An Innovative Model of Cooperation:  
A Strategy to Improve Students’ Academic Performance in Secondary Schools

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Abstract:  
In this paper, we apply Game Theory to discuss a very common problem generated by departmentalization in secondary schools – overloading students by various subject teachers in a class such as vigorous demand on students for attending supplementary lessons. The Nash Equilibrium and Pareto Optimal are analyzed in the case and a solution is suggested to reach the Pareto Optimal in both theoretical and practical bases. An innovative model of cooperation among teachers to improve students’ academic performance is then generated.  

Keywords: Prisoner Dilemma Game, Nash Equilibrium, Organization Change
1. Introduction

Holding frequent supplementary classes is never strange in secondary schools in Hong Kong. While different teachers of a class pay strong effort to hold supplementary classes after school and in holidays to “maximize” students’ academic results, the overall academic performance of students is often unsatisfactory. It is even worse that many teachers feel uncomfortable for their low efficiency in teaching – much input (supplementary lessons and revision tests) without remarkable effects. Therefore holding frequent supplementary lessons become a “lose-lose” game – both teachers and students find unsatisfactory. We may then ask a natural question: Why has this unsatisfactory “game” been iteratively played for over decades in many schools?

In this paper, we attempt to answer the above question by Game Theory. Game Theory is often applied to analyze social behaviour and has made great advances over the decades since it was first published by von Neumann and Morgenstern in *Theory of Games and Economic Behaviour* in 1944 (Leinfellner and Kohler, 1998). It has been applied in many fields such as economics, political science and international relations. Yet it is seldom used to analyze the situations in education. We hope that our attempt will bring new ideas to school leaders. After analyzing our current situation, we point out a possible solution, in which organization (school) change will be involved. Over the past decades, organization theories have been well-developed and organization change has been widely discussed in many texts; see for instance Cummy and Worley (2001), Mastenbroek (1987) and Burke (2002). Although some traditional theories have been adapted to be used in education, see for instance Owens (2004), we attempt to narrow down some advanced theories to solve our problem. In particular, we pay attention to the revolutionary change and evolutionary change.

The outline of the paper is as follows. We give a review on the well-know Prisoner Dilemma Game in Section 2. We then discuss the negative effect of over-drilling students by various teachers of the same class in Section 3. A simplified example and a theoretical analysis will be included. Our solution to the problem will be suggested in Section 4. Finally, concluding remarks will be presented in Section 5.
2. Prisoner Dilemma Game

Prisoner Dilemma Game, invented by A. W. Tucker, is one of the most influential games in Game Theory. The details of the game can be found in many literatures; see for instance Dixit and Skeath (2004), Rapoport (1974) and Watson (2002). A common version of the game is stated below:

Two burglars, A and B, are captured near the scene of a burglary. The police can at least make them a charge of illegal carrying of pistols, but does not have enough evidence to make them a charge of burglary. The police then separately cross-examine A and B. Each has to choose whether or not to confess and implicate the other. If both of them do not confess, then they will both serve their term of imprisonment for two years on a charge of carrying pistols. If each confesses and implicates the other, both will go to prison for 5 years. However, if one burglar confesses and implicates the other, and the other burglar does not confess, the one who has collaborated with the police will be reduced his term of imprisonment to one year, while the other burglar will go to prison for 10 years.


In this case, both A and B have two choices: confess or do not confess. The penalties are the sentences served. Their penalties can be summarized in the following table:

<table>
<thead>
<tr>
<th></th>
<th>Confess</th>
<th>Not Confess</th>
</tr>
</thead>
<tbody>
<tr>
<td>Confess</td>
<td>5_A, 5_B</td>
<td>1_A, 10_B</td>
</tr>
<tr>
<td>Not Confess</td>
<td>10_A, 1_B</td>
<td>2_A, 2_B</td>
</tr>
</tbody>
</table>

Table 1

In Table 1, the numbers in the boxes indicate the prison terms under the only four possible conditions and the sub-indices represent A and B. For example, if A confesses and implicates B and B does not confess, then A and B will have the prison terms of 1 year and 10 years respectively as indicated in the upper right hand corner of the table.

If A wants to minimize his prison term, he should think in this way: “If B confesses, then I have two choices (confess or do not confess). If I confess, then my prison term is 5 years; if I do not confess, then my prison term is 10
years! Therefore it is obvious that I should confess. On the other hand, if \( B \) does not confess, then I still have two choices (confess or do not confess). If I confess, then my prison term is only 1 year. If I do not confess, my prison term is 2 years. To minimize my prison term, I should confess. All in all, I should confess regardless of \( B \) does or not.” Obviously, if \( B \) also wants to minimize his prison term, he would think in the same way as \( A \) and he would also confess. Finally, both \( A \) and \( B \) will go to prison for 5 years. From the table, we can see that their choice is definitely not “optimal” (as their prison term is only two years if they both do not confess).

This story tells us that a “rational choice” may not be “optimal”. It illustrates the clash between individual and group interests; see Watson (2002). If everyone only fight for his/her own interest, we may have a “lose-lose” result. In the following section, we will apply this analogy to analyze the problems of over-loading students by various teachers of a class in secondary schools.

3. A Common Problem Affecting Students’ Academic Performance

In this section, we discuss a common problem which affects students’ academic performance in many secondary schools. Let us begin with a typical example.

3.1 A Simplified Example

Every year teachers who teach Secondary Seven students would pay strong effort in “helping” students to prepare Hong Kong Advanced Level Examination (HKALE). Many teachers hold very frequent supplementary lessons and give a huge amount of compulsory exercises and tests to their students. A typical student studies five subjects in Secondary Seven. The total amount of supplementary lessons, exercises and tests often exceed the acceptable limit of the students. To clarify this problem, we first simplify the case as follows. Suppose that a student only studies two A-Level subjects, say Physics and Chemistry. Also, we assume that if the student gets “C” or above in a subject and gets a pass grade in another subject, the universities will give her an offer to study the subject that the student getting C. We further assume that if the teacher drills the student, the student will get a good grade, say B, in the exam. If the Physics teacher does not drill the student and the Chemistry teacher does so, then
the student will get a bad grade in Physics, say F, and will get B in Chemistry. Without loss of generality, the converse is assumed to be true. Finally, if both teachers do not drill the student, the student will get C in one subject and E in another. (The student would make afford to get a pass grade in both subjects to fulfill the minimum entrance requirement of universities.) Then the whole case can be analogized by Prisoner Dilemma Game. The table below shows the expected results of the student under the four possible situations.

<table>
<thead>
<tr>
<th>Physics Teacher</th>
<th>Chemistry Teacher</th>
</tr>
</thead>
<tbody>
<tr>
<td>Over-drill the student</td>
<td>Over-drill the student</td>
</tr>
<tr>
<td>Does not over-drill the student</td>
<td>F&lt;sub&gt;phy&lt;/sub&gt;, B&lt;sub&gt;chem&lt;/sub&gt;</td>
</tr>
</tbody>
</table>

Table 2

If the Physics teacher wants to maximize the student’s result in his own subject, he would think in this way: “If the Chemistry teacher drills the student, then there will be two choices for me. If I do not drill the student, she will get F in Physics; if I drill her, she will get D in Physics. On the other hand, if the Chemistry teacher does not drill the student, then there will also be two choices for me. If I do not drill the student, she will get C or E in Physics; if I drill her, she will get B in Physics. Therefore in both cases, I should drill the student in order to maximize the student’s result in my subject.” We can expect that the Chemistry teacher would think in the same way. Hence both teachers would choose their “rational choice”: over-drill the student! The student finally gets D in both Physics and Chemistry. The Nash equilibrium is attained. It is obvious that this is not the global optimal (Pareto optimal) point as the student may not have offer in both Physics and Chemistry in universities.

3.2 Theoretical Analysis on the “Over-Drilling” Phenomenon

Although the case in Section 3.1 is over-simplified, the argument is similar for the case of involving more than two subjects. In fact, this
“drilling phenomenon” occurs in many schools. In many cases, each teacher often regards her own subject as the most important one and hence wants her students to spend most of their time to study the subject. When different teachers simultaneously drill the students of the same class, the students would be over-loaded.

There are two kinds of “sequela”. Firstly, different teachers attempt to occupy students’ time outside the boundary of formal timetable. If the school does not have any coordination work, then the students will go to attend the supplementary lessons on “first-come-first-served” basis. Alternatively, students would attend extra lessons taught by teachers having “stronger position power” in the school. Secondly, some school tries to make coordination on supplementary lessons. According to the “principle of fairness”, each teacher is assigned equal amount of extra time to hold supplementary lessons for a class. In both cases, students cannot concentrate on the subjects according to their own interest and ability. The case is even worse for weak students, as they are not strong enough to fulfill all the requirements set by their teachers. As most of teachers’ requirements are compulsory, the students’ study time is almost equally shared by their teachers. Hence they could not get satisfactory results.

It seems ironic that teachers of the same class do not communicate with each other, as assumed in the Prisoner Dilemma Game. There are at least two possible reasons to explain this ironic phenomenon. The first one is the direct consequence of departmentalization in secondary schools. Teachers of different subjects would have poor communication. Each subject panels would hold many meetings to discuss strategies to improve students’ performance in their own subjects. While we may have hundreds of meetings held by different subject panels and functional groups in a school within an academic year, it is not common to hold a meeting involving teachers of different subjects of the same class to discuss the strategy to optimize students’ academic results. Another reason is more critical. As students’ performance in the two public examinations (Hong Kong Advanced Level Examination and Hong Kong Certificate of Education Examination) is often regarded as an indicator of teachers’ teaching effectiveness, many teachers would pay strong effort to drill their students. Thus even if they know that the whole drilling process is not the best for their students, they dare not stop holding supplementary lessons.
The question borne in mind is: “All other subject teachers hold supplementary lessons for this class. If I do not hold enough supplementary lessons, how would the students perform in my subject?” This psychological fear is coherent with that in Prisoner Dilemma Game.

The over-drilling process generates a “snowball effect”. When all teachers fall in this “$n$-person Prisoner Dilemma Game” in a school, no one dare stop this game. As all teachers argue that the drilling action is good for students and can help students get better results, they never stop themselves. It is even very difficult, if not impossible, for school principals to stop this snowball effect, as no one can be publicly accountable for the unexpected (poor) results if she asks to stop drilling the students.

4. A Possible Solution

In this section, we try to provide a solution to solve the problem described in Section 3. Let us begin by roughly classifying students into two types: highly-motivated students and students with low motivation. In the following, we first provide solution for the first type. The solution for the latter type will follow. Practical implementation strategies will finally be presented.

**Students with High Learning Motivation**

Let us explain our idea by the “buffet” analogy. When customers with good appetite enter a restaurant with buffet dinner, what do they want? They want the restaurant to provide many different types of foods and the amount of each type of food should be large enough. In addition, the quality of the food should be good. If the restaurant can satisfy all these conditions, each customer would choose her own food according to her own need. Eventually all customers would be satisfied. Now let us think in this way. If the restaurant provide many types of good quality foods and the amount is enough, but it regulates that all customers should take all foods. Will the customers still enter into this restaurant with compulsory regulations in this liberal society?

There is a parallel in the school context. It is unnecessary for teachers to *drill* highly motivated students. Instead the teachers should provide *services* to them. Teachers should provide many *quality* exercises in
different levels to (motivated) students, but the students have their right to choose to do some parts of the exercises. Teachers should also regard giving tests as providing services to students. Each student has her own desire. For example, each student may have a target subject to study in universities. Thus it is normal and reasonable for her to pay more effort in the relevant subject in A-Level studies. She may do well in some tests and have (relatively) poor performance in some others. As long as the student is paying effort to get an offer from the universities, we should respect her own choices. Even if she cannot enter the universities finally, she should bear her own consequence. To conclude, each teacher should help their students running in their right directions, but not getting good results in a particular subject, regardless of the subject that the teacher teaches the students. We are finding the Pareto Optimal in the point of view of the overall result of the students, but not the maximum gain in the point of view of a particular teacher.

Students with Low Learning Motivation

It seems that the solution in Section 4.1 is ideal but unrealistic, as most teachers face students with low learning motivation every day. However the “buffet model” can be modified to the “half-buffet model” to cope with this kind of students. Let us explain our idea by a practical example. Suppose that a Secondary Five class has to study seven subjects. If seven teachers hold supplementary lessons in their final stage of study before HKCEE, then the students’ study time will be “equally shared” by the teachers as described in Section 3. On the other hand, if the teachers do not hold any compulsory supplementary lessons and let the students attend the supplementary classes according to their needs, then students with low learning motivation may skip all supplementary lessons. Thus an intermediate approach is to ask students to choose at least three, say, subjects to be their focus. However, different students may have different combinations. Each student should have her own focus. Thus seven teachers still hold seven sets of supplementary lessons, but students can choose their own combinations. (For example, Student A chooses to attend supplementary lessons of Physics, Chemistry and Chinese Language; while Student B may attend supplementary lessons of Physics, Mathematics and English Language.) This strategy is to force students, especially weak students, to concentrate on some subjects. At the same time, they can be
free from “eating the whole set of dinner”.

**School Change**

As most schools are restricted by the “natural departmentalization” structure, it must bring changes to the whole school if “buffet model” is applied. However, this creates a great challenge to school leaders. As change represents abandoning the past in pursuit of an uncertain future (Reeves, 2002), school leaders should create readiness for change (Cummings and Worley, 2001, p.156) in order to reduce the resistance to change in the schools. To do this, school leaders not only explain the “calamity” of the present situation (such as holding frequent supplementary lessons) to the teachers, but also strengthen the interdependency among units (departments); see Mastenbroek (1987, p.31). School leaders must shift emphasis on subject-based results to class-based results and student-based results. Under this condition, teachers of the same class would be motivated to hold meetings to discuss strategies to optimize the academic result of each student in the class.

In many schools, the function of Class Teachers becomes routine as the schools become stable. Class Teachers would take up the clerical duties such as taking attendance, collecting parents’ reply slips, … etc. In better case, Class Teachers are also responsible to the disciplinary problems of their students. However, it is not common for Class Teachers to be the academic leaders of their students. If Class Teachers accept this role, it is natural that they should be the person-in-charge of the meetings described above for their own classes. In fact, if Class Teachers could regard themselves as “students’ parents inside the school”, most problems can be solved.

If students’ academic performance is already not acceptable, then a revolutionary change may be necessary. Teachers may have already been motivated to change by the intolerable results. On the other hand, if the apparent result is good or acceptable, then an evolutionary changing approach would be more appropriate. We may use one class to be the testing point. Once teachers of the class are willing to apply the buffet model or the half-buffet model, their success will become a catalyst for other teachers to make changes.
5. Concluding Remarks

It is not common for educationalists to apply Game Theory to analyze the special culture of secondary schools in Hong Kong. We hope that our attempt to manifest the problem by Prisoner Dilemma Game can draw attentions of school leaders.

While we understand that teachers who over-drill students are “irrational” as the burglars in Prisoner Dilemma Game, no one can stop the snowball effect in a school. We suggest applying “buffet model” and “half-buffet model” to highly motivated students and students with low motivation respectively. In fact, this idea can be further extended to cope with students of different levels. In general, as students grow up from Secondary One to Secondary Seven, the “proportion” of optional work should be increased accordingly. For example, there may be only ten percent of assignments which can be classified as optional work for Secondary One students, but most assignments can be regarded as optional work for Secondary Seven students. If the students are not (academically) strong enough, this buffet model can optimize their academic results under the assumption that they are self-motivated to learn.

Another important aspect is how the school leaders perceive “success”. At present, there may be still many principals fall in the trap of departmentalization by holding teachers’ accountability in terms of departmental performance. The “objective” indicators, including HKCEE results, HKALE results and value-addedness information, are then presented according to subjects. This culture enhances teachers’ subject status and eventually they perceive departmental success as their success. Under this condition, optimizing the overall result of individual students is not noticeable.

All in all, we hope that school principals, middle managers and subject teachers can shift their paradigm from departmentalization to the real benefits of individual students. Then teachers who teach the same class would have deep cooperation to optimize each student’s academic performance rather than maximizing results of their own subjects. We hope that this innovative model of cooperation among teachers can bring quality education to our students in the new era.
References


