On Crossover Math Teachers and Certification

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Abstract

Presented here is a case for the development of an alternate certification program for crossover teachers: mathematics teachers not specifically trained in mathematics but who teach mathematics. The problem is one of guaranteeing that crossover teachers are subject matter competent; a notion that has heretofore been defined as holding an undergraduate degree in mathematics. But for various reasons, it is often impractical to require crossover teachers to obtain a BA degree, or its equivalent, in mathematics. The problem of certifying crossover teachers seems to be an international one; the proposed program might help alleviate it.

1. Background: Israel has a centralized educational system with a Ministry of Education that is charged with overseeing all aspects of the K-12 system. But the certification of teachers for K-12 is done in universities and colleges; where in effect the Ministry has entrusted them to develop programs that will produce competent teachers. For the most part, the universities are given the right to develop programs for the certification of high school teachers (grades 9-12), while the colleges are given the mandate to develop programs for the certification of elementary school teachers (grades K-8).

Each university develops its own certification program, but as it has turned out, there are tremendous similarities between the respective university programs with respect to their administrative structure, educational requirements, and underlying philosophies. For example, teacher education programs are usually in the university's department or school of education; they are generally staffed by part-time teachers who themselves are excellent high school teachers; they require their students to already have (or soon to be awarded) an academic degree in the discipline they will be teaching in the high school, and they are built on a mentor-apprentice model. This model has been in use for years and it works well for those students who come to us as freshman math majors. However the program does not work well for those who want to be certified mathematics teachers, but who do not have a first degree in mathematics.

There are two types of undergraduate degrees in mathematics offered by Israeli universities. The Humanities and Social Science Faculty offers the BA degree in mathematics, while the Science Faculty offers the BSc degree in mathematics. The difference between the two degrees is one of extent; roughly speaking the BA degree requires the student to take 56 points in mathematics, whereas the BSc degree requires the student to take 110 points in mathematics. The courses in the BA program are a subset of the required courses in the BSc program. BA degree students sit in the same classes as BSc degree students, but they do not take as many mathematics courses as the BSc students. (BA degree students have two majors, with the second major coming from the H&SS faculty; philosophy, economics, linguistics, and geography are popular choices for the second major.)

2.The Problem: Many high school mathematics teachers in the Israeli school system are not certified to teach mathematics. In fact, they are not certified to teach any subject, but they were hired by the local authorities to be teachers and many of them have been teaching for years. The numbers on this vary widely and are a function of geographic locale and socio-economic factors, but it has been estimated that as many as 30% of the full time mathematics teachers at the high school level are not certified. Generally these individuals work in the less desirable outlying areas where there is a shortage of teachers--and principals have little choice but to hire uncertified ones. These uncertified teachers often have a BSc degree in engineering, or in some sort of technical field, but they do not have a bachelor's degree in mathematics. They have studied some mathematics, but the courses they have taken did not have the orientation, depth, or breadth of the courses that are required of mathematics majors.

From a financial viewpoint alone, it very much behooves these uncertified teachers to become certified; security, prestige and self-image are of course other benefits of certification, but the main motivating factor is money. However the universities have put a stumbling block in their path to become certified. That stumbling block is that all students in the mathematics certification programs must have the equivalent of a BA in mathematics—and although the word "equivalent" is often interpreted very liberally—the bottom line is that it is nearly impossible for these practicing uncertified teachers, crossover teachers, to obtain the equivalent of a BA in mathematics.

The mathematics courses at my university for the BA degree are as follows:

Infinitesimal Calculus 1	6.0 points
Infinitesimal Calculus 2	5.0
Logic and Set Theory	5.0
Discrete Math	5.0
Algebra 1	5.0
Algebra 2	5.0
ODE	4.5
Complex Functions	3.5
Fourier Analysis	4.0
Algebra 3	4.0
Probability	4.5
Computer Science	5.0

Since many of the uncertified teachers have degrees in technical subjects, they have usually taken two courses in calculus, a course in matrices, ODE, CS and probability. They receive credit for these courses as being equivalent to the ones in the above list, even though in reality they usually are not equivalent (because of their depth, level, and orientation). But this still leaves them having to take about six courses to fill out the equivalent of a BA program—and upon hearing this they complain bitterly, that it is not fair.

3. Their Argument: There are several facets to their complaint.

a) They are practicing teachers and as such they are adults often with family obligations--it is impossible for them to take off from their classes twice a week to attend university lectures that are often given at the same hours that they themselves are scheduled to teach.
b) Being required to take six advanced level courses is completely ridiculous—particularly in that the courses are at levels of abstraction that are meaningless to what they do day-in and day-out.
c) University courses are terribly expensive—the equivalent of thousands of dollars must be spent before they can be certified to teach. But to be frank, they haven't the background to succeed in the advanced-level courses being required of them, and they know it. Algebra 1 is a prerequisite for Algebra 2; although they receive an exemption from Algebra 1 for the course in matrices, they do not have the background to succeed in Algebra 2, which is a continuation of the linear spaces course Algebra 1. And so it goes with the other exemptions they receive. In short, the exemptions become meaningless.

And why don't these individuals simply start a BA program in mathematics itself? Well, there are two reasons: 1) They are adults, often in their mid-30's and 40's, and it isn't feasible at this stage of life to start their university studies over again, and 2) in all likelihood, they wouldn't be accepted to the BA program because they wouldn't be able to meet the entrance requirements. Many of the crossover teachers have BSc degrees from Technical Colleges that are notorious for low academic standards.

There are two other facets of their complaint that are harder to ignore. One is that most of the crossover teachers belong to minority factions within Israeli society; often they are Bedouin or Arab, and most Israelis will agree that over the years, these factions have not been treated fairly by the government's policies in general, and by its educational policies in particular. The second factor that is hard to ignore is that teachers who often have a BA in mathematics were themselves only marginal students of mathematics. Perhaps 20 years ago they squeaked through some high-level math courses, but whatever knowledge they had then is not relevant for what they are doing today. The crossover teachers believe that on a day-to-day comparison, teachers who have a BA degree in mathematics are for the most part, doing no better of a job in the classroom than they are doing, but those math teachers are compensated at much higher level than they.

What the crossover teachers are asking for is an affirmative action program for themselves with respect to certification.

4. The Research: The crux of their argument is that it is not reasonable to require them to have the equivalent of a BA in mathematics. Intuitively their argument seems to be ridiculous, but with respect to the few studies that have been conducted in this area, research seems to be on their side!

The late Professor Edward Begle of the Stanford University was one of the architects of the new math movement in the United States. Towards the latter part of this movement he was in charge of a center at Stanford that researched various questions and issues about the teaching and learning of mathematics. One of the studies he initiated investigated the relationship between a teacher's knowledge of mathematics and student performance. He tested teachers of 9th grade algebra in two areas: their knowledge of algebraic structures and numeric concepts. He then built specific exams on these notions for their students, and he administered these tests at the start of the school year and again at the end of it. Begle took the mean score for each class on these notions at the start of the school year and subtracted it from the mean score of the class at the end of the school year. He called this difference *the effect of that particular teacher on his class with respect to algebraic concepts*. He employed a similar algorithm with respect to numeric concepts.

For each teacher Begle then built a vector listing that teachers' personal score of their knowledge of algebraic concepts, their personal score of their knowledge of numeric concepts, and their effect in the classroom for imparting to the students algebraic concepts and numeric concepts. This vector was written as follows:

$$(x_1, x_2, y_1, y_2.), \text{ where}$$

x_1= the teacher's personal score on the algebraic concept test
x_2 = the teacher's personal score on the numeric concept test
y_1 = the teacher's mean effect score in the classroom on algebraic concepts
y_2 = the teacher's mean effect score in the classroom on numeric concepts.

Begle then built a correlation matrix in which he looked at the statistical influence of x_1 on y_1, x_1 on y_2, x_2 on y_1, x_2 on y_2, x_1&x_2 on y_1, etc.

Begle found that there was no meaningfully significant correlation between a teacher's knowledge of subject matter and the performance of their students!

Begle concluded that of course there must be a threshold of minimal knowledge that a teacher must possess, but wherever that threshold is, the teachers in his study were far above it.

One of the problems with Begle's study was that the teachers who participated in it were all recent graduates of an NSF institute for teachers. They had been selected for this institute through a competitive procedure, and as such they were not representative of the average teacher in the field. So I decided to fix this glitch in Begle's design by administering his exams to everyday teachers from the field. I also expanded the number of independent and dependent variables being looked at by including teacher background variables such as the grades they received in specific undergraduate courses, the types of courses they took in their undergraduate programs, the number of years of experience they had in the classroom, and other similar variables. I also administered a questionnaire to the teachers assessing their knowledge of basic logical syllogisms, (a topic that was very popular in those days.) However, Begle's overall design was maintained, where a vector was assigned to each teacher in the study, in which the vector's dependent components were assessments of that particular teacher's effect in the classroom. The only meaningfully significant correlation obtained with respect to student achievement dealt with the number of courses a teacher had taken; not with the grades that teacher had earned in those courses! Begle's conclusion had repeated itself; but this time it had repeated itself on the hoi polloi of teachers. Although there is obviously a lower bound of knowledge teachers must know in order to teach, the teachers in this study were far above this lower bound. **The final conclusion was that obviously something is causing the variance in students' scores, but that it would behoove us (those involved with teacher education), to search for the roots of this variance in variables other than teacher knowledge of subject matter.**

This study generated quite a bit of discussion within the mathematics education community at that time, with individuals who had participated in the original Begle study writing to me endorsing the plea that we should start looking at affective variables in the classroom. But with respect to guarding the gates as to who can become certified to teach mathematics, nothing changed.

5. Two Models For Imparting Subject Matter Knowledge to Teachers: When one is in a forest there are two ways to get the lay of the land. One way is to go from tree-to-tree, taking one's time to seriously investigate the nooks and crooks surrounding each tree; doing this in a very careful and serious way will make one an expert in knowing the ins and outs of that forest. A second way is to climb the highest tree and look down. The topography of the forest floor will reveal itself. These two methods of learning can be used by analogy to describe the training of mathematics teachers.

One way to train mathematics teachers is to take them in a very systematic way through the textbooks from which they are going to teach. By doing this very carefully and systematically, they will become experts of those books—and since there is a tremendous amount of overlap of the content in textbooks that students need to master, regardless of the programs presenting the content, the teachers will be well trained for the classroom. A second method to train mathematics teachers is to take them through high-level courses in which they study the abstractions and generalizations of the topics they will teach on a day-to-day basis. Most undergraduate programs in mathematics are built in this way—where the knowledge one needs is presented in the abstract, and with the applications hopefully being sorted out by the teachers themselves. E.g., the real numbers form a field; the notion of addition can be considered as being a well-defined closed binary operation in which the real number field is mapped into itself, $(+:R \rightarrow R)$. The underlying assumption of this method of teaching is that bits of knowledge like this will make one more knowledgeable and effective in the classroom, particularly when teaching addition to students and that this knowledge will be drawn upon by the teacher in some meaningfully way. Begle put a hole into such assumptions, but of course, no one has listened to him.

As an aside it is instructive to recall that this method of obtaining deeper insights into content matter was one of the underlying tenets for having children calculate in different number bases. But this too did not help students develop a deep understanding of base 10 calculations.

6. Affirmative Action: A Proposed Framework: It seems only proper that an alternative to the standard requirement that all certified math teachers have a BA degree (or its equivalent) in mathematics be available to crossover teachers; mathematics teachers who were trained in some other discipline. The following is proposed as a framework for such a program.

- Alternative certification can be commenced in the second year of teaching. It will only be open to teachers who have been teaching on a full time basis in the same school for at least two years.
- All teachers in the program must pass a written content exam based on the material in the textbooks from which they teach. The exam will be constructed and evaluated by those overseeing the university's mathematics teacher certification program. A teacher may take this examination only twice in a calendar year. If they fail the exam on the first testing, they will have the option to participate in a year course that will take them systematically through all aspects the school curriculum; they will be expected to be able to solve all of the problems in each textbook used in the curriculum.
- Each teacher in the program will be paired with a certified math teacher in a different school who is teaching the same courses as the crossover teacher. E.g., if the crossover teacher is teaching two classes of 9^{th} grade algebra and two of 10^{th} grade geometry, then each class will be paired with those of a certified teacher in a different school. Every effort will be made to match the classes on socio-economic variables.
- The students in both the crossover teacher's class and those in the classroom to which it has been paired, will be tested at the start of the school year and also at the end of it. The test at the start of the year is to ensure that the background of the two groups of students is initially the same. The testing at the end of the school year is to see if the classes have remained equivalent to one another. A minimum of 6 classes must compared; this might be done over one year or over two years.
- If the students of the crossover teacher have done as well as those of the certified teacher in at least 4 of the 6 classes being compared, then the crossover teacher will receive certification and be entitled to all benefits thereof. *Doing as well as* … can be defined as having no statistically significant differences in the end of year mean scores on the exams.
- If the students of the crossover teacher have not done as well as these of the certified teacher in three or more of the classes being compared, then that crossover teacher will not receive certification. Moreover, that teacher will not be allowed to reapply for certification for two calendar years—but when the teacher does reapply, the alternative certification program must be started anew from the beginning, with the teacher taking the subject matter test again.

7. Initial Reactions and Conclusion: It seems clear that something has to be done with respect to certifying crossover teachers. It also seems that holding them to the rigorous standard of having at the very least the equivalent of a BA degree in mathematics is not practical. The above program presents an alternative method for certification, but it is not recommended for everyone. The standard prerequisite of requiring an undergraduate degree in mathematics is preferred over the above route, which at this point is being suggested as an alternative route only for crossover teachers already in the field. Initial reactions to the rationale and to the underlying design of the program have been positive, but it has yet to be implemented, and colleagues believe that getting approval for its implementation will not come without major battles. I spoke about this problem at ICMI-10 in Copenhagen last summer and many colleagues from other countries voiced similar problems with their crossover teachers. But they too had no solution to the problem. Most in the mathematics community know the story surrounding the epitaph: In mathematics there is no royal road; everyone walks the same path. Perhaps with respect to the certification of crossover teachers, it is time for us to implement an alternative path.

Bibliography

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About t he Author

Ted Eisenberg is a professor in the department of mathematics and in the department of education at Ben-Gurion University where he has been on staff for more than 25 years. He is the Israeli representative to ICMI and the editor of the problem solving section of the journal School Science and Mathematics. Recent publications include: *On an Unknown Algorithm for Square Roots*, in IJMEST, 34(1), 2003, 153-158, and *On Concept Images and Square Roots*, in TMIA, 22(3), 2003, 113-122. Nonacademic interests are his family, reading, music, and playing tennis.