Toward Coordinating Mathematics and Science Teaching in High School

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We set the following hypothesis: Students in the sciences should be much more knowledgeable in the fundamental relationships and interdependences of mathematics and the several sciences. This knowledgeability should be cultivated through example and cross-reference to the point that mathematical rigor is applied with ease to scientific systems and mathematical techniques used instinctively in the solution of scientific problems.

At the college level, depth study of single sciences underscores these inter-relationships by the emphasis put upon inclusion of mathematics in specialized curricula and by the free use of mathematical processes in the development of topical material in the sciences. Rigorous standards appropriate to the mastery of the material can be maintained in college that tax the *control* of the pre-college teacher. This admitted dependence of science on mathematics by the scientists is not reciprocated by the mathematicians.

Pre-college depth study of a single subject is simulated through the copying of the college curricular organization of courses. Unfortunately, the worst features of inapplicability survive the translation. Separation of subject matter results in the pre-college student losing sight of the inter-dependencies of the two areas of knowledge. To him, mathematics is mathematics while science is science. There is need for better coordination in instruction of both subjects at the secondary level.

This paper is limited to consideration of the likelihood of attaining that increased coordination in terms of teacher characteristics that permit better person-to-person communication between teachers.

Five principal factors can be stated as the first hypothetical questions to be answered:

1. Do science teachers themselves have enough background in mathematics to be able to communicate freely with their colleague teachers of mathematics?

2. Do the mathematics teachers have comparable understanding of fundamental scientific principles, concepts, and applications to carry their end of a collaborative effort?

3. Is the total teaching experience of individual teachers sufficient to have encountered and overcome the more common teaching problems so as to render them effective in the proposed teamwork?

4. In this rapidly changing and ever-expanding body of knowledge, is training of these teachers recent enough to permit them to work with, rather than against, the trends in emerging curricular patterns?

5. Finally, is the continuity of service in a particular school or school system long enough to develop effective teamwork (not necessarily team teaching) between the mathematics and the science teachers?

DATA AVAILABLE

Because of the availability, teacher characteristics were taken from form 9C-24B application blanks for National Science Foundation institutes in Summer, 1961. The sample is extensive, rather than representative. The total number of records transcribed and coded for machine analysis was 1100 from three institutes of widely different character and appeal.

The principal factors have been implied in the statement of the hypothetical questions above. Subsidiary factors used for sub-sample comparisons are: type of teacher; geographical location; and type of school. Data on other possible factors are available but did not prove to be pertinent to this particular study.

ANALYSIS OF DATA

These definitions are used in the ensuing tabulations:

a. The "Real Math Teacher" is one whose scheduled assignments in 1960-61 included classes in algebra, geometry, or trigonometry; the schedule might include composite or general mathematics, but any teachers who had only those pseudo-academic subjects were omitted from the analysis;

b. The "Math-Science Teacher" had assignments that included algebra or geometry or trigonometry and at least one of the science classes: general science, biology, chemistry or physics;

c. The "Science Teacher" teaches no classes in mathematics. Teachers in each of the above classifications might have other subjects or responsibilities.

The Geographical comparisons set Oklahoma against (a) the adjacent states of Arkansas, Missouri, Kansas, and Texas and (b) the remaining, or "other" states (Table I). This permits comparison within and outside the southwest region.

Since only 33 (4.4%) of the sample taught in separate junior high schools, further comparison for this factor has not been included.

The data in Table I summarizes whether science teachers have studied enough mathematics to be able to communicate with their mathematics teacher colleagues. If calculus be taken as the key course for the science teacher's personal foundation, as recommended by the Cooperative Committee for the Preparation of Physics and Chemistry Teachers, it is obvious that only about one-quarter of the teachers in this sample have sufficient mathematics for this localized collaborative job. Earned credit for further study beyond calculus narrows this group to 15%. The fact that almost 30% have 13 or more hours preceding calculus indicates many science teachers received college credit for remedial course work that did not advance them to the level expected. Considering mathematics, Oklahoma science teachers do not show favorably in comparison with "Adjacent" or "Other States."

In the mathematics preparation of the math-science teachers shown in Table II, there is greater hope for curricular collaboration. Oklahoma teachers show favorably in hours of calculus but fall significantly short in post-calculus training which is being called for by the Mathematical Association of America to upgrade mathematics teachers. The math-science teachers hold a unique position when such teachers are carrying the total assignment in a small school.

Looking at the science backgrounds of these dual-area teachers, the data of Table III do not discriminate among the qualifications for the separate sciences. It should be surprising, though it could be disturbing, that these data show large proportions of teachers lacking study in one or more of the sciences needed for both the superficial presentation of general science as a breadth subject and for supporting the depth presentation of a specialized science such as biology, chemistry or physics. However, comparison of records with criteria such as the Cooperative Committee's recommendations constitutes another subject. Sufficient for this report is the basis of comparing with real math teachers and the functioning as interpreters between two broad areas of knowledge. In this latter function, the math-science teachers are by no means overtrained as a group, yet contain enough individuals (20-25%) who can serve as catalytic leaders or consultants between schools.

Using the Criterion of at least 7 hours in a subject as being sufficient for a foundation understanding, only 20 to 30% of the real math teachers have enough to qualify in each of the sciences (Table IV). The data do not show how many have this criterial number in two or three sciences. There is, then ,serious question whether the mathematics tachers understand science well enough to communicate effectively in the proposed line of collaboration. Geographically, Oklahoma compares most favorably in biology background but unfavorably in the two physical sciences where the applications of mathematics have a more extensive usage.

Overall, there is a decided minority in both groups of teachers (exclud-

TABLE I. MATHEMATICS BACKGROUNDS OF SCIENCE TEACHERS—Data in Percentage in Sub-Sample

Hours Credit	Pre-Calculus Credit				Calculus Credit			Post-Calculus Credit			
	0-6	7-12	13 & over	Number in Sub-sample	0-3	4-7	8 & over	0-3	4-6	7-9	10 & over
Oklahoma	45.1	25.4	29.6	71	80.3	7.1	12.7	90.2	2.8	2.8	4.2
Adajacent States	47.1	32.4	20.6	68	76.5	8.8	11.8	91.1	1.5	2.9	1.5
Other States	34.7	33.7	31.6	98	69.4	13.3	22.4	82.7	6.1	5.1	6.1
Total Sample	41.2	30.6	27.7	238	74.5	10.1	16.4	86.1	3.8	3.8	4.2

TABLE II. MATHEMATICS BACKGROUNDS OF MATH-SCIENCE TEACHERS—Data in Percentage in Sub-Sample

Hours Credit	Pre-Calculus Credit				Calculus Credit			Post-Calculus Credit			
	0-6	7-12	13 & over	Number in Sub-sample	0-3	4-7	8 & over	0-3	4-6	7-9	10 & over
Oklahoma	12.8	6.4	80.8	47	34.1	19.2	46.8	61.7	12.8	10.6	14.9
Adjacent States	7.3	39.0	53.6	41	46.3	34.2	19.5	51.2	4.9	19.5	24.4
Other States	21.4	34.9	42.8	89	38.2	23.6	40.5	64.0	12.4	7.9	15.8
Total Sample	16.3	29.1	57.0	177	40.2	25.6	38.4	62.3	11.1	11.6	18.0

TABLE III. SCIENCE BACKGROUNDS OF MATH-SCIENCE TEACHERS—Data in Percentage in Sub-Sample

Field	Biology			Chemistry			Physics		
Hours	0-6	7-9	10 & over	0-6	7-9	10 & over	0-6	7-9	10 & over
Oklahoma	38.3	8.5	53.2	40.4	36.2	23.4	36.2	40.4	25.5
Adjacent States	41.0	14.6	43.8	31.7	56.1	12.2	36.5	43.8	19.5
Other States	42.7	13.5	43.8	40.5	34.8	24.7	55.1	21.4	25.8
Total Sample	41.0	12.4	46.2	38.2	39.8	21.4	45.4	31.6	24.3

TABLE IV. SCIENCE BACKGROUNDS OF MATHEMATICS TEACHERS—Data in Percentage in Sub-Sample

Field	Biology			Chemistry			Physics		
Hours	0-6	7-9	10 & over	0-6	7-9	10 & over	0-6	7-9	10 & over
Oklahoma	63.7	22.1	14.3	71.6	24.7	3.9	71.5	18.2	10.4
Adjacent States	46.9	15.6	37.3	74.9	20.3	4.7	73.3	20.3	6.2
Other States	56.2	16.9	26.9	60.3	29.7	10.9	52.6	19.7	21.1
Total Sample	56.1	17.8	26.0	65.4	26.9	8.2	62.9	20.4	17.0

ing the math-science in-between groups) that probably deters action and effective development of a collaborative program.

The next factor concerns teaching experience as summarized in Table V. Teachers with 1 to 3 years experience must be considered inexperienced, with 4-6 years as having limited experience barely enough to collaborate effectively. The teachers with 7 to 12 years experience are largely post-war trained and have enough seasoning to continue handling their subjects and still embark on significant modifications of curriculum. It is probably this sub-group that has the personal attributes needed in a collaborative effort. This group numbers around 25%. The additional 20-25% of the teachers with more extensive experience can give considerable stability to a movement but may retard progress because of an earlier and older education or of a more solid feeling of security based on maintaining a status quo.

The disturbing thought about this experience distribution lies in the 40% of science teachers in the inexperienced class. Coupled with turnover information, the science teachers constitute the weakest component of the necessary working team.

TABLE V. TOTAL TEACHING EXPERIENCE, YEARS

Data in Percentage in Sub-Sample

Group	Number	1-3	4-6	7-12	13-18	19 or more
Real Math Teachers	344	24.1	25.3	26.1	11.0	13.4
Math-Science Teachers	157	33.3	17.8	29.3	7.6	12.1
Science Teachers	237	41.8	16.0	20.2	9.6	12.2
	738	31.7	19.3	24.9	9.8	12.7
Oklahoma	188	32.4	16.2	26.6	10.6	14.4
Adjacent States	162	28.4	21.6	23.4	10.5	16.0
Other States	387	34.1	22.5	23.7	9.3	10.8
	737	32.4	20.7	24.3	9.8	12.7

TABLE VI. RECENCY OF UNDERGRADUATE TRAINING

Data in Percentage in Sub-Sample

		Year of Bachelor's Degree		
Group	Number	1952-1960	1940-1951	Before 1940
Real Math Teachers	321	45.1	37.7	17.1
Math-Science Teachers	171	58.2	28.7	13.1
Science Teachers	228	60.1	22.3	17.5
Oklahoma	188	54.8	28.2	17.0
Adjacent States	166	51.7	29.5	18.6
Other States	393	56.0	30.0	14.0

If limited experience is a disadvantage, then recent training will partially offset as an advantage. These younger teachers should have more awareness of the newer developments in mathematics and the sciences. They should cling less to obsolescing approaches and disappearing material. Table VI shows these younger graduates to have a decided majority since 1952. The continued teaching of about one in six with pre-World War II preparation lends a seasoned perspective, a necessary and desirable component in any effective program. But the fact remains that real math teachers are older in their preparation and can be expected to be the more conservative element in the team.

The final factor required in a collaborative effort concerns stability of personnel. This in turn relates to staff turnover. The data in Table VII are calculated as percentage of individuals teaching over the previous four years in the "same place" (same school or school system) as in 1960-61. The difference from 100% represents a measure of turnover. It is again obvious that the real math teachers do not move as much as the science or the math-science teachers. The short tenure of Oklahoma science teachers is well illustrated by comparison with Adjacent and Other States.

SUMMARY

Any effective coordination of mathematics and science instruction at the pre-college level depends on five major teacher characteristics for implementation. This is the area for teacher-to-teacher teamplay, not for ready-made curricular proposals handed down from higher up.

Science teachers know too little mathematics and mathematics teachers have studied science too limitedly to make communications easy through

TABLE VII. CONTINUITY OF TEACHING IN SAME PLACE

Data Expressed as Percentage of Those in

Same School in 1960-61.

Group	Number	2 years	3 years	4 years	5 years
Real Mathematics Teachers					
Oklahoma	77	80.5	67.5	58.4	41.5
Adjacent States	62	77.2	61.2	54.6	46.6
Other States	208	79.7	67.7	48.5	35.6
Math-Science Teachers					
Oklahoma	47	68.1	46.8	38.3	23.4
Adjacent States	41	82.9	58.5	31.7	29.3
Other States	89	75.2	57.2	41.5	37.0
Science Teachers					
Oklahoma	70	64.6	38.6	30.0	24.3
Adjacent States	65	76.9	50.8	40.0	36.9
Other States	85	88.1	67.0	44.8	37.6

one jointly understood medium of communications. The experience in teaching is too limited for many to have encountered most of the upsetting episodes that disturb the inexperienced teacher. Too many teachers in this sample are so inexperienced that they cannot be expected to review critically their present curricula.

Parallel with this limited experience, the many who have recently graduated from college may be relatively free from fixed ideas and so may be more receptive to tuning in with curricular changes.

Since this paper is concerned with chances of success with local action programs, then the turnover rates operate against development of good continuing teamplay.

In this comparison, the real mathematics teachers show more stability within their schools, have a higher percentage of seasoned and veteran members, have a foundation in science approximating the shaky mathematics backgrounds of the science teachers. But the prospect of leadership would seem to have come from these mathematics teachers. Whether the chances for developing initiative are overcome by the rigors of their discipline with its resulting conservatism remains moot.

In comparing Oklahoma teachers with those within the surrounding states and with those from outside the region, the comparison shows favorably in the mathematics and the science backgrounds of math-science teachers, in the science backgrounds (for breadth purposes) of real mathematics teachers, in the seasoned and veteran real mathematics teachers' experience and on turnover rates of real mathematics teachers. On corresponding factors for the science teachers, the comparison is even or unfavorable.

The best hope for any implementation of curricular coordination seems to lie with initiative taken by the more stable teachers of real mathematics in their own schools. This requires an effort on their part to become better informed on the applications of mathematics to scientific problems.

The other factors appear to be reflections of chronic problems besetting the schools. Further progress seems inhibited until some of the teacher qualification problems are resolved.