A Game-Theoretic Model of Curriculum Integration and School Leadership

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Introduction

Nearly all American youth take at least one vocational credit during their high-school careers and over 40% take three or more (Silverberg, Warner, Goodwin, & Fong, 2002). In the latter group, an increasing proportion—often referred to as "dual concentrators"—pursue formal programs of study that include rigorous sequences of both academic and vocational courses (Stone & Aliaga, 2003). According to the 1998 High-School Transcript Study (Roey et al., 2001), students who earn 12 credits or more in college preparatory academic classes and 3 credits or more in a specific labor market preparation field increased from about 9% of high-school graduates in 1982 to over 19% by 1998.[1]

Curriculum integration (CI) is an educational strategy aimed primarily at students who take significant numbers of both academic and vocational courses either as part of a formal program or on their own. Its goal is to enhance the learning of these students by breaking down the traditional barrier that exists in most schools between the two curricula. As a philosophy of education, CI can be traced back at least as far as John Dewey (1916) who argued against the separation of academic and vocational education and for a combined approach which he referred to as “education through occupations.” Over the past 15 years, CI has moved to the forefront of reform efforts in the vocational education field. An important reason for its ascendancy is the emphasis placed on it by federal legislation during the 1990s. All three of the most important laws funding work-based education passed during this period [i.e., the Carl D. Perkins Vocational and Applied Technical Education Act of 1990, the School-to-Work Opportunities Act of 1994 (STWOA), and the Carl D. Perkins Vocational and Technical Education Act of 1998] contain language encouraging the practice.

Most published research on CI can be classified into one of three groups. The first group consists of broad conceptual discussions of alternative CI approaches and their relationship to other educational reform efforts. Grubb's (1995a, 1995b) pioneering 2-volume collection of edited papers on CI provides many examples of this type of work, including several authored or co-authored by Grubb himself. The second group is made up of qualitative studies of CI implementation in individual schools or districts. Again, several useful examples may be found in the Grubb volumes, particularly Ramsey, Eden, Stasz, and Bodilly (1995) and Katz, Jackson, Reeves, and Benson (1995). Two more recent studies in this genre have been carried out by Charner, White, and Johnson (2003), and Castellano, Stringfield, and Stone (2003). The former employs case methods to identify some of the determinants of CI in schools, and the latter uses the same approach to assess the impact of whole-school reform on CI. The third group of studies consists of quantitative analyses of student CI involvement and outcomes. Haimson and Deke (2003), for example, present data from the Mathematica study of STWOA implementation showing the extent of student participation in certain career-focused class activities. Plank (2001) carries the analysis one step further by measuring the effect of alternative combinations of vocational and academic courses on academic achievement and the likelihood of dropping out.

What is missing in the literature—and what this paper attempts to provide—is a formal model of CI implementation as it takes place in a school. The starting point for constructing such a model is a set of institutional and behavioral assumptions about the key decision makers. CI decisions are made by individual teachers and administrators who (a) are independent actors with possibly differing professional objectives, (b) work in an educational environment characterized by limited information and constrained resources, and (c) must contend with the reality that the link between CI and learning may be complex and potentially expensive to exploit. Existing conceptual and qualitative analyses of CI reform efforts are full of important details about the programmatic characteristics and implementation experiences of various CI alternatives. They are typically less specific about their underlying assumptions concerning agent motivation, school decision-making processes, CI implementation costs, and student learning.

This lack of specificity has two dimensions. First, to the extent that assumptions are made at all, they are often implied rather than stated outright. Second, whether implicit or explicit, they are often at odds with the fundamental facts of real-world schools enumerated above. For example, many non-quantitative studies simply assume that we know with certainty that CI can be implemented at relatively low cost, that it will have a significant positive effect on student outcomes, and therefore that it is unambiguously a "good thing." They also assume that CI will seldom be adopted independently by teachers even though their students would benefit from it. The reason for this inaction is typically left unspecified, but the implied explanation is usually based on some conception of teacher inertia (i.e., on the belief that teachers are never more than passive replicators of past practices). Therefore, it is necessary for school administrators to implement CI in a centralized fashion by exercising educational leadership.

This picture of the CI implementation process, while probably accurate to some degree, oversimplifies a complex decision-making situation. First of all, there may be teacher-initiated CI efforts that we do not know about because of the absence of baseline studies. Further, there are probably multiple reasons why we do not see more teacher-initiated CI. Inertia is one explanation, but there are others that are equally plausible. Perhaps recalcitrant teachers are actually correct in ignoring CI because it is ineffective in producing student learning or too costly relative to the gains achieved. Alternatively, CI may be cost-effective from a schoolwide perspective but not from an individual classroom perspective. Teachers thus may think they are doing the best for their students by ignoring CI when actually they are not. Finally, the underlying theory of learning in the typical CI study seldom goes beyond the idea that more CI leads to more learning. As shown below, what CI options are chosen by schools and whether those choices are good or bad depend crucially on a more sophisticated conception of how CI affects student learning.

This paper represents a preliminary effort to address the above concerns by using game theory to model the CI implementation process. Its primary goals are to deepen our thinking about CI as an educational reform strategy and to provide an intellectual foundation for future empirical work. Special attention is paid to those results that run counter to the conventional wisdom in the CI area.

Form of Curriculum Integration

CI means different things to different people. One interpretation of the concept is concerned only with patterns of student course-taking. From this perspective, a student's curriculum becomes more integrated to the extent that more courses are taken outside a major track. This would occur, for example, if a health care concentrator substituted a biology class for one dealing with hospital management. An alternative, school process-oriented approach has been proposed by Charner et al. (2003). After observing CI mechanisms in many schools, he and his colleagues conclude that CI is best thought of as "a series of conscious and informed strategies used to connect academic and vocational content so that one becomes a platform for instruction in the other over an extended period of time" (2003).

The form of CI studied in this paper is an example of Charner's more general conception. Specifically, CI is analyzed as one possible outcome of decisions made by teachers and administrators to improve student learning. In those situations where CI is the chosen strategy, vocational content is introduced into the academic curriculum and academic content into the vocational curriculum.[2] Using Charner's terminology, each curriculum then becomes a platform for some instruction in the subject matter of the other curriculum. In terms of Grubb's (1995c) comprehensive taxonomy, this version of CI represents an amalgamation of his Model 1 (i.e., incorporating more academic content in vocational courses), Model 3 (i.e., making academic courses more vocationally relevant), and Model 4 (i.e., horizontal and vertical curriculum alignment).

Overview

The paper's core model is developed in the next four sections. Specific assumptions about the knowledge and motivations of the principal actors, and about the learning mechanism on which their decisions are based, are presented in the next two sections: Setting and Learning Theory. The course-content outcomes generated by the model and their implications for student learning are described in the subsequent two sections: Equilibrium and School Welfare. The penultimate section, School Leadership, uses the core model to identify situations where the achievement of schoolwide learning goals requires the exercise of educational leadership by the school principal. The final section provides a summary of the paper's main conclusions and a discussion of their implications for further research.

Setting

The core model describes decision making by teachers concerning course content for a group of students during a particular semester at the hypothetical John Nash High School (JNHS). Each student takes two courses at JNHS during the term in question: one academic, the other vocational. The academic course is taught by an academic instructor and the vocational course by a vocational education instructor.

Standardized Tests

Subject matter learning is assessed in each course at the end of the semester using standardized tests. This assumption fixes in advance the content that the students are expected to know. Let T_A represent the average student score on the academic exam and T_V the average score on the vocational exam.

Symmetry

The two courses are identical in every way except subject matter. They have the same number of contact hours, provide the same number of credits, and are equally valued by the school. In addition, it is assumed that the learning effects of CI (described in detail in the next section) are the same for both courses.

Teacher-Initiated Change

This paper does not assume that teachers never independently alter their course content or pedagogy. At JNHS, both the academic and vocational teachers make course changes on their own initiative prior to the beginning of the semester in question.

Two Choices

In particular, each teacher replaces an old discipline-specific unit in his class with one of two possible new units. The first candidate is a CI unit that includes related material from the other curriculum. For example, a math instructor might choose a unit on construction applications of trigonometry because his students are also taking a carpentry class. The second candidate (labeled NCI) is a new discipline-specific unit with no cross-curricular content. Each of the four possible CI/NCI combinations that can result from the teachers' decisions produces two learning outcomes: one for the academic class and one for the vocational class. These outcomes are represented in the model as changes in T_A and T_V.

Full Information

Each teacher has a general knowledge of what is covered in his colleague's class and specific knowledge of all four pairs of learning outcomes. Each also knows his colleague's CI/NCI decision as soon as it is made, and that his colleague behaves rationally (as defined below) in making that decision. Finally, each knows that his colleague knows the same things he does, and that his colleague knows he knows them.[3]

Bounded Teacher Rationality

Teachers have professional goals and make rational choices to achieve them. At JNHS, each teacher's goal is assumed to be maximizing "own class" learning as measured by the average score on the end-of-the-semester standardized test in his subject. This means each chooses between the CI and NCI units on the basis of their relative impact on this score.

No Collaboration

Although both teachers know the educational payoffs resulting from alternative combinations of CI and NCI units across the two courses, they make their course-content decisions independently. This assumption mirrors the well-documented reality of rigid programmatic separation in most comprehensive high schools. As Little (1993) and others have noted, academic and vocational teachers live in two different worlds and seldom interact.

Sequential Decision Making

Since the teachers do not collaborate and they have some period of time before the semester starts to decide between the CI and NCI units, their decisions are not simultaneous. One or the other is the first mover (unspecified) and his colleague is the follower.

Passive Educational Leadership

The JNHS principal, like the teachers, has full information about course-content decisions and learning outcomes in her school, but she exercises no leadership with respect to those decisions. That is, she lets the teachers decide entirely on their own what and how to teach. This assumption is relaxed in the school leadership section of the paper.

Learning Theory

Most of what is written about education practice and policy is based on some theory of learning—that is, a hypothesized relationship between a set of educational inputs (curriculum, resources, pedagogy, etc.) and a set of student knowledge or behavioral outcomes. Often this theory is implied rather than stated explicitly. This paper goes to the opposite extreme and specifies the underlying theory in detail because the actions of the model's actors and the resulting student outcomes depend on the values of specific learning parameters.

Three Effects

A teacher is observed choosing the CI unit over the NCI unit for his class. I hypothesize that this decision can have three possible impacts on student learning as measured by the average test scores T_A and T_V: a direct effect, an indirect effect, and an interaction effect. All three represent additions to, or subtractions from, the scores that would have resulted if the NCI option had been selected.

Direct effect (α >, =, or < 0). The direct effect, symbolized here by α, measures the own class impact of the CI choice assuming the other instructor chooses NCI. A priori reasoning suggests that this effect can be either positive or negative. On the one hand, selection of the CI unit necessarily involves some substitution of "out-of-subject" for "in-subject" content that could then adversely effect scores on the subject-specific exam. For example, the mathematics teachers who introduces carpentry applications to his students has to allocate some scarce class time to construction-related subject matter that will not be covered on the standardized mathematics exam at the end of the semester. This sacrifice of own class content is relevant to vocational, as well as academic, teachers. Grubb (1995a) notes that a common complaint among vocational teachers asked to incorporate more academic material in their courses is that doing so will "compromise the integrity of the vocational curriculum."

On the other hand, the cross-curricular content of the CI unit may encourage students to take more overall interest in their subject-specific material because they see that it is connected to what they are learning in their other class. Further, in the case of a CI unit in an academic class, students discover that what they are studying actually has some relevance to the real world. Whatever the specific cause, the resulting increase in motivation could lead to greater student effort and hence higher exam scores even though the amount of class time devoted to tested material has been reduced.

When the substitution factor outweighs the motivation factor, α is negative. When the reverse is true, α is positive. As a tentative hypothesis, it seems likely that the relative strength of the two competing influences depends on the size of the CI unit. The larger the percentage of the course represented by the CI unit, the more likely it is that the substitution factor dominates the motivation factor and α is negative.

Indirect effect (β > 0). The indirect effect, symbolized by β, measures the "spillover" impact of the CI unit on learning in the other class. This effect is assumed to be always positive for two reasons. First, more instructional time devoted to a subject, regardless of the course in which the instruction takes place, should lead to more learning. When a mathematics class includes some building applications, the students should score higher on their carpentry exam simply because they are seeing the material covered by the exam more often. Second, the motivation factor discussed above may also extend to learning in the other class. Students can perhaps be expected to put more effort into mastering carpentry when they see the subject, in effect, validated by their mathematics instructor.

Interaction Effect (ϕ > 0). The interaction or synergy effect, symbolized by ϕ, occurs only when both teachers choose the CI option and is assumed to be always positive. It measures the additional learning (beyond the direct and indirect effects) that results when students experience vocational instruction in their academic class and academic instruction in their vocational class. This effect is included to capture the idea expressed by Lewis (2003) and others that a given amount of CI is more effective if distributed between academic and vocational classes rather than being concentrated in one or the other. The origins of the effect presumably lie in the enhanced motivation students acquire when they see what they are learning in each of their courses reinforced by units covering similar material in the other class. The presence of the interaction effect makes it possible for schools to use CI as a mechanism for achieving economies of scope from their academic and vocational programs. Thus, the more important the effect is, the stronger the argument for CI as a whole-school, rather than piecemeal, reform strategy.

Learning-Added Equations

The overall impact of the three effects can be represented using learning-added equations. These relationships, one for each course, show how average test scores vary with the CI or NCI decisions made by the two instructors. Let

ΔT_i = the change in average test score (i = A, V);

X_A = 1 if the academic teacher chooses the CI unit, 0 if he chooses the NCI unit; and

X_V = 1 if the vocational teacher chooses the CI unit, 0 if he chooses the NCI unit.

The learning-added equation for the academic course can then be written as follows:

(1) $\Delta T_A = \alpha X_A + \beta X_V + \phi X_A X_V$.

Because of the symmetry assumption, the equation for the vocational course has the same structure:

(2) $\Delta T_V = \alpha X_V + \beta X_A + \phi X_A X_V$.

Some properties of these equations may be noted. First, if both teachers choose the NCI option, X_A and X_V are zero and, hence, so are ΔT_A and ΔT_V. Second, if both select the CI option, X_A and X_V are one and ΔT_A and ΔT_V each equal what is henceforth referred to as the combined effect: the sum of the direct, indirect, and interaction effects. Third, if $\alpha > 0$, a teacher's decision to choose CI necessarily leads to an increase in own class learning regardless of what the other teacher does. Fourth, if $\alpha \leq 0$, a teacher's decision to choose CI may lead to an increase, decrease, or no change in own class learning depending on what the other teacher does and the strength of the indirect and interaction effects.

Equilibrium

Given the preceding behavioral and learning assumptions, what choices do the two teachers make? To answer this question, I use a simple game theory structure with payoff matrix shown in Figure 1. This is a nonrepetitive, dichotomous choice game in which the players are the teachers, the “pure strategy” options are CI or NCI, and the payoffs are increments to student learning as measured by changes in the two test scores. Because of the no collaboration and sequential decision-making assumptions, it is also a noncooperative game with a first mover and a follower.

The values for the payoffs in the matrix are obtained from equations (1) and (2). The northwest (NW) cell shows ΔT_A and ΔT_V when both teachers choose CI. The northeast (NE) and southwest (SW) cells show these outcomes when one teacher chooses CI and the other chooses NCI. The southeast (SE) cell shows the outcomes (zero, as noted above) when both choose NCI.

The selections teachers make in this situation depend on the strength and (in one case) direction of the learning effects identified in the previous. To see this, we first examine the case where $\alpha > 0$ and then the case where $\alpha < 0$.

Positive Direct Effect ($\alpha > 0$)

The direct effect is positive when the motivation factor from a CI unit outweighs the substitution factor. In this case, both teachers have a dominant strategy: always select CI. The academic teacher’s preferred choice is CI if the vocational teacher selects CI (because $\alpha + \beta + \phi > \beta$) and also if the vocational teacher selects NCI (because $\alpha > 0$). Either way, CI leads to more academic learning so the academic teacher always chooses it. The vocational teacher behaves in a similar fashion because of the symmetry assumption. Game equilibrium is in the NW cell, leading to average test score gains in each class equal to the combined effect ($\alpha + \beta + \phi$).[4] This cell is an example of a Nash equilibrium because in it each teacher makes the learning maximizing choice given the decision of the other teacher.[5]

Negative Direct Effect ($\alpha < 0$)

The direct effect is negative when the substitution factor outweighs the motivation factor. Game equilibrium, in this case, depends on whether the combined effect is greater or less than the indirect effect.

Combined effect < indirect effect ($\alpha + \beta + \phi < \beta$). Consider first the case where $\alpha + \beta + \phi < \beta$. Here, each teacher's dominant strategy is NCI. If the academic teacher selects CI, the vocational teacher's best choice is NCI (because $\alpha + \beta + \phi < \beta$). If the academic teacher selects NCI, the vocational teacher's best choice is still NCI (because $\alpha < 0$). A parallel argument applies to the academic teacher so game equilibrium is the SE cell. Again, this is a Nash equilibrium because each player optimizes given the choice of the other player.[6]

Combined effect > indirect effect ($\alpha + \beta + \phi > \beta$). When $\alpha + \beta + \phi > \beta$, neither player has a dominant strategy and the game has two Nash equilibria. More specifically, it is an example of a coordination game where each teacher's best choice is to mimic the choice of his colleague. If whichever teacher goes first chooses CI, the other teacher's best choice is CI (because $\alpha + \beta + \phi > \beta$). If, on the other hand, the first mover chooses NCI, the other teacher's best choice is also NCI (because $\alpha < 0$). This means that both the NW and SE cells are Nash equilibria.

Game equilibrium might seem to be indeterminate in this situation but it is not. The logic of the setting and assumptions dictate that both teachers end up choosing CI. To see this, note that the full knowledge assumption means each teacher knows the Figure 1 payoff matrix and that his colleague is an own-class test score maximizer. Each also knows that his colleague knows both of these things and that any decision by one teacher is known instantly by the other. Since both teachers have to make decisions before the semester starts, one teacher must necessarily be the first mover and the other the follower. The first mover knows who he is (because he knows his colleague has not made a decision yet), and he chooses CI because this maximizes his students' own class average test score given that he is sure his follower colleague will make the same choice. The follower teacher, after learning of the first mover's decision, then validates his colleague's choice by selecting CI on his own, based on the reasoning in the previous paragraph. Game equilibrium is therefore in the NW cell.

Diagrammatic Summary

The main results of the previous two subsections are summarized in Figure 2. Values of ϕ are shown on the vertical axis and values of α on the horizontal. In the right quadrant, both α and ϕ are positive and both teachers choose CI. In the left quadrant, α is negative and ϕ is positive. Here, the equilibrium choice depends, as noted above, on the relative sizes of the combined and indirect effects.

Setting the combined effect equal to the indirect effect yields the equation

(3) $\alpha + \beta + \phi = \beta$,

which simplifies to

(4) $\phi = -\alpha$.

Plotting this relationship in Figure 2 for negative values of α generates a negatively sloped 45° line through the origin in the left quadrant. Points above the line in the quadrant represent situations where

(5) $\phi > -\alpha$,

and hence

(6) $\alpha + \beta + \phi > \beta$.

For these parameter combinations, both teachers choose CI. At points below the line, inequalities (5) and (6) are reversed and the teachers both choose NCI.

In sum, both teachers choose CI when α and ϕ are in Region I (light shading) of Figure 2 and NCI when they are in Region II (dark shading). These results show that teachers will select CI on their own initiative in some circumstances. In this model, they do so when the direct effect is positive or when it is negative and smaller in absolute value than the interaction effect. When neither of these conditions hold, teachers select NCI. They make the latter choice, not because of inertia, but because they believe that NCI leads to better outcomes for their students. Note that the size of the indirect effect ultimately plays no role in the determination of game equilibrium. As shown below, however, the welfare properties of some equilibria do depend on this parameter.

School Welfare

The previous section identifies the course-content decisions teachers make under alternative parametric specifications of the learning-added equations. We now examine the school welfare implications of those decisions.

Measuring School Welfare

The first step is to specify how school welfare is to be represented in the analysis. The ultimate purpose of schooling is student learning, and at JNHS academic and vocational education are equally valued (part of the symmetry assumption). Therefore, it is assumed in what follows that school welfare (S) is measured by average learning in the two classes added together:

(7) $S = T_A + T_V$.

Welfare Results of Teacher Decisions

As we saw in the previous section, game equilibrium is always in the NW or SE cells of the payoff matrix. It follows that the CI choice by both teachers is optimal from a school perspective (because it maximizes S) when

(8) $\alpha + \beta + \phi > 0$.

And the NCI choice is optimal when

(9) $\alpha + \beta + \phi < 0$.

To determine the circumstances under which the teachers do (and do not) make these optimal choices, set the combined effect equal to zero, obtaining

(10) $\alpha + \beta + \phi = 0$.

Rearranging (10) yields

(11) $\phi + \beta = -\alpha$.

For a given value of β, Equation 11 can be represented as a negatively sloped 45° line with horizontal intercept $-\beta$ in a diagram with ϕ on the vertical axis and α on the horizontal. Figure 3 is obtained by adding this line (for negative values of α less than $-\beta$) to Figure 2. Points above and to the right of this line (including those in the right quadrant) represent parameter combinations where

(12) $\phi + \beta > -\alpha$,

and hence

(13) $\alpha + \beta + \phi > 0$.

For points below and to the left of the line, these inequalities are reversed.

The two relationships of Equations 4 and 11 divide Figure 3 into three regions: I, IIa, and IIb. Region I in Figure 3 (light shading) is the same as Region I in Figure 2. Regions IIa (dark shading) and IIb (medium shading) jointly comprise Region II in Figure 2. For the combinations of α and ϕ in Region I, both teachers select CI, and CI is the optimal choice from a schoolwide learning perspective (because $\alpha + \beta + \phi > 0$). For combinations in Region IIa, both teachers select NCI, and NCI is the optimal schoolwide choice (because $\alpha + \beta + \phi < 0$). Finally, for combinations in Region IIb both teachers select NCI, but the optimal schoolwide choice is CI (because $\alpha + \beta + \phi > 0$).

Implications

Three important conclusions flow from the preceding analysis. First, CI is not always the right choice for schools. If the direct effect is negative and large while the interaction and indirect effects are small (Region IIa), a school is better off having its teachers focus exclusively on subject-specific material.

Second, under some conditions, decentralized teacher decision making leads (as if guided by an invisible hand) to the optimal pattern of course content. Specifically, this occurs when the learning parameter combinations are represented by Regions I or IIa in Figure 3. In the former case, teachers correctly select CI and in the latter they correctly select NCI. It is therefore not invariably the case that school administrators have to guide teachers to make the right choices.

Third, there are conditions under which teachers make the wrong choices. These are represented by the parameter combinations in Region IIb. Here teachers select NCI when they should select CI to maximize schoolwide learning. In this region, $\phi < -\alpha$ but $\phi + \beta > -\alpha$; that is, the interaction effect by itself is not enough to overcome the negative direct effect, but the sum of the interaction and indirect effects is. The region's size (as shown in Figure 3) is thus determined by the value of β. When the indirect effect is zero, the relationships of Equations 4 and 10 are the same and Region IIb does not exist. In this case, teachers' choices always maximize school welfare. When the indirect effect is positive however, there are learning parameter combinations that lead teachers to make the wrong choices. Put differently, when there are positive spillover learning effects from CI, teachers may underproduce it—a variation on a standard outcome in the literature on externalities. Further, the stronger the spillover effect is, the bigger Region IIb is, and therefore the more combinations of α and ϕ that yield an underproduction outcome.

An example of this last situation is shown in Figure 4 for parameter values $\alpha = -10$, $\beta = 8$, and $\phi = 7$. Examination of the payoff matrix in the figure reveals the classic prisoners' dilemma structure. For each player, the dominant strategy is always to select NCI so game equilibrium is in the SE cell. However, this outcome is adverse both from the perspective of the individual teachers and the school as a whole. Each teacher would be better off if equilibrium were in the NW cell because his average student would achieve 5 points more on the end-of-the-semester exam, and the school would be better off because S is 10 points higher in the NW than the SE cell.

School Leadership

The analysis in the preceding four sections is based on the assumption that CI decisions are made exclusively by teachers who desire to maximize own-course learning and who work in a full information environment. The JNHS principal plays no role in the decision process. In this section, the passive leadership assumption is relaxed so that the principal can intervene if necessary to change course content. It is further assumed that she engages in such interventions only when independent decisions by teachers are suboptimal from the school perspective in the sense that they do not maximize school welfare. Finally, it is assumed that intervention is always a rational choice for her because its cost is low relative to the learning gains achieved.

A comprehensive theoretical treatment of the role of school leadership in CI implementation is beyond the scope of this paper. Instead, we focus on four specific situations where decentralized decision making can produce suboptimal outcomes. In the first, suboptimality emerges out of the core model—a possibility examined in detail in the previous section. In the remaining three, suboptimality occurs because one of the key assumptions of the core model does not hold. In all four cases, alternative forms of principal intervention are examined.

Prisoners' Dilemma Equilibrium

Here, we consider the role of the principal when all assumptions of the core model except passive leadership continue to hold. For learning parameter combinations represented by Regions I and IIa in Figure 3, teachers on their own make the right choices for the school even though that is not their specific intention. Passive leadership by the principal is therefore appropriate in these settings. For Region IIb combinations, however, because of the prisoners' dilemma game structure, teachers choose NCI when the school learning maximizing choices are CI. Here, active leadership by the principal is necessary to move the teachers from the SE to the NW cell of the game matrix. This leadership may take a variety of forms. One possibility is to attempt informally to breakdown the barrier between the academic and vocational programs by encouraging academic and vocational teachers to meet together and plan for the coming semester. A second possibility, if voluntary collaboration fails, is to establish a structure of formal incentives to ensure that both instructors make the right choices.

Less Than Full Information

Suppose now that the full information assumption does not hold. There are several ways this can happen. We only examine the case where teachers have inaccurate information about the values of the learning parameters and hence about the payoffs in the game matrix. In this situation, they may choose CI when they should choose NCI, or vice-versa. Given the bounded teacher rationality assumption continues to hold, appropriate principal intervention consists only of obtaining accurate information about the learning parameters from the education research community and making it available to the JNHS teachers. Once this information is in hand, teachers independently make the right course-content decisions without any further administrative action (except, as noted above, in the prisoners' dilemma case).

Teacher Inertia

Alternatively, suppose the full information assumption continues to hold but that teacher behavior is primarily inertial as many education researchers, administrators, and policymakers apparently believe. This implies that neither the teacher-initiated change nor the bounded teacher rationality assumptions of the core model hold. Teachers continue to do the same thing semester after semester even in situations where they know that change would lead to increased own class learning. In this case, the principal must first, through informal or formal means, create an environment where teachers are expected to modify their courses on a regular basis to enhance student learning. Once this change in the school's academic climate is effected (certainly not an easy task), she can shift to playing a more passive role (except, again, when the game is a prisoners' dilemma).

Asymmetry

Finally, we consider a case where the symmetry assumption does not hold. Suppose the state or national standards that schools are required to meet apply only to academic performance. This will cause learning in the JNHS vocational course to be valued less by the school than learning in the academic course.

In the most extreme situation, vocational learning is not valued at all. Here, school welfare is measured by T_A rather than $T_A + T_V$, and the principal wants the school equilibrium to be in the game cell where ΔT_A is the highest. Because the indirect and interaction effects are always positive, a necessary condition for ΔT_A maximization is that the vocational teacher choose CI. For the parameter combinations represented by Region I in Figure 3, this will come about automatically as a result of the vocational teacher's independent course-content decision. Region I equilibria are in the NW cell where ΔT_A ($\alpha + \beta + \phi$) is greater than in any other cell. For the Region IIa and IIb combinations, however, decentralized decision making does not produce the optimal equilibrium because the vocational teacher chooses NCI. For these combinations, the principal must intervene to induce the vocational teacher to select CI even though it means reduced subject-specific learning in his course. Given this intervention is successful (and that the academic teacher knows that it is going to be), the academic teacher independently chooses NCI so the school equilibrium is in the NE cell where $\Delta T_A = \beta$ (greater than its value in the other cells: $\alpha + \beta + \phi$, 0, and α).

Conclusions and Implications for Future Research

Schools are seldom given abundant resources to accomplish their mission. This makes it imperative that resources they do receive are allocated efficiently. The analysis in this paper yields four principal conclusions about the allocation of resources to one particular reform strategy. These are briefly recapitulated below and some implications for future research are discussed.

CI Is Not Invariably the Right Choice for Schools

Whether or not CI is an appropriate reform strategy for a school depends on the values of the parameters in the learning-added equations. If the direct effect is strongly negative (because the substitution factor dominates the motivation factor) and the indirect and interaction effects are weakly positive, schoolwide learning is maximized by having each teacher concentrate exclusively on subject-specific content. For this (and other) reasons, there is obviously a great need for empirical research on student learning which focuses explicitly on measuring the strength and direction of the three effects.

Teachers Will Independently Choose CI Under Certain Circumstances

As noted at the beginning of this paper, it is usually assumed that teachers do not independently choose CI as a course improvement strategy. The game theory model developed in this paper demonstrates, on the other hand, that there are circumstances under which they make this choice. These differing perspectives suggest two lines of empirical research. The first would seek to measure the extent to which teachers on their own do or do not introduce CI material into their classes. The second would seek to explain the observed pattern. If, for example, the standard assumption is correct and teachers do not independently undertake CI, what explains this behavior? Are they responding rationally to a particular set of CI learning parameters or is there some other reason, perhaps the inapplicability of one or more of the core model's assumptions?

Teachers' Independent CI or NCI Choices May Be Optimal From a Schoolwide Perspective

It is also usually assumed in the education practice and policy literature that active school leadership is a necessary condition for school success. As a result, research on leadership focuses almost entirely on strategies for mobilizing school staff to undertake changes deemed essential by the principal or other administrative officers. The analysis in this paper, however, shows that there are situations where teachers individually make the right choices and there is no need for administrative intervention with regard to course content. If intervention occurs in such cases, it produces failure not success. This possibility suggests that research on school leadership needs to be broadened to include the analysis of cases where the best leadership is no leadership.

School Leadership Is Called for When Teacher Choices Are Suboptimal

School suboptimality can come about because the particular combination of learning parameters in the core model leads to a prisoners' dilemma game for teachers or because one or more of the assumptions in the core model do not hold. In either case, principal intervention is called for to maximize school welfare. As we saw in the preceding section, however, the appropriate type of intervention depends on the specific source of the suboptimality. Depending on the source, the principal may need to provide information, encourage collaboration, create a school climate supportive of continuous improvement, or some combination of all three. At present, little appears to be known about how principals undertaking CI choose among these alternatives and whether their choices are appropriate. More research about this decision making process and its consequences is needed.

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Footnotes

[1] Using different data, Delci and Stern (1999) estimate that the proportion of dual concentrators increased from less than 1% in 1982 to almost 7% in 1997.

[2] A case where CI occurs only in the vocational curriculum is briefly discussed near the end of the paper.

[3] In game theory, the assumption that each of two players knows X, knows his rival knows X, knows his rival knows he knows X, and so on, is often referred to as the common knowledge condition (Dixit & Skeath, 1999).

[4] If $\alpha = 0$, CI is the weakly dominant strategy for both teachers. By choosing CI in this case, each teacher is either in a better position (if his colleague also chooses CI) or in no worse a position (if his colleague chooses NCI).

[5] Given that this is a sequential game, it might appear (both here and in the $\alpha < 0$, $\alpha + \beta + \phi > \beta$ case below) that each teacher will rush to be the first mover to ensure the CI outcome for both—thus, in effect, converting a sequential game into a simultaneous game. The full information and rationality assumptions preclude this, however. Neither teacher is in a hurry

because each knows the other teacher will never select NCI because it would be irrational to do so. The academic teacher, for example, knows that in the $\alpha > 0$ case, the vocational teacher will never choose NCI because the vocational teacher knows he (the academic teacher) will respond by choosing CI, leaving the vocational teacher in a worse position than if his initial choice had been CI ($\beta < \alpha + \beta + \phi$).

[6] In this case, it might appear that each teacher will delay his decision until the last possible moment, in hopes of being the follower just in case his colleague selects CI (since $\beta > 0$). As in the case described in the previous footnote, this possibility is precluded by the full information and rationality assumptions.

Figure 1

Learning Payoffs for Alternative Course-Content Decisions by Academic and Vocational Teachers

		Academic Teacher	
		CI Unit	NCI Unit
Vocational Education Teacher	CI Unit	$\Delta T_A = \alpha + \beta + \phi$ $\Delta T_V = \alpha + \beta + \phi$	$\Delta T_A = \beta$ $\Delta T_V = \alpha$
	NCI Unit	$\Delta T_A = \alpha$ $\Delta T_V = \beta$	$\Delta T_A = 0$ $\Delta T_V = 0$

Figure 2

Teacher Decision Regions for Alternative Values of α and ϕ

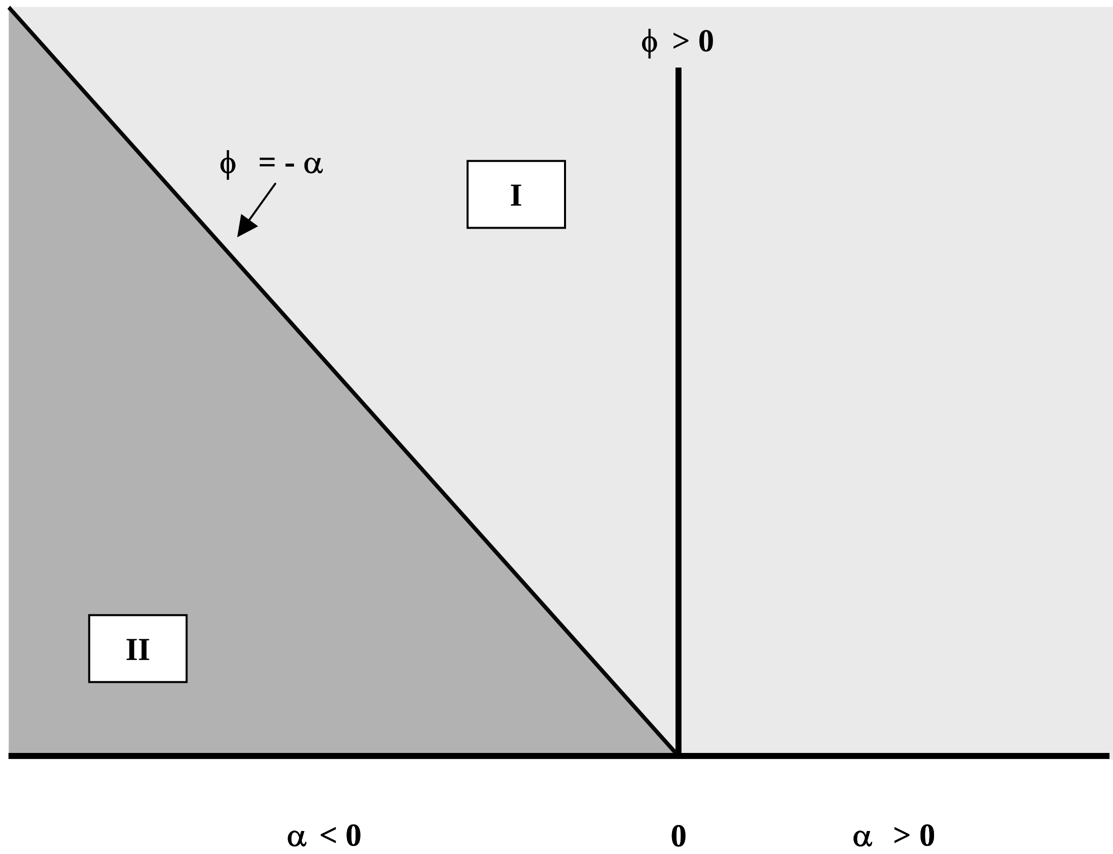

Figure 3

School Welfare and Teacher Decision Regions for Alternative Values of α and ϕ, Given β

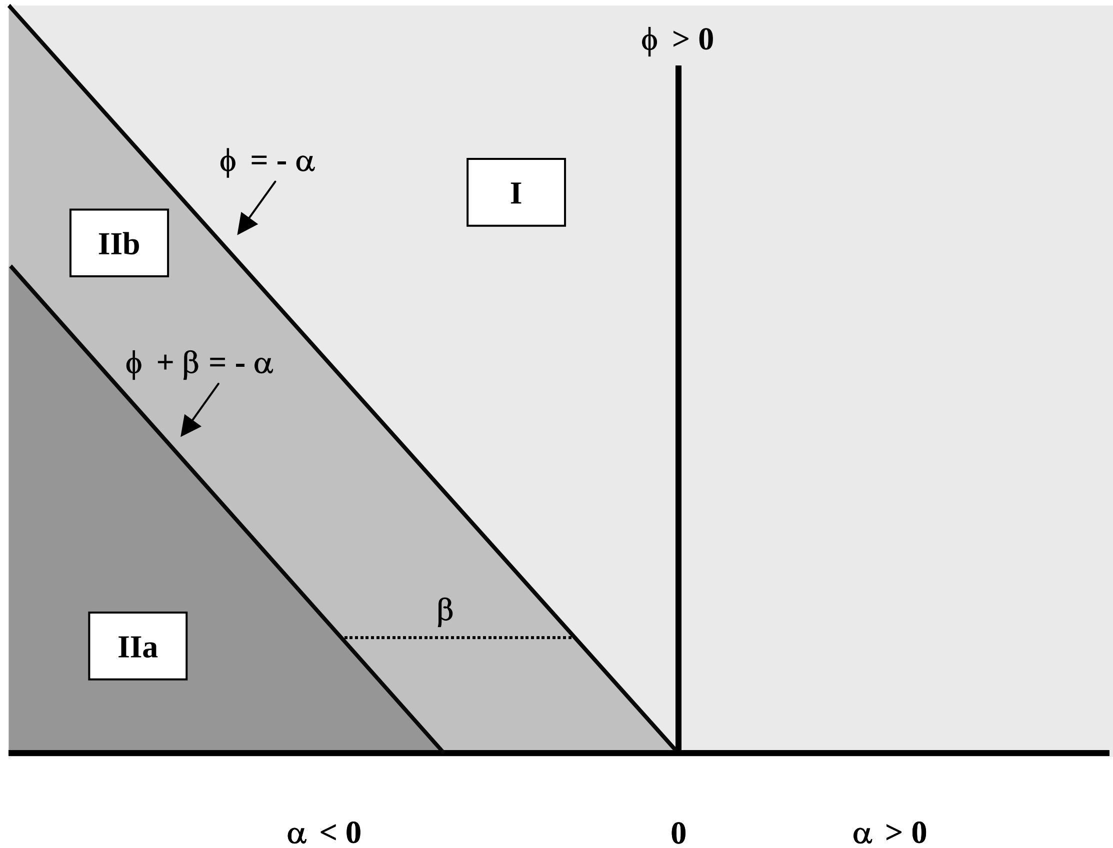

Figure 4

Region IIb Prisoners' Dilemma Game for α = -10, β = 8, and ϕ = 7

		Academic Teacher	
		CI Unit	NCI Unit
Vocational Education Teacher	CI Unit	$\Delta T_A = 5$ $\Delta T_V = 5$	$\Delta T_A = 8$ $\Delta T_V = -10$
	NCI Unit	$\Delta T_A = -10$ $\Delta T_V = 8$	$\Delta T_A = 0$ $\Delta T_V = 0$