	61.4	12.6
		Initial[c]	30.2		90.5		134.5		44.8	
70%	91	50	4.9	8.5	80.7 + 0.0	12.4	45.2 + 8.1	33.5	161.1	39.7
		100	6.4	5.9	83.8 + 0.0	10.9	70.2 + 3.5	27.8	136.1	34.1
		500	11.4	4.8	82.2 + 0.0	8.9	123.3 + 0.0	12.3	83.1	15.7
		Initial[c]	23.4		70.1		154.9		51.6	
80%	95	50	1.7	2.1	54.1 + 0.0	9.8	27.3 + 9.5	15.9	207.5	22.2
		100	2.7	2.3	57.4 + 0.0	9.7	48.9 + 5.2	21.8	185.9	26.8
		500	4.6	2.6	59.8 + 0.0	9.9	117.1 + 0.3	11.9	118.2	15.1
		Initial[c]	16.2		48.7		176.3		58.8	
88%	31	50	0.5	0.8	36.1 + 0.0	8.0	21.8 + 8.5	18.2	233.0	21.7
		100	0.8	1.0	38.9 + 0.0	8.2	39.0 + 5.4	19.1	215.9	23.0
		500	2.2	1.5	41.6 + 0.0	7.7	116.2 + 1.5	13.4	138.6	16.3
		Initial[c]	11.0		32.9		192.1		64.0	

[a]Model runs were generated using the FRL values of the data for the MDCPS 7th grades displayed in Figure 1. These results have been grouped into intervals of 10 percentage points each over the FRL range from 15 to 85 percent. The first and last intervals span 7-15% and 85-91%, respectively. The FRL percents are the averages across the intervals rounded to the nearest integer, and the number of values in each interval is given in the column immediately to the right.

[b]The average in this column displays the average number of original non-core members in the group (on the left of the plus sign), and the average number of non-core members of the other group converted to the group's non-core—the crossovers (on the right). The sum of the two is the total number in the group's non-core at the end of the run.

[c]The term initial here refers not to the values used to initialize the stocks, but to the initial distributions reflected in those initial values, adjusted to sum to 300 across the four "Achievement" stocks. As such, they represent the outcomes that would have resulted had the model runs had no effect. The distribution is the same regardless of the climate weighting.

the non-core sub-groups to which they have "crossed over."

To summarize the table contents briefly, the cores form non-linear increasing patterns in opposite directions. The non-cores vary inversely with the cores. Of equal importance are the standard deviations of the averages; they grow larger in the center of the FRL range. These measures make the volatility of the middle of the FRL range evident in the table. The variability is exceptionally high at the lowest climate value, at which value student interaction is maximized.

In fact, all the results shown in the table are exceptionally sensitive to Climate—perhaps most notably the crossovers. Never large in quantity, the crossovers overlap the FRL midpoint only at low Climate values, and almost disappear altogether beyond the Climate setting of 100.

This summary gives an indication of the information available for reference as the model results are applied to questions arising from the proposals for the Economic Integration of Schools reform. The interested reader is invited to peruse the table as desired.

Discussion

Implications of the model for the Economic Integration Reform

At the secondary educational level, influence over student behavior shifts away from parents (the home environment) and more toward the social environment. There, peer influence is but one of several variables affecting achievement that is thought to be subject to manipulation, but it may be one of the more important for a middle-school strategy to raise achievement.

The question before us here is this: Is it possible to apply a knowledge of peer influence in the service of an ideology-driven reform—the Economic Integration of Schools—in such a way that the resources that school districts currently possess can be effectively used? If we assume that the model has adequately captured at least the gross behavior of the peer influence phenomenon, then we may draw inferences from it concerning the reform.

Results from the model appear to support the EIS assumptions. Examination of the model results indicates that where FRL is above 60 percent, there is not a lot that can be done to raise achievement. Even the students who are not at risk have little incentive to improve their performance, and some may succumb to the pressures of conformity to the dominant Counter-Achievement values. Below 40 percent FRL, high achievement tends to increase whatever the policies or resources brought to bear. At first glance, then, the case for EIS appears to be made, although concerns about transportation and neighborhood integrity remain, unresolved since the days of racial integration (see for example Lamm 2002). The model indicates the obvious—there is little chance for improving achievement at high FRL, and it is practically guaranteed at low FRL. It would seem to follow that moving poor students to middle class schools would produce the desired results.

However, the role of peer influence in promoting achievement is more complex than it at first appears. An examination of the details indicates that there are difficulties and complications that give pause to an uncritical endorsement of an EIS policy. Three issues are examined from the standpoint of the model's implications: 1) the claim to help poor students achieve; 2) the claim that middle class students are not harmed in the process; and 3) the logical ramifications of an effectively applied EIS policy.

What about the claim that lower FRL helps poor students? There are two distinct ways in which a lower FRL can help to boost the achievement of poor students through peer influence. First, economic integration alone—that is, reducing the FRL percentage—can increase a High Risk group's average achievement level, simply by reducing the influence of the group's own peer attraction. The weaker the attraction the fewer Under Achieving students will be lured into the even lower achievement performance of the Counter Achievement core. So even modest improvements in FRL status will show an improvement in the school's average score.

But what the EIS people really want and expect is crossover—the conversion of At Risk Students into Not At Risk Students. If the achievement environment is strong enough—that is, if the core of high-achieving students is large enough—then some of the High Risk group of students will leave the values of their own group behind and begin behaving in the manner of their fellows who are not at risk of failure. However, if the reasoning incorporated in the model is right, this will require much greater reductions in FRL than simple majority middle class, even if the actual Convert-to-Low-Risk curve is more generous than that used in the model. As presently constructed, for example, at the lowest applied Climate weighting of 50, the average percentage of At Risk Students diverted to Average Achievement at 12% FRL is 22.5 (from Table 1, 10.0/(10.0+34.0+0.5)*100=22.5). Not much, considering that the size of the whole High Risk group at that FRL percentage is only about 15 percent of the total enrollment. And the percent converted drops off quickly from there: 14.9% of the Under Achievement group at 20% FRL, 7.3% at 30% FRL, and 4.5% at 40% FRL.

The numbers crossing over also decrease rapidly as the Climate weighting increases. The core averages just do not get big enough when the climate value is large. These results are certain to focus attention on the Convert-to-Low-Risk function that I have chosen. The curve is not tied to empirical data (i.e., it is an "educated guess"), and it may be of interest as a point of further research, since the crossover activity is sensitive to its shape. However, if the concept is itself correct, it is unlikely that the number of crossovers will increase to any great extent in the middle range of FRL where most of the schools are likely to gravitate under an aggressive EIS policy, however generously drawn the conversion curve.

What about the claim that EIS will not interfere with the educational progress of middle class students? The model indicates that there is symmetry. The converse of what happens to the High Risk group will happen to the Low Risk group. Raising the FRL percentage even modestly—and this is what must follow from moving poor students to middle class schools—has implications for all students. Moderate increases to a low FRL percentage lessens the attraction of the High Achievement core, resulting in fewer middle class students becoming High Achievers (though there will be little chance that any will become Under Achievers). Lowering the FRL percentage down into the middle of the FRL range, say below 40 percent, will create a situation where a dominant Counter Achievement core could be a frequent result, further reducing the High Achievement core and having a strong effect on the school's average test scores, assuming of course that an effective staff and/or programs do not counter these effects.

What are the likely implications of a widely adopted and successfully applied EIS reform? To maximize an EIS policy is to equalize all schools in a district at the same FRL percentage. For any district, that equal percentage will be the district mean. The problem is that the at-risk portion of the population can be so large that a direct and problem-free policy of economic integration is not feasible. The state of Florida, for example, had in the school year 2001-2002 an average middle school FRL percentage of 45.9 % spread over 67 school districts (Florida Department of Education, 2003). Of these 67 districts, only 18 (27%) had mean middle-school FRL percentages under 40 percent. Twelve (18%) had FRL percentages of over 60 percent. For these 12 districts, EIS is not a practical solution.

The majority of districts had an FRL percentage falling between 40 and 60 percent. Twenty-two districts (33%) had mean middle school FRL percentages in the 40 to 50 percent range, and 15 (22%) had FRL percentages between 50 and 60 FRL percent. Together they constituted a majority of the state's school districts in 2001-02. These districts fall in the volatile middle of the FRL range, where the Low Risk and High Risk groups are relatively evenly matched.

Within this "central zone" of 40 to 60 percent FRL, certain conditions prevail. For crossover, one of the ironies is that near 50% FRL, neither core gets big enough to attract students from the other group. Both peer influence cores are smaller, grow more slowly, and finish the year smaller, than does a dominant core farther from the center. Consequently, there will be fewer High Achiever middle class students, *and* fewer crossovers, than at lower FRL percentages. For this reason, peer influence alone (and thus moving students around to equalize the poverty level in order to manipulate this variable) cannot begin to resolve the low achievement problem. It can only set some conditions.

The model indicates, contrary to the more optimistic views, that to ensure success and avoid problems, the integration must be of small numbers of at risk students into solidly middle-class schools—preferably maintaining an FRL percentage of under 40%. In the less affluent schools of the 40 to 60 FRL range, one can strive to increase the probability of occurrence of High Achievers, driving down the Counter-Achievers. This will ensure that the At Risk students—while still performing below average—will be amenable to remedial programs and good teaching. The kinds of things that good administrators and good teachers know how to do can offer a constructive challenge here, and with hope of substantial improvement. The schools should also have a greater percentage of more active parents than would have been the case in those schools that were previously constituted of higher FRL percentages. On the other hand, there will not be as many high achievers as there would have been in the schools that were previously constituted of lower FRL percentages; this is the price paid by the middle class students. Success will depend more than ever on skilled administration and teachers, and on carefully crafted programs that work for all students.

In sum, the condition in which all schools fall in the 40-60 FRL range is a likely result of the reform. Confined to this range, the reform will be a compromise for everyone most of the time. However, the problem of under-achieving peer influence should be more manageable, and it is after all only one of the key variables. Much will depend on staff quality and the ability to mobilize parents—elements that should also improve with the reform. The challenge just might lead to better educational skills and a more satisfying experience for all.

Educational research and system dynamics

I began this paper by noting a renewed interest on the part of policy makers in "scientifically based research" for the creation of better school policies and programs. The question at this point is, Where in the new scheme of educational research does a paper such as this one fit? I answer at three levels of generality.

At the most basic level, that of direct application to a particular problem, the answer is straightforward. Taken altogether, the peer influence model seeks to fill in a part of the "theory of change toward higher achievement" underlying the program of economic integration described by Kahlenberg and others, making the reform's theory more explicit and reducing ambiguity. The model permits the identification of weaknesses in the original assumptions as described, suggests new strategies, and poses new questions to be evaluated by more conventional methods.

The next level of generality is that of categories within the field of educational research. System dynamics is not common enough in educational research to have its own niche, but it fits best in a general category called "Theories of Change," which in its application to program evaluation is known as program theory. Theories of Change uses a chain of causal events, designated as the theory, to identify the mechanisms by which events are predicted to occur. A congruence between the theoretical predictions and the actual data outcomes is assumed to validate the theory, to be detected by an observed consistency or pattern match between theory and reality over a series of events.

I suggest that this category also encompasses system dynamics. Theories of Change is well suited to (almost "made for") the application of system dynamics models, although there has been almost no use made of them (McClintock, 1990, is the only exception of which I am aware). There is, however, a nascent awareness of the need for the type of system analysis that system dynamics has pioneered, as program theory researcher Patricia Rogers (2000) has indicated.[7] For these reasons, I place the present paper in this category.

Finally, there is the most general level, that of the field of educational research itself. As I noted earlier, assessments of that research have recently become more stringent. The Department of Education, some members of Congress, and the Bush administration all favor hard quantitative research, meaning that all "softer" methods are considered subordinate to the randomized experiment and closely associated approaches. A well reasoned and cogent superiority-but-not-exclusiveness argument in favor of the randomized experiment has been advanced by veteran researcher Thomas Cook (2002), who argues that softer methods are "valuable " and "serious forms of research," but only as subordinate complements to the randomized experiment.

In the course of his argument, Cook explicitly recognizes the importance of the Theories of Change approach. "Few advocates of experimentation," he writes, "will argue against the greater use of substantive theory to guide measurement and analysis in experimental evaluations" (p. 194). He does not, however, accept the approach's claim to the ability to stand alone. Citing a list of perceived weaknesses,[8] he concludes that "theory-based evaluations are useful complements to randomized experiments but not alternatives to them" (p. 195). System dynamics then, insofar as it falls within the Theories of Change category, shares this designation. Consequently, as a piece of educational research, I submit that the present paper falls into the role of "useful complement to randomized experiments."

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Notes

1. Although the unit (the aggregate test percentile for the school) was the same across all years, the standard deviations by year and the version of the test (the Stanford Achievement Math Comprehension Test) varied through the years. The conversion to z scores was made for this reason.

2. Coincident with the emergence of a stronger role for peer influence, test scores also drop substantially in middle school, across the whole of the FRL range. For example, in the Miami-Dade district in 1999, 48 middle schools received into their 6th grades the students who had graduated from 5th grade the year before. Of the 48, 21 had 6th grade median percentile math scores in 1999 that were lower than the 1998 median percentiles of the 5th grades of any of the elementary schools contributing students to them. Another 12 scored lower than all save one of their contributing 5th grades. In one feeder pattern, the middle school's test average was lower than that of its poorest contributing elementary. (Compiled from data published by the Office of Educational Planning, 2000.)

3. The *Webster's New World Dictionary* distinguishes between attraction, which according to that source "implies the exertion of a force such as magnetism to draw a person or thing and connotes susceptibility in the thing drawn;" and captivation, which "implies a capturing of the attention or affection, but suggests a light, passing influence." (3rd Edition, 1994).

4. I am indebted to Hannon and Ruth (1994, Chapter 6), for the initial inspiration for this model structure.

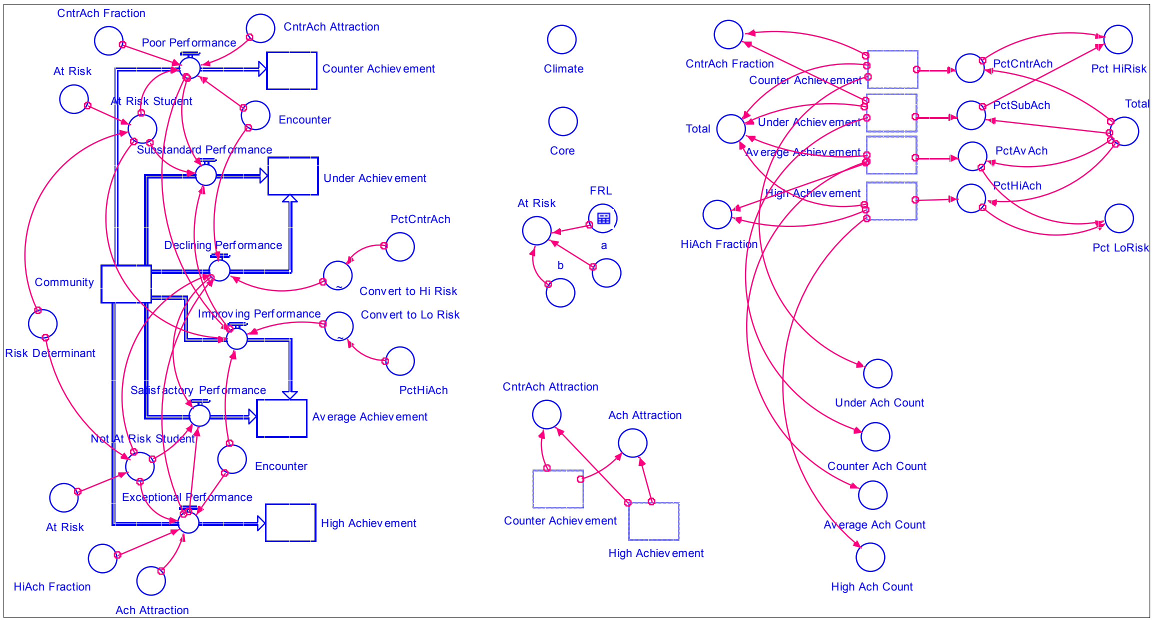
5. There are more elegant ways of estimating local variance across a range. One is suggested by the work of Efron and Tibshirani (1991). My experience in the present instance, however, particularly since the Ns are large, indicates that the results do not differ greatly from simpler methods.

6. Although the majority of middle schools in the Miami-Dade district are of the 6-8 configuration, the district has moved fairly recently from the 7-9 junior high school configuration, and many elementary schools retain a sixth grade. To confuse matters more, there is a recent move toward adopting a K-8 configuration.

7. In an overview of causal models in program theory, Rogers has written that "causal models are at the heart of program theory evaluation, yet there has been surprisingly little discussion of the different types of causal relationships that might be useful for program evaluation" (p. 47). She acknowledges that causality is complex, and that the simple causal chains in PTE theories are usually gross oversimplifications. She is further aware of the possibility that the relationship between cause and effect is not linear, and notes that feedback loops are rarely if ever included in the program logic. However, although she writes that a few "causal models from systems theory . . . appear to be potentially useful for program theory" (p. 52), her sole source of reference outside her own field is Senge's *Fifth Discipline*. The conclusion must be that (1) system dynamics would make a much needed contribution to this field, but (2) it is as yet little known there.

8. Cook's major objection is that there is no counterfactual. He points out that there may be multiple theories that fit the patterns to be matched, and so causality cannot be convincingly established. He does recognize Scriven's 1976 concept of signed causes that create a pattern so unique that cause cannot be mistakenly attributed, but he dismisses the method on the grounds that the requirements are too difficult to be met in practice. However, anyone familiar with system dynamics knows that unique patterns are not uncommon in even the simpler models. I have argued elsewhere (Morris, 2001) that it is possible to establish cause based partly on Scriven's reasoning, using a system dynamics approach, and I included an example in which unique patterns are matched.

Appendix: The Peer Influence Model




```
Average_Achievement(t) = Average_Achievement(t - dt) + (Satisfactory_Performance +
Improving_Performance) * dt

INIT Average_Achievement = (1-Core)*(1-AT_RISK)*Climate

Satisfactory_Performance = IF (Not_At_Risk_Student=1) AND (Exceptional_Performance=0) AND
(Declining_Performance=0) THEN 1 ELSE 0

Improving_Performance = IF(At_Risk_Student=1) AND (Poor_Performance=0)  AND
(Encounter<Convert_to_Lo_Risk) THEN 1 ELSE 0

Community(t) = Community(t - dt) + (- Poor_Performance - Substandard_Performance -
Satisfactory_Performance - Exceptional_Performance - Declining_Performance -
Improving_Performance) * dt

INIT Community = 300

Poor_Performance = IF (At_Risk_Student=1) AND
(Encounter<CntrAch_Attraction*CntrAch_Fraction) THEN 1 ELSE 0

Substandard_Performance = IF (At_Risk_Student=1) AND (Poor_Performance=0) AND
(Improving_Performance=0) THEN 1 ELSE 0

Satisfactory_Performance = IF (Not_At_Risk_Student=1) AND (Exceptional_Performance=0) AND
(Declining_Performance=0) THEN 1 ELSE 0

Exceptional_Performance = IF (Not_At_Risk_Student=1) AND
(Encounter<Ach_Attraction*HiAch_Fraction) THEN 1 ELSE 0

Declining_Performance = IF (Not_At_Risk_Student=1)  AND (Exceptional_Performance=0) AND
(Encounter<Convert_to_Hi_Risk) THEN 1 ELSE 0

Improving_Performance = IF(At_Risk_Student=1) AND (Poor_Performance=0)  AND
(Encounter<Convert_to_Lo_Risk) THEN 1 ELSE 0

Counter_Achievement(t) = Counter_Achievement(t - dt) + (Poor_Performance) * dt

INIT Counter_Achievement = Core*At_Risk*Climate

Poor_Performance = IF (At_Risk_Student=1) AND
(Encounter<CntrAch_Attraction*CntrAch_Fraction) THEN 1 ELSE 0

High_Achievement(t) = High_Achievement(t - dt) + (Exceptional_Performance) * dt

INIT High_Achievement = Core*(1-AT_RISK)*Climate
```

```
Exceptional_Performance = IF (Not_At_Risk_Student=1) AND
(Encounter<Ach_Attraction*HiAch_Fraction) THEN 1 ELSE 0

Under_Achievement(t) = Under_Achievement(t - dt) + (Substandard_Performance +
Declining_Performance) * dt

INIT Under_Achievement = (1-Core)*At_Risk*Climate

Substandard_Performance = IF (At_Risk_Student=1) AND (Poor_Performance=0) AND
(Improving_Performance=0) THEN 1 ELSE 0

Declining_Performance = IF (Not_At_Risk_Student=1)  AND (Exceptional_Performance=0) AND
(Encounter<Convert_to_Hi_Risk) THEN 1 ELSE 0

a = 0.03

Ach_Attraction = 1+(High_Achievement-Counter_Achievement)/
(Counter_Achievement+High_Achievement)

At_Risk = a+b*FRL

At_Risk_Student = IF (Risk_Determinant<=At_Risk) THEN 1 ELSE 0

Average_Ach_Count = Average_Achievement - INIT(Average_Achievement)

b = 0.94

Climate = 50

CntrAch_Attraction = 1+(Counter_Achievement-High_Achievement)/
(Counter_Achievement+High_Achievement)

CntrAch_Fraction = Counter_Achievement/(Counter_Achievement+Under_Achievement)

Core = 0.25

Counter_Ach_Count = Under_Achievement- INIT(Under_Achievement)

Encounter = RANDOM(0,1)

FRL = 0

HiAch_Fraction = High_Achievement/(High_Achievement+Average_Achievement)

High_Ach_Count = High_Achievement - INIT(High_Achievement)

Not_At_Risk_Student = IF (Risk_Determinant>At_Risk) THEN 1 ELSE 0

PctAvAch = Average_Achievement/(Total+1)*100

PctCntrAch = Counter_Achievement/(Total+1)*100

PctHiAch = High_Achievement/(Total+1)*100

PctSubAch = Under_Achievement/(Total+1)*100

Pct_HiRisk = PctSubAch+PctCntrAch

Pct_LoRisk = PctAvAch+PctHiAch

Risk_Determinant = RANDOM(0,1)

Total = Under_Achievement+Counter_Achievement+Average_Achievement+High_Achievement

Under_Ach_Count = Counter_Achievement- INIT (Counter_Achievement)

Convert_to_Hi_Risk = GRAPH(PctCntrAch)
(0.00, 0.015), (10.0, 0.03), (20.0, 0.05), (30.0, 0.08), (40.0, 0.125), (50.0, 0.165),
(60.0, 0.225), (70.0, 0.305), (80.0, 0.41), (90.0, 0.595), (100, 0.935)

Convert_to_Lo_Risk = GRAPH(PctHiAch)
(0.00, 0.015), (10.0, 0.03), (20.0, 0.05), (30.0, 0.08), (40.0, 0.125), (50.0, 0.165),
(60.0, 0.225), (70.0, 0.305), (80.0, 0.41), (90.0, 0.595), (100, 0.935)
```