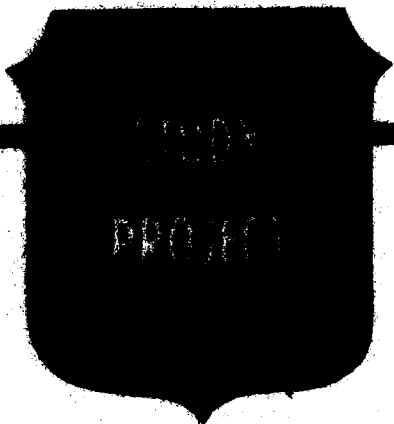


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SECONDARY MATHEMATICS EDUCATION IN THE SOVIET UNION
AN INDIVIDUAL STUDY PROJECT

by

Colonel James S. Armstrong

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US ARMY WAR COLLEGE
MILITARY STUDIES PROGRAM PAPER

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AN INDIVIDUAL STUDY PROJECT

BY

COLONEL JAMES S. ARMSTRONG

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INTRODUCTION

When the Soviet Union launched Sputnik I in October, 1957, most people in the United States were startled. Scientists, educators, and government officials were suddenly awakened to the realization that the United States was in grave danger of being surpassed as the world's leader in technology and science. Earlier that year, George S. Counts, Professor of Education at Teachers College, Columbia University and keen observer of education in the Soviet Union, had warned of the "... unparalleled growth and scope of the Russian educational machinery" (Counts, 1957, jacket). He also called attention to disturbing statistics that showed the Soviet Union was graduating three times as many engineers as the United States and expending 10 percent of its national income on education compared with a 3 percent expenditure by the United States. But it was not until after Sputnik I that the National Science Foundation began its massive funding of numerous curriculum-reform projects, aimed primarily at the secondary school curricula. The theoretical rationale for reforming the curriculum in science, mathematics, and other disciplines was developed at the historic Woods Hole Conference in 1958. Convened by the National Academy of Science, this was a conference composed predominantly of scientists, mathematicians, and psychologists. The proceedings of the conference were summarized by the conference chairman, Jerome S. Bruner, in his veritable curriculum manifesto, The Process of Education (Tanner and Tanner, 1975). The

Woods Hole Conference focused on the education of the academically gifted and gave curriculum priority to science and mathematics. Hence, the alleged superiority of Soviet scientific education " . . . was to be matched and surpassed by the American pursuit of academic excellence." (Tanner and Tanner, 1975, p. 409)

But the new curriculum reform of the 1960s and 1970s proved to be no cure-all and today we read and hear new, urgent warnings of a growing educational-gap between the Soviet Union and the United States, particularly in mathematics and science education at the pre-university level. Listen to Izaak Wirszup, Professor of Mathematics at the University of Chicago:

It is my considered opinion that the recent Soviet educational mobilization, although not as spectacular as the launching of the first Sputnik, poses a formidable challenge to the national security of the United States, one that is far more threatening than any in the past and one that will be much more difficult to meet (Wirszup, 1981, p. 360).

For example, Wirszup states that,

. . . the Soviet compulsory mathematics program for all students covers the equivalent of at least 13 years of American schooling in arithmetic, algebra, and calculus, and does so much more thoroughly and effectively (p. 358).

Albert Shanker, President of the United Federation of Teachers, says that,

In the next 10 to 20 years, the weakness or strength of the United States will largely be determined by the number and quality of scientific and technical personnel we have . . . our military strength in the future is being determined in our classrooms today. The average Soviet college-bound high school graduate has had up to 2 years more algebra and calculus than his American counterpart, 8 years more geometry, 4 years more physics, 3 years more chemistry, 3 1/2 years more biology and a year more astronomy (Shanker, 1982, p. E9).

Others warn of sagging science and math test scores, small enrollments in secondary courses in science and mathematics, and the rather surprising observation that seven states do not require high school

mathematics for graduation. (Marsh, 1982; Walsh, 1981.)

The aim of this paper is to acquaint mathematics educators and teachers with the current status and trends in Soviet mathematical education at the secondary level. We can not allow ignorance of Soviet successes and abilities to blind us in our task of improving American education. Nor can we afford to wait for such external stimuli as the Sputnik to galvanize public and professional support for needed improvements in public education.

A cautionary note at the outset: Soviet schools and curricula should be judged by the role they are expected to play in Soviet society and against the historical background of the Russian struggle against poverty and backwardness. Soviet educational reforms continue to play a major role in this struggle.

HISTORICAL BACKGROUND

The Tsarist government provided limited public education in the form of two-year district and one-year village schools which taught reading, writing, and basic arithmetic operations (Vogeli, 1971). For example, in 1914-1915 there were 1,800 schools classified as secondary (in the European sense) that enrolled only 564,600 pupils in a country of approximately 180 million people (Counts, 1957). The October Revolution brought significant educational reforms.

In the 1920s, the new Soviet government began the formidable task of organizing a free, four-year, compulsory general and polytechnical education for all Soviet citizens up to 17 years of age. The first priority was simply to teach people to read and to write. This would prove to be a slow process and as late as 1926, "forty-two percent were still illiterate in European Russia; the minority areas were much worse" (Grant, 1964, p. 20). Western techniques and experiments in education, such as John Dewey's project methods and the child-centered approach found their way into Soviet classrooms. "Teachers were relegated to the back of the classroom, to be consulted by the pupils when they needed help" (Levin, 1963, p. 4). Vogeli (1971) reports that:

The mathematics syllabus of the Unified Labor School, published in 1921, included many innovations. The study of arithmetic was compressed into four years, and plane and solid geometry were partially integrated. The function concept was emphasized as a major unifying theme. The syllabuses for the eighth and ninth grades included elements of both analytic geometry and introductory calculus. But in actual practice, the 1921

syllabus proved too difficult for general use, and a less demanding syllabus - known as the minimal syllabus - was employed by most schools. (p. 6)

By the 1930s, this experimentation was terminated and replaced with a series of strict Stalin reforms; formal teaching and examinations, a centralized curriculum with a prescribed syllabus for each subject, and strict classroom discipline. "By 1939, the literacy rate had risen to eighty-one percent and the production of specialists and skilled personnel was increasing rapidly" (Grant, 1964, p. 21). "Six hours of instruction in mathematics per week at each grade level was made mandatory in the new ten-year schools. Mathematics manuals by Kiselev and other pre-revolutionary mathematicians were resurrected, revised, and adopted as the official textbooks until new books could be published" (Vogeli, 1971, p. 7).

"Beginning with the early 1950s, criticism of Soviet schools was directed at their inadequacies in providing polytechnical labor training, thereby separating school from life" (Shabanowitz, 1978, p. 40). Also, the rising number of secondary school graduates far exceeded the number of available positions in institutions of higher education. These deficiencies were corrected by the polytechnic school reforms promulgated by Nikita Khrushchev between 1958 and 1964. Chairman Khrushchev's demands for a greater diversity of schools, and a wider range of choice after completion of the eight-year school, drew a surprising reaction from Soviet mathematicians. A group of scientists and mathematicians, concerned that the school program in mathematics would be diluted by Khrushchev's reforms, petitioned the Communist Party leadership to establish special schools for the brightest secondary students who showed promise as future scientists and mathematicians. The Ministry of Education authorized limited experimentation with

special schools and by 1965 more than one hundred schools were in operation, with a total enrollment of over 25,000. Perhaps the most significant feature of these special schools was their role as an experimental test-bed for innovative curricular designs that would ultimately be adopted by the entire secondary school system. Polytechnical education, however, was not without its critics and the expanding need for greater professional competence in a highly sophisticated scientific and technological society, brought on another period of curriculum reform (Vogeli, 1971).

In November 1966, after the political demise of Khrushchev, the Soviet Union extended the goal of universal secondary education from eight to ten years and raised the level of courses in all grades, particularly in the natural sciences and mathematics. A joint commission was established to prepare new curricular for all subjects in Soviet public schools. "The chairman of the syllabus commission for mathematics was the distinguished Soviet mathematician, Academician A. N. Kolmogorov" (Vogeli, 1971, p. 9). Kolmogorov set the goals of the new program and designed the curriculum in every detail. The result of his efforts is a ". . . program for mathematics instruction that is modern in content, innovative in approach, well integrated, and highly sophisticated" (Wirszup, 1981, p. 358). A brief analysis of the strengths and weaknesses of this curriculum is the subject of another section of this article. But before we get to this analysis, it is important to recall a statement made earlier - that Soviet schools, and of course their curricula, should be judged by the role they are expected to play in Soviet society. The next section deals briefly with Soviet educational philosophy and pedagogy.

EDUCATIONAL PHILOSOPHY AND PEDAGOGY

Educational Philosophy

In his seminal work, Basic Principles of Curriculum and Instruction, Ralph W. Tyler says that any statement of educational philosophy should deal with the question, "Should the educated man adjust to society, should he accept the social order as it is, or should he attempt to improve the society in which he lives" (Tyler, 1949, p. 35)? Lenin answered this question with remarkable clarity in the following passage from his early writings.

In the field of peoples' education, the Communist Party sets itself the aim of concluding the task begun by the October Revolution of 1917 of converting the school from a weapon for the class domination of the bourgeoisie into a weapon for the destruction of this domination, as well as for the complete destruction of the division of society into classes. The school must become a weapon of the dictatorship of the proletariat. (Counts, 1957, p. 47)

In 1934, Stalin made it clear that there had been no change in Lenin's philosophy when he said, "Education is a weapon whose effect depends on who holds it in his hands and who is struck with it" (Counts, 1957, p. 47). The message is as clear today as it was in the time of Lenin and Stalin: education in the Soviet Union is primarily a political tool for the construction of a communist society.

In November 1958, the Central Committee of the Communist Party issued a policy statement that emphasized the critically important concept of "upbringing" as a goal of Soviet education.

Upbringing must inculcate in the school children a love of knowledge and of work, and respect for people who work; it must shape the communist world outlook of the pupils and rear them in the spirit of communist morality and of boundless loyalty to the country and the people, and in the spirit of proletarian internationalism. (Grant, 1964, p. 2)

"Upbringing" is the educational process used to produce what the Communists refer to as "the new Soviet man," a builder of communism. This process is perhaps the most distinctive and unique feature of Soviet education. The new Soviet man has a Communist world-view, a changing view of the world dictated at given times by party leaders (Long & Long, 1980).

Soviet education has of course other purposes and effects, but the two principal tasks are: first, to produce sufficient technicians, scientists, and laborers to overcome the historical backwardness of the Soviet Union and to insure the country's continued growth toward the world's greatest industrial and military power; second, to create and develop the new Soviet man. The entire educational process is under the monolithic direction of the Communist party.

Pedagogy

The USSR Academy of Pedagogical Sciences, established in 1943, plays a unique, scholarly and pedagogical role in the educational system of the Soviet Union. It has become the chief educational research and development center for the USSR. The Academy's primary functions include pedagogical research; developing experimental curricula, syllabi, and textbooks; furnishing guidance in teacher training; and acting as a clearinghouse for educational studies. The Academy comprises 12 research institutes, 100 laboratory schools, and has 31 members and 64 associate members, chosen from distinguished Soviet scholars, scientists, and educators. The Academy, along with the USSR Academy of

Sciences, played a major role in the curriculum reforms of 1966. (Shabanowitz, 1978; Kilpatrick & Wirszup, 1975.) According to Owen and Watson (1975, p. 12) most of the teachers in the laboratory schools have "little freedom of maneuver, since not only content but method of approach is prescribed after discussion and decisions at national level reflect the 'best' techniques."

A. A. Makarenko's theories and ideas on the "collective" have had a profound influence on Soviet education (Levin, 1964). One of the most interesting and unique features of the present-day Soviet school is the "collective." A student is a member of a group of students, called the "collective," and every student in the group has a learning responsibility toward every other student in the group. If a student is not learning satisfactorily, not doing the prescribed homework assignments, or is coming to class late, the "collective" must deal promptly with the delinquent student. The concept of the "collective" extends beyond the school into the family environment. The family unit shares the responsibility for making sure that Soviet students get their work done properly and on time (Davis & Romberg, 1979, pp. 6-8). Romberg (1981, p. 367) also reports that "Soviet schools are designed to train children to become good members of the 'collective,' so completing lessons is a collaborative, not a competitive, effort." In fact, most Western observers are somewhat startled to learn that Soviet math students are encouraged to copy answers from other students, or from the teacher. This "copying" is not viewed as a form of cheating in the Soviet Union, it is an acceptable form of "helping" among the members of the educational "collective."

The importance of learning mathematics in the context of using it

is a popular theme among US educational psychologists. The Soviet psychologist, P. Ya. Galperin and his followers seem to agree:

Application of knowledge is the basic means for mastering it, not the concluding stage. There is no knowledge until it is applied (Goldberg, 1978, p. 378).

At the present time, the bulk of Soviet educational research is guided by Galperin's three approaches to the learning process. The following brief description of each approach was taken from Goldberg (1978, p. 379):

First type. The mastering of knowledge occurs spontaneously and is an unguided process. The formation of concepts and skills in acts proceeds according to trial and error.

Second type. A student works under continuous supervision, receiving all the necessary instructions which will result in a correct action or an action with only minor errors. Transfer occurs when new tasks have something in common with instructional tasks.

Third type. Advantages are added to those of the second type of learning. In this type of learning the cognitive interests and abilities of students are broadly developed, and a generalized transfer of skills and abilities to new knowledge is obtained.

These approaches match, in part, those of Gagné, Bruner, and Skinner.

According to Kilpatrick and Wirszup (1975), one major difference between Soviet and American educational research techniques is that Russian psychologists favor qualitative methods rather than quantitative methods of research (so prevalent in the United States). Regardless of this difference in approach, Soviet psychologists seem to be reaching conclusions that are compatible with current Western principles of learning. For example, N. A. Menchinskaia (1977, p. 90), Director of the Scientific Research Institute of General and Educational Psychology of the USSR Academy of Pedagogical Sciences, reports that Soviet psychologists have identified several significant factors that indirectly

influence the results of learning: the motivations for the learning activity, the learning interests of the pupil, his position in the collective, and many features of his personality. These factors have the familiar ring of the Tyler rationale.

Kilpatrick and Wirszup (1975) note that Soviet psychologists take sharp exception to Piaget's theory that ascribes a limited significance to the role of instruction in developing a child's mind. According to Piaget, a child's thinking develops in specific stages and at certain age levels relatively independent of conditions of instruction. Soviet psychologists maintain, as do most leading Western psychologists, that instruction broadens the potential of development and may even accelerate it.

Soviet pedagogy differs from US pedagogy in many ways. To mention only a few, Grant (1964) notes that the rather common US practice of sectioning students by ability, whereby a child may be in a top section of English and a low section of mathematics, is ignored in the Soviet Union. "Every class is expected to have a complete cross-section of ability, from the brilliant to the plodder, all doing the same courses at the same pace" (p. 43). Soviet students also have little choice in the courses they take. They all take the same course in history, geography, Russian, and science. Also, in their visit to the Academy of Pedagogical Sciences, Owen and Watson (1975) saw little evidence of the use of programmed learning in the secondary schools and detected little enthusiasm for its use in institutions of higher education. Lastly, Davis and Romberg (1979) were unprepared for the teaching they observed in Soviet classrooms.

It consisted entirely, as nearly as we could judge, of rote instruction! Students are told that this is the hyperbolic

sine ($\sinh x$) and they are told that its graph looks like this, and so on (p. 18).

They were even more surprised when Soviet teachers expressed the belief that everyone teaches mathematics that way, and in fact, it was the only way to teach it.¹

Educational technology is slowly finding its way into the Soviet classroom. Widespread use is made of movie projectors and TV monitors, but there are essentially no hand-held calculators, or the Soviet equivalent of Cuisenaire rods or Dienes MAB blocks in Soviet schools. (Davis and Romberg, 1979)

Keeping in mind the foregoing overview of Soviet educational philosophy and pedagogy, let us now turn our attention to the new 1975 mathematics curriculum for the 10-year general education school.

MATHEMATICS IN THE 10-YEAR
GENERAL EDUCATION SCHOOL

Soviet general education covers a broad range of academic disciplines in the humanities, the natural sciences, and mathematics. It is based on the pragmatic principle that each student should assimilate a definite body of knowledge. (Shabanowitz, 1978)

Long and Long (1980) provide a brief, but up-to-date and insightful description of the general education school:

All general education schools in the USSR are public, co-educational, secular, and tuition-free. School throughout the country begins on 1 September and extends to 20 May or into June for those taking eight-year or 10-year learning examinations. Except in a few republics where the school starting age is 6, Soviet children begin school at the age of 7 and attend a 10-year general education school. The school is usually organized into primary education (grades 1 through 3), incomplete secondary (grades 4 through 8), and complete secondary (grades 9 through 10). It is compulsory for everyone to complete the eighth grade. Upon graduation from the eighth grade, most young people continue in the 10-year general education school. A third of the students, however, go directly to work or enroll in a vocational or technical school. An urban child remains in the same school and with the same group of children for either eight or ten years. A rural child, however, may attend two or three different schools, for a Soviet village often has only one school - a primary school. (p. 15)

According to Romberg (1981) classes meet from early in the morning to late in the afternoon, six days a week, for most of the year. Formal subject matter instruction occurs in the morning and informal "upbringing" in the afternoon (sports, music, clubs, and political instruction). It is important to note that the afternoon "special

interest" classes are held in what the Soviets call Pioneer Palaces. These are impressive structures set apart from the "school" building. In this way the special interest courses are not part of the school at all. The "school" deals only with academic courses!

An analysis of the relative allocation of classroom hours in broad subject areas, given in Table 1, reveals an increased emphasis on the natural sciences and mathematics.

TABLE 1
RELATIVE ALLOCATION OF CLASSROOM HOURS
IN SOVIET SECONDARY GENERAL EDUCATION
SCHOOL CURRICULUM. (SHABANOWITZ, 1978, p. 30)

Subject Areas	Total Hours Weekly		Percent	
	In new* curriculum	In 1959 curriculum	In new curriculum	In 1959 curriculum
Mathematics	58	59	21	18
Natural Sciences	47	46	17	14
Humanities	118	130	43	39
Fine arts and music	13	15	5	4
Labor Training	20	58	7	18
Physical culture	20	22	7	7
Total required hours	276	330	100	100

*The new curriculum in mathematics refers to the most recent, 1975 curriculum developed by A. N. Kolmogorov.

Mathematics is usually taught in six, 45-minute periods each week. Over the entire 10-year period, the Soviet child spends more time on mathematics than on any other single subject.

The following brief description of the new mathematics curriculum is taken from Davis (1979, pp. 41-45) and Shabanowitz (1978, pp. 55-72).

Grades 1 to 3 (ages 7 to 10):

In these grades are included the operations of addition, subtraction, multiplication, and division; the basic laws for these operations; the beginnings of algebra; measurement (including area and volume); the basic geometric concepts of point, line, and angle; and elementary surveying, actually carried on outdoors.

Grades 4 and 5 (ages 10 to 12):

The arithmetical operations are extended to fractions and decimals. Extensive use is made of number lines; simple equations are used for physics ($s = v \cdot t$, etc.) and for geometry (areas, volumes, etc.). Geometric topics include: use of the ruler, protractor, and compasses in geometric constructions; Theorem of Pythagoras and other well-known congruence theorems on angles and triangles. Concepts of set theory are developed in relation to the topics studied.

Grades 6 through 8 (ages 12 through 15):

The concept of function as a mapping is introduced in grade 6. Other topics include: inequalities; graphical representation of functions; the properties of integer exponents; polynomial functions; the solution of two equations in two unknowns (both algebraically and graphically); rational functions; and factoring of polynomials. Geometric topics include: circles; chords; arcs and central angles; translation and rotations; descriptive geometry; and engineering drawing - in essence, a plane geometry course. Trigonometry is introduced in the eighth grade as a part of the geometry course. Fundamental trigonometric functions and their graphs are studied.

At this point, the work of the eight-year school is completed and students' paths begin to diverge. Up until this point, all students have had the same program, irrespective of individual differences in ability or desire.

Grades 9 and 10:

For those students who continue in the ten-year school the course-load in mathematics is reduced from 6 to 5 hours per week.² Topics include: limit of infinite sequences; limits of functions; continuity (ϵ -method); the derivative; vectors; trigonometry; differentiation of trigonometric, exponential, and logarithmic functions (applications to growth and decay problems); anti-differentiation; definite integrals (volumes and surface areas of solids); selected second-order differential equations; combinations; and probability and the law of large numbers. Geometric topics include vector geometry and the development of the axiomatic approach to geometry. The course concludes with an introduction to electronic computers and

a visit to a computer center.

Features of the foregoing new school mathematics curriculum include a vector based approach to solid geometry, the early introduction of elements of analysis and the theory of probability, a rigorous theoretical foundation based on set theory, a higher generalization level, and new textbooks designed to better articulate the new material in all grades. Prominent Soviet mathematicians have taken a leading role in writing new textbooks and implementing the content of school mathematics. For example, A. N. Kolmogorov is a co-author of a new geometry textbook for the sixth grade (Shabanowitz, 1978). "Textbooks in Russian are assured of a huge sale since only those provided by the Ministry of Education are used and there are over 2 million children in each grade" (Owen and Watson, 1975, p. 11).

There is in the Soviet Union a theme of "quality" or "excellence" to accompany the egalitarian theme which is so prevalent throughout the eight-year and ten-year schools. There are, for example, four boarding schools offering a specialization in mathematics. Each school is sponsored by either a university or the Academy of Science, and A. N. Kolmogorov teaches at one of them three days a week. Boarding school pupils study algebra and analysis, linear algebra, discrete mathematics, geometry, probability theory, problem-solving, functions of a complex variable and elements of group theory. Instruction in mathematics and physics occupies nearly 17 hours per week, or 51 percent of the total number of 33 hours per week (Davis and Romberg, 1979).

Vogeli (1968) reports there are also about 100 special secondary schools in the Soviet Union that offer a specialization in computer programming. Much of the work done here by students in junior and senior high school, some as young as 12 years old, is very complex and

highly professional.

The new school mathematics curriculum, adopted in 1967 but not fully implemented until 1975, is still in its infancy. Nevertheless, there are early signs that the Soviets may be experiencing problems similar to the problems we experienced with the "new-math" of the 1960s. Soviet educators, not unlike US educators, continue to have difficulty answering these two basic questions: "Is the new sophisticated curriculum truly suitable for all students?" and "How can teachers be adequately trained to teach the new curriculum?" More on the latter question later. Now, we will turn to several specific strengths and weaknesses of the new curriculum, as identified by US and Soviet educators.

First, the perceived strengths of the curriculum. The newest version of Soviet "school mathematics" was not developed "overnight" and adopted the "next day." As mentioned earlier, the development phase lasted nearly 10 years and included a successful evaluation in the special schools before it was ordered "into" all Soviet schools. Each Soviet student is required to take the new mathematics curriculum, which Wirszup (1981) says, "... surpasses in quality, scope, and range of implementation that of any other country" (p. 358). Contrast this with the declining emphasis on science and mathematics in our school system, a trend that unless reversed, "... means that important national decisions involving science and technology will be made increasingly on the basis of ignorance and misunderstanding" (National Science Foundation, 1981, p. 369). For example, the elective program in many US high schools often encourages students to take the path of least resistance.

The sophisticated, theoretical underpinnings of the Soviet curric-

ulum represents another source of internal strength. This new feature closely parallels the widely acclaimed strength of the structure-of-a-discipline approach taken in this country in the 1960s. Although our approach met with little success, I think the Soviet, top-down bureaucratic system of curriculum reform will overcome most of the major problems encountered by US educators, such as poor instructional techniques and improperly trained teachers.

Another notable strength of the Soviet curriculum is that, unlike most US curriculums, it is much more than a mere listing of subjects to be taught. For example, it includes a detailed syllabus and a methods manual which together provides the Soviet teachers specific instructions on daily lessons and even suggested questions that the teachers might ask the students. Educators in this country experimented with this "scripted" approach only a few years ago with such programs as the Madison Project. Although this sizeable program involved over 30,000 teachers and achieved significant successes, it suddenly declined in size and vigor and no longer exists. However, even today similar but much smaller programs continue to exist in certain parts of the country (Davis, 1979).

Examinations are a critically important component of any serious academic curriculum. In analyzing the new Soviet mathematics curriculum it is virtually impossible to classify the examinations as an absolute strength or weakness. Observers from the US invariably comment on the extreme difficulty of these examinations. Goldberg and Swetz (1977), tell us the Soviet examination system (oral and written) is strongly supported by both parents and educators as a means of screening out weak students. They also say that mathematics examinations have been "... a major stimulus in the proliferation of specialized mathematical sec-

ondary schools, the expansion and popularization of mathematical olympiads" (p. 215). Yet, in the opinion of Owen and Watson (1975), examination questions " . . . seemed to lend themselves to rote-teaching and rote-learning" (p. 12). Thus, it would appear that Soviet mathematics examinations will continue to be difficult compared to US standards and that they may encourage rote-learning by the students.

Soviet psychologists are also closely monitoring the implementation of the new curriculum. For example, Maslova, et al. (1977) observed quite early that the new material " . . . is being adequately learned by school pupils for the most part" (p. 95), and they have demonstrated an ability to learn advanced material at a much earlier age than was previously believed possible. To illustrate their point, they say that seventh graders now have the same knowledge and skills on the topic of inequalities as ninth graders had under the old curriculum.

Let us now turn our attention to some of the perceived weaknesses of the new curriculum. Perhaps the most pronounced weakness observed so far by both US observers and Soviet critics is the level of frustration experienced by teachers, pupils, and parents. Students appear to be overworked, teachers overburdened, and parents dissatisfied. These complaints are familiar to American curriculum reformers of the 1960s. One factor which may well contribute to this feeling of frustration is the pace of mathematical instruction in Soviet schools. One observer has commented on the "unbelievably slow" pace of US instruction compared to the more rapid, Soviet pace (Davis, 1979). Another possible frustration factor relates to the Soviet attitude toward individual differences. They recognize the existence of such differences but consider them unimportant. The new curriculum attempts to accommodate individual

differences by providing optional courses. However, these courses, according to Shabanowitz (1978), do not replace the basic courses, but are taken in addition to them! Other less significant US criticisms include a recent NSF report which states that only a minimal amount of laboratory work is included in the two-year science courses, and the observation by Walsh (1981) that "there is widespread skepticism in the United States that fifteen and sixteen-year-olds across the board will attain a very high proficiency in calculus" (p. 68). I would only add that the latter is probably less of a problem in the Soviet Union than it would be in this country.

The new curriculum has its Soviet critics as well. For example, Maslova, et al. (1977) have identified the need for improvement in the following areas: more work needs to be done to retrain teachers (this point was alluded to earlier); increased effort is needed to improve teaching methods and to place greater emphasis on the frequent and systematic use of review exercises (which suggests some students are experiencing difficulty with the new material); fundamental concepts such as polynomial factorization and identities of short multiplication continue to cause students difficulty; the use of non-standard problems to develop creative initiative in pupils is not progressing as planned; and ninth-graders fail to realize that a derivative is a function and their drawings are not illustrative.

More recently, Kolyagin, et al. (1980) have added to the list of difficulties. They cite the following: syllabuses and textbooks contain too much material of a secondary importance; excessive use is being made of the spiral method of teaching; textbooks use a language that fails to account for the pupil's level of maturity; and poor use is made of problems and exercises (previously noted by Maslova, et. al.).

Problems such as those mentioned above prompted a 1977 resolution of the CPSU Central Committee ordering a review and revision of all school curriculums, and of mathematics in particular (Wirszup, 1981) Wirszup goes on to say that, ". . . Kolmogorov's modern approach and rigor have been attacked by academicians who advocate a return to more traditional methods" (p. 360).

It would seem that the Soviets are at the same mathematics crossroad US educators faced in the 1970s. One Soviet view is to return to Kiselev (a return to basics) and the other view is to provide more extensive updating of the current curriculum. Yet, Kolyagin, et al. (1980) quite correctly observes ". . . that both views can be justified, and the justifications appear outwardly conclusive" (p. 75).

Curriculum synthesis is not an easy task, and public debate and discussion over the strengths and weaknesses of the new Soviet curriculum will surely continue. But given the incredible progress made by the Soviets in public education since the October Revolution, I see no reason to believe that Soviet educators will stumble over the few, relatively minor obstacles facing them today. One of the principal reasons for this optimistic assessment of the Soviet ability to overcome these obstacles is that they have a strong, pedagogically sound system of teacher education.

TEACHER EDUCATION

The two major goals of teacher education in the Soviet Union are to develop teachers into - (1) strong role-models of the new Soviet man or woman, and (2) active propagandizers of party ideology. A Soviet teacher must be a member or supporter of the Communist party and a militant atheist. It goes without saying that teachers are also expected to know their subject thoroughly and to teach it effectively. But their first and most important responsibility is to mold the moral character of their students into the morality of the new Soviet man or woman (Long and Long, 1980).

In 1979, Soviet authorities reported that,

The Soviet school presently employs 2,731,000 teachers - almost ten times more than 1914. Over 90 percent of the teachers of grades 5-10 . . . have a university or pedagogical institute education. On average, the pupil-teacher ratios 19 compared with 29 in 1940/41 school year. (Reproduction of Pedagogical Cadres, 1979, p. 42)³

According to the same source there were 316,000 mathematics teachers, of whom 76 percent had higher education training. Another 15 percent had teacher training institute or an equivalent level of pre-service education. These figures are particularly significant because, beginning with the fourth grade, mathematics is always taught by a specialist teacher who teaches nothing but mathematics (Davis and Romberg, 1979).

In view of the responsibility of every school teacher for the "upbringing" of his pupils, it is not surprising that demands on a

teacher's time go far beyond the average 20-25 hours per week actual classroom work. Teachers are expected to visit the homes of their pupils, attend PTA meetings and political seminars, improve school offerings of labor and polytechnical training, and work systematically on vocational guidance. As a result, there are frequent complaints about excessive demands on teachers' time. (Grant, 1964; Aleksandrov, 1979)⁴

Two critical and related factors of teacher effectiveness are the teacher's skill and educational level and the degree of his or her pedagogical mastery.

Preservice Training

To be admitted to a Soviet institution that develops teachers an applicant must be a graduate of the 8-year or 10-year school, have a good academic record, and provide suitable references from previous teachers and classmates. Most elementary teachers are trained in pedagogical schools which offer two-year and four-year courses. The two-year course is almost exclusively pedagogical in nature and is taken by the 10-year school graduate. The four-year course, taken by the 8-year school graduate, provides ninth and tenth grade subjects and the two-year pedagogical training. The majority of the pedagogical students in Russian area schools are females, whereas in the non-Russian area schools the proportion of females is a much lower fifty percent (Long and Long, 1980; Grant, 1964).

Secondary teachers are trained primarily in pedagogical institutes and universities. Entrance to these institutions is by competitive examination and character reference. The course of study is four years for certification in one subject and five years for two subjects. Long

and Long (1980) state that, "Over 60 percent of all teachers are certified in two subjects" (p. 27). The curriculum in pedagogical institutes consists of three major parts: political courses, psychological-pedagogical courses, and specialized, discipline-oriented courses. The psychological-pedagogical courses are mandatory for all students and consist of such topics as history of education, general psychology, methods of "upbringing," and methods of teaching various subjects. It is interesting to note that this curriculum (except for the political courses) closely matches our curriculum for the Doctor of Arts degree, an alternative to the Ph.D. that is designed especially for prospective college teachers.

What is the nature, scope, and magnitude of the specialized, disciplined-oriented courses, particularly for secondary mathematics teachers? Vogeli (1968) provides a partial answer:

Teachers for secondary schools with specialization in computer programming [and also mathematics] receive a total of 4,388 hours of classroom and laboratory instruction. In contrast, graduates of four-year American colleges and universities receive about 2,000 hours of classroom instruction and laboratory work. Of the 4,388-hour Soviet total, 2,730 hours (or 62 percent of the total college program) are in mathematics, and 450 hours are in physics and electronics [so that physics, mathematics, and electronics represent 72 percent of their entire 'college' education]! This is 5 times as much instruction in mathematics and physics as comparable US teachers receive (pp. 39-40).

Inservice Training

The Soviet Union has developed a comprehensive and far-reaching program of inservice education. In view of the requirement that each Soviet teacher be recertified every five years, the Ministry of Education has established an extensive network of institutions that help teachers keep up to date with the latest developments in subject-matter and teaching methods. Teachers may enroll in pedagogical schools and

institutes, universities, or in evening or correspondence courses offered by other higher education institutions. In addition, they may take work in one of the 178 institutes for advanced training of teachers (Long and Long, 1980). According to Aleksandrov (1979), the Deputy Minister of Education of the RSFSR, "Approximately 2 million teachers have taken courses in advanced training institutes to prepare for work under the new curricula" (p. 46). If true, that represents over 70 percent of the entire teaching force, a truly remarkable achievement! To supplement this national system of formal training, annual conferences are held at the district level for teacher-trainers who later conduct inservice training at the local level (Owen & Watson, 1975).

The Soviets attach great importance to the use of teaching-methods centers as a means of providing inservice teacher training. Nearly twenty years ago, Levin (1963) reported that "each school had a 'method room' which contained educational journals, visual aids, and copies of 'model' lessons given by good teachers." Aleksandrov (1979) also reports that nearly 800 methods manuals and an unspecified number of sets of visual aids have been developed to accompany standard textbooks for the new curriculum.

Certainly one indirect measure of the effectiveness of the entire Soviet system of teacher education is the number of students that successfully complete the program of instruction. In this regard, Aleksandrov (1979) tells us that there were "871,000 failing pupils in RSFSR schools in 1965 compared with 108,000 in 1977" (p. 46).

Problems

There remains a great disparity between urban and rural teachers. For one thing, nearly 88 percent of upper-grade, urban teachers have a

complete higher education, while only 68 percent of upper-grade, rural teachers have a comparable education. Furthermore, teachers do not like to serve in rural areas. To overcome this dislike for rural service, Soviet law requires that new teachers must teach their first three years in a school designated by the government. Presumably, they then are free to choose an urban post. As a result, it is reasonable to infer that the higher proportion of inexperienced teachers in the rural areas leads to an imbalance in the quality of education in favor of the urban areas.

The pay-scale for teachers in the Soviet Union is quite low, even relatively lower than in the US. Soviet teachers are also apparently dissatisfied with their working conditions. In fact, the Communist party joint decree of 1977 called attention to the national problem of too few university graduates taking teaching jobs; especially acute in the natural sciences and mathematics (Long and Long, 1980; Reprod of Pedagog Cadres, 1979). Perhaps the appealing lure of higher industrial wages is as strong to Soviet graduates as it is to US graduates. But, Long and Long (1980) have identified what may well be an even more serious factor related to the Soviet inability to attract sufficient numbers of university graduates to the teaching profession. They suggest that university graduates avoid the teaching field because they do not wish to assume the role-model of the new Soviet person and be required to teach "truths" as defined by the Communist party. To the extent that this hypothesis is true, it signifies a breakdown of ideological discipline within the ranks of the educated Soviet citizenry that may prove extremely difficult to repair.

CONCLUSIONS

The Soviet educational system continues to grow at an alarming rate and appears fully capable of achieving significant successes in all fields of academic endeavor, particularly in the scientific fields. The USSR government is totally dedicated to the success of this system and treats it as a matter of first-rate, national importance; a viable means of shedding the cloak of cultural backwardness and becoming a leading world power. The purposes of education are clearly stated in the Soviet philosophy of education and they serve as the fundamental basis and unifying theme for every secondary curriculum in the country. The strength of the Soviet educational threat to our national security and position as world leaders in science and technology derives more from this sense of national dedication and unity of purpose than from any particularly unique characteristics of the educational system itself.

In this paper we have examined many interesting facets of Soviet mathematics education, and in many ways found individual components of the Soviet program apparently superior to comparable components in the US mathematics program: teacher education and certification programs; the mandatory nature of the mathematics curriculum; the use of laboratory schools and educational research results to support curriculum reform measures; and finally the Soviet recognition of the vital role played by parents in the child's learning process and their ability to get the parents actively involved in this process. There is much that

US educators and teachers can learn from the Soviet experiences in these areas and we must resist the temptation to attribute Soviet educational successes to the monolithic, suppressive nature of the Communist government. As a matter of fact, this investigator did not discover a single instance of Soviet innovation in the learning process that had not been attempted at one time or another in this country. Where we can learn from the Soviets is in their ability to identify successful educational experiments and their willingness to implement them on a national scale. In this country, we apparently have not yet developed the will or the ability to do this. We seem to have an incessant fixation on the excitement associated with continued experimentation at the expense of the more difficult, less exciting implementation of promising experimental results.

One particular aspect of Soviet mathematics education that deserves special comment is the new 1975 mathematics curriculum. On paper, the content and scope of this curriculum are remarkably similar to the mathematics curricula found in most US schools. If claims that Soviet high school students receive a superior mathematics education are true, it is due more to the synergistic effects of the other, previously mentioned components of the educational process, than to the content and scope of the new curriculum. Based on the available evidence, which is far from conclusive, there is good reason to believe that the "best" US mathematics students are slightly superior to the "best" Soviet mathematics students; and the "average" Soviet students are superior to the "average" US students. The future of the new curriculum rests squarely on the Soviet student's ability to learn and assimilate the new material. If the subject matter proves to be too difficult, as many Western

observers believe, then curriculum modifications can be expected.

In conclusion, the United States can successfully meet the Soviet educational challenge by strengthening, not weakening, federal support of education. This is not the time to withdraw that support. For example, recent federal legislative actions to provide federal tax breaks to certain private schools, to abolish the new Department of Education, and to reduce federal aid to higher education can only serve to increase the danger of the Soviet threat.

ENDNOTES

1. A detailed listing and insightful discussion by Gibsh of his ten principles of mathematical instruction for the Soviet Union may be found in Soviet Studies in the Psychology of Learning and Teaching Mathematics (Volume VIII), 1975, edited by Kilpatrick et al. Gibsh takes the point of view that mathematics must be presented in a logical sequence, that it is learned by solving problems, and that the connection between theory and practice is vital to student mastery of mathematical concepts.

2. Soviet examinations are extremely difficult. A typical question on the examination for promotions from grade 9 to grade 10: Find the value of r such that the graph of the function $y = x^r$ will pass through the point $P (3/4, \sqrt{100}/4)$. (Shabanowitz, 1978, p. 75)

3. These figures are consistent with another Soviet source; F. R. Filippov's article in Soviet Education, April 1979.

4. Recall the reference to mathematics teachers' sense of frustration (over-worked) in the previous section.

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