An Analytic Approach to the Choice between Content and Method in Teacher Education

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In this paper methods frequently used in economic theory are applied to the analysis of the optimal distribution of the time available for teacher education between teaching/learning "content", i.e., what to teach and "method", i.e., how to teach. The results obtained do not provide a simple formula to specify that distribution. However, they provide a framework for the analysis of the problem that is likely to be useful for the administrators of institutions educating teachers, and, also, it indicates the types of statistical information that is likely to be most useful.

Key words: mathematical modeling; educational theory; educational policy

Introduction

The identification of the criteria that should be used to distribute the time available for the education of prospective teachers between courses dealing with "content", i.e., what to teach and "method", i.e., how to motivate students to learn that content, has been and is one of the main concerns of the administrators of institutions of teacher education. Evidence of this is

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provided, for example, by Cruickshank and Cruz (1989) and by Leavitt (1991). The former, referring to the U.S., indicate that in the past 50 years more than 25 reports have addressed the problem to be studied here. As examples of what Cruickshank and Cruz (1989) likely had in mind, it is useful to mention the study by Hodenfield and Stinnett (1961) in which they report the proceedings and results of "three great national conferences aimed at getting the warring segments of American education to sit down together and talk sense about how our teachers should be prepared"(p.ix). These authors indicate that the key question addressed by the conferences of the National Commission on Teacher Education and Professional Standards held in Bowling Green in 1958, Kansas City in 1959 and San Diego in 1960 was "do teachers spend too much time learning what to teach, and not enough time learning how to teach?". For further confirmation of the statements of Cruickshank and Cruz (1989) it is useful to refer to the historical survey of American thought prepared by Borrowman (1952), who indicates that the problem considered here has been a subject of debate since the earliest days of systematic teacher education.

Leavitt (1991 and 1992) summarizes studies made in 21 countries. He indicates that "(T)he world's most prevalent issue is teacher education's uneasy relationship with the university and the school system...teacher educators must find the balance between discipline oriented subject matter and practical professional preparation..."(Leavitt, 1991, p.323). Katz and Raths (1990), reviewing studies for 12 countries, provide evidence of the diversity of approaches that are used for research on teacher education and of the paucity of results obtained, despite the substantial effort that has been made.

The references presented above suggest that, despite the long history of the problem, a definitive solution is not yet available, nor is it likely to be obtained in the near future. This paper does not pretend to provide the answer. Its objective is to call attention to the possibility of using the methods of economics to analyze the problem and to the contribution that this approach can make.

Economics is usually defined in one of the following two closely re-

lated ways. In the first definition, emphasis is on the rational behavior of economic actors such as consumers and managers, while in the second, attention is paid to optimal choice among available alternatives. These two definitions are related because an individual is assumed to behave rationally if he/she selects optimally from among the available alternatives.

Selection of the optimal distribution of time between the teaching/learning of content and of method can be seen as a typical economic problem. All that is needed is to adapt standard methods of economic theory to the analysis of a specific problem. However, it is necessary first to make appropriate use of the knowledge that practicing teachers, their instructors and the administrators of educational institutions have accumulated on the topic.

Since this paper is written by an economist, it may not give sufficient attention to the points of view of education professionals or of their students. If so, it may become a first statement in an interesting dialog that will be beneficial to both economists and education professionals.

Operational Specification of the Problem of Allocating Time to "Content" and "Method" in Teacher Education

No attempt is made in this section to analyze the problem of choice between "content" and "method" in teacher education in its full generality. The main reason for this is that preliminary analyses showed that no interesting results were obtained. The presentation below is limited to a somewhat simplified analysis of the problem.

The point of departure is the assumption that the achievement of the students taught by a teacher depends upon the teacher's knowledge of the subject matter and the method used for teaching it. This relationship is a particular case of the production functions of education or of achievement frequently used by economists. A more detailed analysis of these functions is presented, for instance, by Correa (1995).

In the presentation below it is assumed that the relationship just mentioned has the form of a constant elasticity of substitution (CES) production function, i.e.,

$$a = \alpha[\beta_* c^{-\rho} + (1-\beta)_* m^{-\rho}]^{-1/\rho} \tag{1}$$

where

a = average student achievement

c = index of the teacher's knowledge of the subject matter

m = index of the teacher's command of the method that should be used to teach the subject matter

α, β, ρ parameters

This function formalizes the idea that different levels of achievement are obtained by students taught by teachers with different levels of preparation in the subject matter they teach and in teaching methods. This relationship is characterized by the values of the parameters and α, β and ρ

The constancy of the parameter r is the reason why the function in (1) is called the constant elasticity of substitution (CES) function. Its different values indicate the different combinations of c and m needed to generate student achievement. More concretely,

1. For ρ approaching infinity, the function in (1) specifies that fixed proportions of content and methods should be combined in the educational process. If this is not the case, achievement is determined by the more scarce input. The supply of the other input in excess of the required proportion is wasted.

2. When ρ is equal to 0, both content and method are needed for student achievement, but regardless of the quantity of one, increments in the other will increase student achievement.

3. When ρ approaches -1, the function (1) specifies that either content or method are sufficient for student achievement. This type of function seems to be applied in university education where professors usually do not have any formal preparation in teaching methods.

While ρ deals with the combinations of c and m required for student achievement, β refers to the importance of each of these 2 inputs by themselves. Specifically, the importance of the contribution of the teacher's knowledge increases with the value of β, while that of his/her command of

method decreases. If $\beta = 0$, the minimum value that this parameter can have, a teacher's preparation in method alone is sufficient for student achievement. On the other hand, if $\beta = 1$, the maximum value that the parameter can have, teachers need preparation only in content.

The parameter α has a minor role in the CES function in (1), and it does not influence the final results of the analysis to be presented below. It simply modifies the values of the the rest of the function in (1) to adapt them to the generally arbitrary scales used to evaluate student achievement. Specifically, the same average achievement of the same group of students could be evaluated on a scale ranging from 0 to 10, or on another ranging from 0 to 100. This would not depend on the contribution of c and m to that achievement, and would not be reflected in the values of β or ρ. However, the value of α would be larger if the second, rather than the first, scale is used.

The next step of the analysis is to determine how teachers obtain their skills in content and method. For this, the influence of the time spent educating prospective teachers in content and method on their command of these two topics must be considered. This is done here using the extremely elementary functions in (2) and (3) below.

$$c = g*t_1 \tag{2}$$

and

$$m = h*t_2 \tag{3}$$

where

t_i = time used in teaching/learning content for i = 1 and method for i = 2, and g and h are parameters reflecting the productivity of the time used in the two activities.

The functions in (2) and (3) simply indicate that a teacher's command of either content or method is proportional to the time spent on these topics while he/she was a student. The parameters g and h reflect the productivity of teaching-learning time on the achievement of prospective teachers in these

2 topics.

Finally, it is recognized that the time available for the education of prospective teachers is limited. The constraint in (4) states that the sum of the time assigned to prepare prospective teachers in what to teach, i.e., t_1, plus that assigned to prepare them in how to teach, i.e., t_2, should equal the total time available, that is,

$$t_1 + t_2 = t \tag{4}$$

where

t = total time available per student in teacher education.

Functions (1) to (4) operationalize the problem of the distribution of time between content and method in teacher education. Specifically, function (4) emphasizes the obvious point that increments in the time assigned to teach content to future teachers reduce the time available to teach them method, and vice-versa. However, an increment in time assigned to content and the corresponding reduction to that assigned to method may or may not increase achievement, depending on the distribution of time before the changes were introduced and the values of the parameters in functions (1) to (4). This fact is overlooked in analyses that, while recognizing that teachers should be prepared in both content and method, do not specify the amount of time that should be assigned to these 2 topics in teacher education programs.

Optimal Allocation of Time between Content and Method in Teacher Education

The main contribution of the formalization of the problem in functions (1) to (4) is that it makes it possible to use standard optimization methods to determine the amount of time that should be assigned to prepare prospective teachers in content and in method in order to maximize the achievement of the students that they will teach during their professional lives. This is equivalent to the problem of maximizing achievement in (1), subject to the constraints in equations (2) to (4). The solution of this problem is presented below.

As a first step in the process of solving the optimization problem presented above, equation (5) is derived from equations (2) to (4).

$$c/g + m/h = t \qquad (5)$$

With this, the problem reduces to the maximization of (1) subject to the constraint in (5). The Lagrange function of the problem, specified in (6), is used.

$$L = \alpha_*[\ \beta_* c^{-\rho} + (1-\beta)_* m^{-\rho}]^{-1/\rho} - \lambda_*(c/g + m/h - t) \qquad (6)$$

As shown, for instance, by Chiang (1984), only the first order conditions for the optimization must be specified, since the CES function in (1) is quasiconcave and the constraint in (5) is convex. From these conditions, equation (7) is derived.

$$\lambda = a_* g[\beta_* c^{-\rho} + (1-\beta)_* m^{-\rho}]^{-1/\rho-1} {}_* \beta_* c^{-\rho-1} = \alpha_* h_*[\beta_* c^{-\rho} + (1-\beta)_* m^{-\rho}]^{-1/\rho-1} {}_*(1-\beta)_* m^{-\rho-1} \quad (7)$$

Finally, the optimal values for c and m presented in (8) are obtained by solving the system of equations formed by the right side equality in (7) and the constraint in the function in (5).

$$optc = \frac{g_* h[g_* \beta]^{\sigma} {}_* t}{h_*(g_* \beta)^{\sigma} + g_*[h_*(1-\beta)]^{\sigma}}$$

and

$$optm = \frac{g_* h_*[h_*(1-\beta)]^{\sigma} {}_* t}{h_*(g_* \beta)^{\sigma} + g_*[h_*(1-\beta)]^{\sigma}} \qquad (8)$$

where

$\sigma = 1/(1+\rho)$ is the elasticity of substitution between c and m, and

optc and optm denote the values of c and m that maximize a.

The results in (8) for optc and optm clearly specify the optimal allocation of time between preparation in content and preparation in method. This allocation depends on the values of the parameters in the functions (1) to (3). At this point the analysis can proceed by either one of 2 alternative routes. First, the implications of the results for c and m in equations (8) can

be explored without assigning numerical values to the parameters of functions (1) to (3). This is called qualitative analysis of the optimization problem presented above, and is presented in Section (4) below. An alternative that has more practical utility is based on statistical evaluations of the parameters in functions (1) to (3). Observations on this approach are presented in Section (5).

Qualitative Analysis of the Optimal Choice between Content and Method in Teacher Education

The 3 extreme possibilities for the parameter r presented above will be considered in the qualitative analysis of the optimal values of c and m in (8).

First, consider the case in which r approaches infinity. As observed above, this means that there is no possibility of substitution between c and m, and, as a consequence, any excess of one over the other is wasted. These conditions are confirmed by the mathematical analysis showing that the optimal values of c and m are those given in the following equation (9):

$$optc = optm = g * h * t / (g + h) \tag{9}$$

Despite this, the optimal values of t_i, $i = 1, 2$, are

$$optt_1 = h * t / (g + h) \quad \text{and} \quad optt_2 = g * t / (g + h). \tag{10}$$

The expressions in (10) indicate that the time assigned to c and m should not be equal, even though optc = optm. Specifically, if the time assigned to, say, content is more productive than that assigned to method, i.e., if $g > h$, then $t_2 > t_1$, i.e., more time should be assigned to method. This implies that more time should be spent on the less efficient educational process. This can be justified by observing that, due to the impossibility of substitution between c and m, $a = \min(c, m)$, i.e., achievement is equal to the minimum of c and m. As a consequence, achievement is maximized if the time available for the education of teachers is assigned in such a way that the lower productivity of the time spent for method is compensated for by spending more time on it. This conclusion is, of course, reversed if it is assumed that

h > g.

The second case to be considered is when $\rho = 0$. Here the values for c and m that maximize a are those given in the following 2 expressions in (11):

$$\text{optc} = \beta * g * t \quad \text{and} \quad \text{optm} = (1-\beta) * h * t. \tag{11}$$

From the information in (11) it follows that the time assigned to c and m should be that indicated in (12).

$$\text{optt}_1 = \beta * t \quad \text{and} \quad \text{optt}_2 = (1-\beta) *)t. \tag{12}$$

The equations in (12) show that the amounts of time that should be assigned to c and m depend on the values of β and $1 - \beta$, i.e., on the influence of c and m on the achievement of the students as specified in the production function in (1). In the case under consideration, the productivity of the time used to educate prospective teachers in content and method, that is, on the parameters g and h of the functions (2) and (3), does not influence the time that should be used to teach these topics to prospective teachers.

The final possibility to be considered here occurs when c and m are perfect substitutes, i.e., when ρ approaches -1. In this case, if $g * \beta > h * (1-\beta)$, then $\text{optt}_1 = t$ and $\text{optt}_2 = 0$. This means that under the conditions assumed previously, all the time available for teacher education should be spent on their preparation in the content of the subjects they will teach, and none on their preparation in teaching methods. Naturally, the result just presented is reversed if it is assumed that $h * (1-\beta) > g * \beta$.

Observations on the Statistical Estimation of the Parameters of Functions (1) to (4)

The results in the previous section provide some insight into the influence of the parameters of functions (1) to (4) on the optimal distribution of time available for educating prospective teachers between content and method. However, they do not indicate what the optimal distribution of time should be for the education of prospective teachers of different subject matter, to students of different ages, abilities, educational backgrounds, etc. For

this reason, the results above are just one additional contribution to an extended discussion of the topic. For practical applications of the approach presented here, information on the actual values of the parameters of functions (1) to (4) for different educational settings are needed. This information can be obtained only through statistical analyses.

The first step in these analyses is the specification of the educational setting to be studied. This means that it should be determined that the parameters of equations (1) to (4) are going to be evaluated for institutions educating prospective teachers of, say, mathematics in elementary schools. A separate analysis would be needed for the education of prospective teachers of social studies, English, etc.

The next step is the specification of the data needed. In the case under consideration this includes data on student achievement, denoted with a, teachers' command of the subject matter they teach, denoted with c, and teaching method, denoted with m.

Indices of student achievement such as the scores in different types of tests are well known and frequently used in educational research. For this reason there is no need to analyze them in detail here.

The specification of indices for c and m is more controversial. Evidence of this is provided by the difficulties encountered in the attempts to evaluate teachers' competency reported, for instance, by Medley (1984). Part of the problem is that a clear specification of teaching method does not seem to be available. Studies on this topic, such as those by Cruickshank (1996, pp. 15-28) and Pearson (1989, pp. 130-142) emphasize the complexity of the concept. It includes not only the approaches that teachers should use to facilitate the retention and understanding of a subject, but also ways to motivate students of different abilities and backgrounds, to maintain discipline in the classroom, etc. In addition, Gimmestad and Hall (1995) report that since 1990 there is much more awareness of the complementarity of content and method for successful teaching.

The different elements mentioned above are conceptually integrated in what is called Pedagogic Content Knowledge (PCK), introduced by

Schulman (1986). Attempts to construct indicators of the level of PCK used by different teachers of mathematics, social sciences and English are reported by Carter (1990). These evaluations do not include separate measures of c and m.

Interpreting these studies from the point of view of the model in this paper, it can be said that PCK analysts are well aware of the complementarity between c and m in generating student achievement. This means that, experientially, they know that different values of the parameter r of the production function (1) bring about different levels of achievement. On the other hand, the approach they use does not generate estimates of r in actual cases. For this, separate data for c and m must be analyzed with appropriate statistical methods.

In view of the lack of indices for c and m, it is currently impossible to obtain estimates of the parameters g and h of the functions (2) and (3). An alternative is to measure c and m with the amount of time assigned to the education of prospective teachers in each of the 2 areas. This is equivalent to arbitrarily assuming that $g = h = 1$. Similar assumptions are frequently used in educational research. For instance, the level of education of a population or a labor force of a country is routinely measured using the average number of years that their members spent in attending educational institutions.

Once the specification of the indices of a, c and m has been completed it is possible to proceed to the collection of the data required to estimate the parameters of the production function (1). The actual approach to be used depends on whether the researcher is able to conduct controlled experiments.

Under conditions of experimental research, the data required are limited to students of comparable ages, abilities, educational and non-educational backgrounds, etc. taught by teachers of comparable abilities, education, experience, etc. These teachers would differ only in the amount of time that was assigned to their education in content and methods. Once these data are available, the values of the parameters a, b and r of production function (1) can be estimated with, say, standard non-linear regression analysis.

On the other hand, under conditions of non-experimental research, information about all the differences among the students and teachers is needed. This means, for instance, that data on the different levels of innate abilities of the students, their different backgrounds, etc. would have to be collected. It also implies that larger samples are needed.

The information on the different characteristics of students, teachers, classroom conditions, etc. is introduced in the statistical analyses together with that on the values of the a, c and m variables. With this, the influence of these differences on the values of the parameters of the production function in (1) can be, to some extent, controlled. The actual procedures are, again, standard statistical techniques.

The observations above show that, in principle, there are no major problems for the estimation of the parameters of the production function in (1). The cost of obtaining the information needed is likely to be the main obstacle. An additional complication is that there is no reason to believe that the same values of the parameters are valid for different subject matters, levels of education, types of students, etc. More specifically, the values of a, b and r for motivated high school students are likely to differ from those for non-motivated college students. This implies that, for actual use of the model presented here, the parameters of the production function in (1) must be estimated several times.

Once the estimates of the parameters of function (1) are obtained, the formulas in (8) for optc and optm can be used to specify the optimum distribution of time between content and method in the education of prospective teachers.

Conclusions

In this paper a typical educational problem is analyzed using elementary methods of mathematics and economics. The approach is relevant mainly because it clearly specifies the statistical studies that are needed to solve a long-lasting controversy among researchers and administrators in education.

On the other hand, and as usual in any scientific inquiry, the methods

and results presented here cannot be considered definitive. Some observations on possible improvements are presented below.

An issue not considered in the previous sections is that of the sequence in which content and method should be presented in the education of prospective teachers. Attention was paid only to the amount of time that should be assigned to each topic. This clearly simplifies the analysis of the problem. However, it is possible that the solution obtained would be modified if attention were paid to alternative ways in which the presentation of the 2 topics could be interrelated. For instance, although content could be presented before method or vice-versa, they could also be presented simultaneously. It should be observed that methods are available to analyze this type of problem, but the educational theory required to deal with them is not known to the author of this paper.

There are several possibilities when a broader frame of reference is used. For instance, in the analysis presented here, no attention is paid to the fact that the educational achievement of the students depends not only upon the qualifications of their teachers, but also upon the students' active participation in the learning process. In other words, achievement depends not only on the qualification of the teachers, but also on the interaction between teachers and students.

Analytical methods for the study of teacher/student interaction are presented by Correa and Gruver (1987) and Correa (1997). However, these studies do not consider the teachers' command of content and method. The integration of analyses based on teacher/student interaction with those in which the background of teachers in content and method is considered would be an interesting topic for further research.

To conclude, it does not seem possible to treat appropriately in one paper even the narrowly-defined problem considered above. However, it is hoped that the approach used here will extend to teacher education the dialog that has been taking place between educational researchers and economists. This will encourage additional useful contributions to the two disciplines.

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