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ABSTRACT

A program to prepare interdisciplinary research and development specialists in mathematics education and structural learning at the doctoral level is described. Program objectives, course offerings, faculty, information about trainees (educational background, examination records, research, publications, present position), and publications resulting from the program are all listed. Requirements for the doctoral degree in mathematics education research are specified and sample programs are included. (DT)

STRUCTURAL LEARNING SERIES

UNIVERSITY of PENNSYLVANIA
Philadelphia

FINAL REPORT
Grant No. OEG-0-71-3477 (320)

GRADUATE TRAINING IN MATHEMATICS EDUCATION RESEARCH AND STRUCTURAL LEARNING

Joseph M. Scandura
Graduate School of Education
University of Pennsylvania
Philadelphia, Pennsylvania

August 1972

U.S. DEPARTMENT OF
HEALTH, EDUCATION, AND WELFARE

Office of Education
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U.S. DEPARTMENT OF
HEALTH, EDUCATION, AND WELFARE

Office of Education
Bureau of Research

REPORT RECEIVED
AND APPROVED

Chief, Research Training Branch

Final Report

Program Objectives

The primary aims of the program were to prepare interdisciplinary research and development specialists in mathematics education and structural learning at the doctoral level (Ph.D. and Ed.D.).

The long-term objective to which this program addressed itself was to increase understanding of the learning, teaching, measurement, and creation of mathematics and other structured knowledge, at all levels, and to develop rationales and methodologies, based on such understanding, for the technological development of instructional materials and measuring instruments.

The program, itself, was concerned with the graduate training of bright, innovative, and tenacious students who had received bachelor's or master's degrees at recognized colleges or universities with majors in mathematics, logic, formal linguistics, statistics, experimental psychology, or mathematics education. More specifically, the program was designed to provide the trainee with:

(a) sufficient understanding of mathematics and its nature as a structured discipline so that he is able to prepare suitable mathematical materials for use in research and to discuss mathematical questions with mathematicians in an intelligent manner,

(b) sufficient familiarity with the area of research concern (i.e., mathematics education) as it exists in practice to provide a common bond between other colleagues in mathematics education whose primary concerns are of a more clinical nature,

(c) sufficient grounding in research methodologies, technologies, and the philosophy of science to independently undertake most research projects and to be able to converse intelligently with specialists concerning unusual technical problems in research design and analysis, and

(d) sufficient understanding of the underlying behavioral sciences of psychology and educational psychology so that, in his quest for increased understanding and improved technologies, he may bring to bear relevant knowledge and appropriate research techniques and converse intelligently with scientists in the parent behavioral disciplines.

We feel that these objectives have been achieved and that education in our country has and will benefit as a result.

The trainee was also expected to select one or more subareas within the four areas indicated above for special emphasis, the choice depending on the type of research he wished to undertake after graduation. For more details concerning the nature of the programs see the appended item "Requirements for the Ph.D. and Ed.D. in Mathematics Education Research."

Courses offered in the Program

Course No.	Course Title	Semester Hours	Class Hours	
Educ. 728	Proseminar in Structural Learning	3	3	required
Educ. 729	Research in Mathematics Education	3	3	required
Educ. 828	Seminar in Structural Learning	3	3	required
Educ. 829	Seminar on Innovation in Mathematics Curriculum and Instruction	3	3	required
Educ. 830	Seminar on Psychology of Mathematics Learning	3	3	required
Educ. 839	Practicum in Mathematics Education	3	3	required
Educ. 928	Research Seminar in Structural Learning	3	3	required
Educ. 929	Research Seminar in Mathematics Education	3	3	required
Educ. 660	Proseminar in Educational Psychology	3	3	Elected by most students
Educ. 867	Experimental Design and Analysis of Variance and Covariance	3	3	Elected by most students
Educ. 871	Seminar in Experimental Design	3	3	Elected by most students
Ling. 642	Mathematical Logic	6	3 each sem.	Elected by most students
Math. 510	Topics in Analysis	3	3	Elected by most students
Math. 520	Topics in Geometry	3	3	Elected by most students
Math. 530	Topics in Algebra	3	3	Elected by most students
Math. 365	Foundations of Analysis	3	3	Elective
Math. 370	Algebra I	3	3	Elective
Math. 371	Algebra II	3	3	Elective
Math. 380	Honors Analysis I	3	3	Elective
Math. 381	Honors Analysis II	3	3	Elective
Math. 410	Complex Variables	3	3	Elective
Math. 420	Theory of Differential Equations	3	3	Elective
Math. 430	Probability	3	3	Elective
Math. 440	Numerical Analysis	3	3	Elective
Math. 460	Differential Geometry	3	3	Elective
Math. 600	Geometric Analysis	3	3	Elective
Math. 601	Real Analysis	3	3	Elective
Math. 602	Algebra	6	3 each sem.	Elective
Math. 607	General Topology	3	3	Elective

Course No.	Course Title	Semester Hours	Class Hours	
Math. 609	Complex Analysis	3	3	Elective
Math. 641	Intro. to Algebraic Topology	3	3	Elective
Math. 691	Theory of Logical Models	6	3 Each sem.	Elective
Educ. 761	Psychology of Human Learning	3	3	Elective
Educ. 762	Psychology of Human Development	3	3	Elective
Educ. 768	Test Construction I	3	3	Elective
Educ. 769	Test Construction II	3	3	Elective
Educ. 863	Seminar in Educ. Psychology	3	3	Elective
Educ. 871	Seminar in Experimental Design I	3	3	Elective
Educ. 872	Seminar in Experimental Design II	3	3	Elective
Psych. 600	Proseminar in General Psychology	3	3	Elective
Psych. 710	Developmental Psychology	3	3	Elective
Psych. 725	Verbal Learning and Behavior	3	3	Elective
Psych. 750	Mathematical Learning Theories	3	3	Elective
Phil. 436	Intro. to Philosophy of and Logical Foundations of Mathematics	3	3	Elective
Phil. 524	Problems in Logic and Modern Methods	3	3	Elective
Phil. 536	Set Theory	3	3	Elective
Ling. 602	Formal Linguistics	3	3	Elective
Ling. 603	Mathematical Systems in Linguistic Structure	3	3	Elective
Ling. 630	Proseminar in Formal Linguistics	3	3	Elective
Ling. 643	Theory of Recursion	3	3	Elective
Ling. 644	Seminar in Logic	3	3	Elective
Ling. 645	Linguistics and Mathematical Logic	3	3	Elective
Ling. 654	Linguistic Transformations	3	3	Elective
E.E. 623	Intro. to Digital Computers: Programming and Logic	3	3	Elective
E.E. 640	Theory of Automata	3	3	Elective
E.E. 674	Mechanical Languages	3	3	Elective
E.E. 675	Programming Languages	3	3	Elective
Stat. 601	Intermediate Statistics	3	3	Elective
Stat. 602	Proseminar in Mathematical Statistics I	3	3	Elective
Stat. 602	Proseminar in Mathematical Statistics II	3	3	Elective
Stat. 623	Design of Experiments and Experimental Optimization	3	3	Elective
Stat. 624	Regression and Variance Analysis	3	3	Elective
Stat. 625	Multivariate Analysis I	3	?	Elective
Stat. 625	Multivariate Analysis II	3	3	Elective

Faculty

The faculty responsible for the program and courses related to the program were:

Joseph M. Scandura, Ph.D., Program Director and Associate Professor of Education
Neal Gross, Ph.D., Dean of the Graduate School of Education
Morris S. Viteles, Ph.D., Emeritus Professor of Psychology (Former Dean of the Graduate School of Education)
Justin [illegible], Ph.D., Professor of Psychology
Andrew R. Baggaley, Ph.D., Professor of Education
Eugenio Calabi, Ph.D., Thomas A. Scott Professor of Mathematics
John W. Carr, Ph.D., Professor of Electrical Engineering
William B. Castetter, Ph.D., Professor of Education (Former Acting Dean of the Graduate School of Education)
Frederick B. Davis, Ed.D., Professor of Education
James M. G. Fell, Ph.D., Professor of Mathematics
Peter J. Freyd, Ph.D., Professor of Mathematics
Henry Gleitman, Ph.D., Professor of Psychology
Henry Hiz, Ph.D., Professor of Linguistics
Francis W. [illegible]in, Ph.D., Professor of Psychology
Albert Nijenhuis, Ph.D., Professor of Mathematics
Dock Sang Rim, Ph.D., Professor of Mathematics
David Shale, Ph.D., Professor of Mathematics
Steven Shatz, Ph.D., Professor of Mathematics
Richard L. Solomon, Ph.D., Professor of Psychology
Erling E. Boe, Ph.D., Associate Professor of Education
Roger L. Sisson, MS, Associate Professor of Operations Research and Statistics
David R. Williams, Ph.D., Associate Professor of Psychology
Joanna P. Williams, Ph.D., Associate Professor of Education
John Corcoran, Ph.D., Associate Professor of Linguistics
Zoltan Domotor, Ph.D., Assistant Professor of Philosophy
Charles E. Dwyer, Ph.D., Assistant Professor of Education
Dorothy L. Jones, Ph.D., Assistant Professor of Education
Robert C. Jones, Ph.D., Assistant Professor of Operations Research and Statistics
Sandra W. Scarr, Ph.D., Assistant Professor of Education
John H. Durnin, Ph.D., Lecturer on Education (part time)
George F. Lowarre, Ph.D., Lecturer on Education (part time)
George Zampetti, M.S., Supervisor of Student Teaching (part time)

Trainees

There were a total of 26 students enrolled in the program over the past six years. Of these 17 received some support from the U.S. Office of Education. Of these students enrolled in the program, five students received Ph.D.'s, one received a Ph.D. from Louisiana State University), five students received Master degrees and five students expect to receive Ph.D.'s during the 1972-73 academic year.

U.S. Office of Education Supported Trainees

Mr. Louis Ackler, age 28

Education	Overall GPA	Math GPA
U.S. Air Force Academy, 1961-64	2.93	3.34
B.A. University of Denver, 1965	3.47	3.50
University of Penna. (in program) 1968-69	3.88	4.0
1969-70	3.25	

Graduate Record Examination: December, 1967

Scores: 610 Verbal Percentile Rank 73
790 Quantitative Percentile Rank 97
730 Advanced Math Percentile Rank 68

Language Examinations passed: French: 8/69
Ph.D. Preliminary Examination: Not taken
Research: The effects of irrelevant attributes and operations on rule learning (with D. Voorhies)
Publications: None.
Present position: Mathematics teacher, Council Rock School District
Degree: M.A., 1970

Miss Margaret Ahern, age 38

Education	Overall GPA	Math GPA
B.A. College of St. Rose, 1967	3.55	4.0
University of Penna. (in program) 1967-1968	3.25	3.0

Graduate Record Examination:

Scores: 580 Verbal
610 Quantitative
530 Advanced Math

Language Examinations passed: None taken
Ph.D. Preliminary Examination: Not taken
Research: None
Publications: None
Present position: Unknown

Mrs. Joan Barksdale, age 28

Education	Overall GPA	Math GPA
B.A. University of Massachusetts, 1966	3.47	3.5
University of Penna. (in program) 1966-1969	3.42	3.5

Graduate Record Examination: April, 1967

Scores: 540 Verbal Percentile Rank 69
680 Quantitative Percentile Rank 97
750 Advanced Math. Percentile Rank 96

Language Examinations passed: Spanish 12/67
Ph.D. Preliminary Examination: Not taken
Research: An unexpected relationship between failure and subsequent mathematics learning. Psychology in the Schools, 1969, 4, 379-381. (with Scandura, J. M; Durnin, J.; and McGee, R.)
Present Position: Unknown
Degree: M.A., 1969

Dr. Joanna Burris, age 42

Education		Overall GPA	Math GPA
B.A. Trenton State College, 1943		3.0	
M.S. University of Penna., 1966		3.75	4.0
University of Penna (in program)	1966-1967	3.1	3.2
	1967-1968	3.4	3.0
	1968-1969	3.6	

Graduate Record Examination: Admitted before required
Language examinations passed: French, 4/67 and German, 6/67
Ph.D. Preliminary Examination: Passed, 4/69
Research: Dissertation
Publications:
Present position: Assistant Professor of Mathematics and Coordinator of Developmental Research in Mathematics Education, Burlington County College
Degree: Ph.D., 1972

Dr. John Durnin, age 34

Education:		Overall GPA	Math GPA
B.A. Oregon College of Education, 1963		3.0	3.0
M.S. University of Utah, 1966		3.3	3.3
University of Penna (in program)	1966-1967	3.6	3.75
	1967-1968	3.6	3.0
	1968-1969	3.9	3.0

Graduate Record Examination: June, 1967

Scores: 540 Verbal Percentile Rank 77
650 Quantitative Percentile Rank 94
640 Advanced Math Percentile Rank 86

Language examinations passed: French, 10/67 and Spanish, 4/68
Ph.D. Preliminary Examination: Passed, 11/69
Research: Basic research in mathematics education (See publications). Assisted with development of mathematics text for elementary teachers.
Publications: Extra scope transfer in learning mathematical strategies. Journal of Educational Psychology, 1968, 59, 301-321. (with Scandura, J. M.)
An unexpected relationship between failure and subsequent mathematics learning. Educational Studies in Mathematics Learning, 1969, 1, 247-251. (with Scandura, Barksdale and McGee)
Present position: Research Associate, University of Pennsylvania
Degree: Ph.D., 1971

Dr. Walter Ehrenpreis, age 39

Education:		Overall GPA	Math GPA
B.S. Central Connecticut State, 1954		3.3	3.5
M.A. University of Conn., 1959		3.3	3.3
Post Masters, University of Pennsylvania		3.8	3.8
University of Penna. (in program)	1967-1968	3.7	
	1968-1969	4.0	

Graduate Record Examination: Admitted before required
Language examinations passed: German 6/67, French 10/67
Ph.D. preliminary examination: Passed, 4/69
Research: Assisted with development of mathematics text for elementary teachers. Dissertation
Publications: An Algorithmic Approach to Mathematics Concrete Behavior Foundations (with Scandura, J. M., Durnin, J. H., and Luger, G.)

Present Position: Associate Professor of Mathematics and Mathematics Education, Trenton State College
Degree: Ph.D., 1972

Miss Francine Endicott, age 24

Education:		Overall GPA	Math GPA
B.A., Fontbone College, 1968		3.8	3.8
Univ. of Penna. (in program)	1968-69	3.75	3.66
	1969-70	3.40	

Graduate Record Examination: October, 1967

Scores:		
710 Verbal	Percentile Rank	92
710 Quantitative	Percentile Rank	88
620 Advanced Math	Percentile Rank	45

Language Examinations passed: French, 1/70; German, 9/70
Ph.D. Preliminary Examination: Passed 9/71
Research: Rule generality in the selection of mathematical rules
Publications: None
Present position: Student
Degree expected: Ph.D., 1972

Miss Judith Gera, age 27

Education:	Overall GPA	Math GPA
B.S. California State College, 1966	3.2	3.5
University of Penna. (in program) 1966-69	3.33	

Graduate Record Examination: Not taken
Language Examinations Passed: None taken
Research:
Publications: None
Present Position: Unknown
Degree: M.S., 1967

Dr. Gerald Goldin, age 28

Education:	Overall GPA	Math GPA
B.A., Harvard University, 1964	3.4	3.7
M.A. Princeton, 1966		
Ph.D., Princeton, 1969		

Graduate Record Examination: January, 1964

Scores: 710 Verbal
790 Quantitative
920 Advanced Physics

Language Examinations Passed: None required
Ph.D. Preliminary Examination: Not taken
Research: Mathematical Models for Theory of Knowledge and Structural Learning
Publications: 1. Non-Relativistic Current Algebras as Unitary Representations of Groups, Journal of Math. Physics, 1971. (2) Lie Algebras of Local Currents and their Representatives (with D. H. Sharp), 1969 Battelle Summer Recontres Proceedings.
Present Position: Assistant Professor of Education, University of Pennsylvania

Sister Jeannine Gramick, age 29

Education:	Overall GPA	Math GPA
B.A. College of Notre Dame, Md. 1965	3.6	3.6
M.A. University of Notre Dame, 1969	3.61	3.61
University of Penna., 1969-1970	3.6	3.0

Graduate Record Examination: Feb. 1969, and Advanced Math, May, 1965.

Scores: 630 Verbal Percentile Rank 76
660 Quantitative Percentile Rank 92
750 Advanced Math Percentile Rank 71

Language Examinations Passed: French, 10/70; German, 6/70
Ph.D. Preliminary Examination: Passed, 9/71
Research: Assisted in the development of new materials for teacher training. Dissertation
Publications: None
Present position: Student
Degree expected: Ph.D., 1972

Mrs. Linda Hunsicker, age 24

Education:	Overall GPA	Math GPA
B.A. University of Penna., 1969	3.17	3.36

Graduate Record Examination: October, 1969

Scores: 650 Verbal
590 Quantitative
640 Advanced English

Language Examinations passed: None taken
Ph.D. Preliminary Examination: Not taken
Research:
Publications: None
Present position: Unknown

Mr. Myron Kaplan

Education:		Overall GPA	Math GPA
B.A. Temple University, 1966		3.77	3.94
M.A. University of Penna., 1968		3.42	3.42
Univ. of Penna. (in program)	1968-1969	3.6	
	1969-1970	3.5	

Graduate Record Examination: January, 1966

Scores: 560 Verbal Percentile Rank 76
750 Quantitative Percentile Rank 99
730 Advanced Math Percentile Rank 96

Language Examinations Passed: French 9/66; German 5/68
Ph.D. Preliminary Examination: Not taken
Research: Developing new techniques and formulas for test item analysis
Publications: Two identities involving polygonal number exponents, The Pi Mu Epsilon Journal, Fall, 1965. Design and operation of the Boynton linear compressor program. Keystone Computer Associates, December, 1966. Weighting parts of a test or a test battery: An iterative procedure and proof of convergence. The Meter-Write, 1969, I (Technical Report in Measurement and Evaluation at U. of Penna.) Considerations in selecting test items according to difficulty. Lunneborg, C. E. (Ed.), Monograph in Commeration of Paul Horst's Work. Seattle: University of Washington (in press).
Present Position: Assistant Professor of Mathematics, Bucks County Community College
Degree Expected: Ph.D., on leave

Dr. George Lowerre, age 39

Education:		Overall GPA	Math GPA
A.B. Hamilton College, 1954		3.7	4.0
M.A. Cornell University, 1957			
Post Masters, Univ. of Washington		4.0	4.0
Univ. of Penna. (in program)	1967-1968	3.75	4.0
	1968-1969	4.0	4.0

Graduate Record Examination: Advanced Math, March 1967

Score: 950 Advanced Math Percentile Rank 99

Language Examinations Passed: French 4/68; German 4/68
Ph.D. Preliminary Examination: Passed, 11/69
Research: Assisting with writing of a mathematics text for elementary teachers.
Publications: Solutions of Problems to Fibbonacci Quarterly
Present position: Assistant Professor of Mathematics and Education, Our Lady of Angels College
Degree: Ph.D., 1972

Mr. Robert McGee, age 36

Education:		Overall GPA	Math GPA
B.A. Holy Cross College 1958		3.2	2.8
M.S. Notre Dame, 1960		2.8	2.8
M.Ed. S.U.N.Y. at Buffalo, 1968		3.3	3.3
University of Penna (in program)	1966-1967	3.6	4.0
	1967-1968	3.5	3.0
	1968-1969	3.5	3.5

Graduate Record Examination: January, 1958

Scores: 650 Verbal Percentile Rank 90
700 Quantitative Percentile Rank 99

Language Examinations Passed: German, 6/68 and French, 8/68
Ph.D. Preliminary Examination: Passed, 4/69
Research and Practicum: Developmental project to identify, measure and teach kindergarten children fundamental processes of mathematics (1966-1969). Practicum Experience with Bureau of Research, U. S. Office of Education (summer, 1967).

Publications: An unexpected relationship between failure and subsequent mathematics learning. Educational Studies in Mathematics 1969, 1, 247-251. (with Scandura, Barksdale and Durnin). A Note on a Very Elementary Proof, New York State Mathematics Teacher, June, 1968. Group Isomorphism: An Approach Using Cycle Graphs. New York State Mathematics Teacher, in press. Problem Solutions to Fibbonacci Quarterly.
Present Position: Chairman and Assistant Professor of Mathematics and Mathematics Education, Cabrini College
Degree expected: Ph.D., on leave.

Mr. Christopher Toy, age 27

Education:		Overall GPA	Math GPA
B.A. San Francisco State College,	1965	3.7	3.6
M.A. San Francisco State College,	1967	3.8	
University of Penna. (in program)	1967-1968	3.6	3.5
	1968-1969	3.75	3.5
	1969-1970	3.33	

Graduate Record Examination: May, 1965

Scores:		
640 Verbal	Percentile Rank	88
680 Quantitative	Percentile Rank	96
880 Advanced Math	Percentile Rank	99

Language Examinations passed: Not taken
Ed.D. Preliminary Examination: Not taken
Research: Teacher education in mathematics.
Publications: None
Present Position: Assistant Professor of Mathematics, New Hampshire College of Accounting and Commerce.
Degree: MA., 1970

Mr. Donald Voorhies, age 26

Education:		Overall GPA	Math GPA
B.S. Loyola University, 1967		3.9	4.0
University of Penna (in program)	1967-1968	3.75	3.33
	1968-1969	3.75	3.0
	1969-1970	4.0	4.0

Graduate Record Examination: November, 1966

Scores:		
610 Verbal	Percentile Rank 84
730 Quantitative	Percentile Rank 99
380 Advanced Math	Percentile Rank 99

Language Examinations Passed: French, 6/68 and German, 8/68
Ph.D. Preliminary Examination: Passed, 9/70
Research: The effect of relevant attributes and operations on rule learning (with Louis Ackler). Investigation of logical rule usage with high school students.
Publications: The role of irrelevant attributes and irrelevant operations in rule learning. Journal of Educational Psychology, 1971, 62(4), 352-356. (with Scandura).
Present Position: Student
Degree expected: Ph.D., 1972

Mr. Wallace Wulfeck, age 25

Education:	Overall GPA	Math GPA
B.A. University of California, Santa Barbara, 1968	2.82	3.00
M.A., U.C.S.B., 1971	3.10	4.0
University of Penna. (in program) 1971-72	3.75	

Graduate Record Examination: October 1970

Scores:	
750 Verbal	Percentile Rank 99
780 Quantitative	Percentile Rank 98
660 Advanced Education	Percentile Rank 99

Language Examinations Passed: To be taken
Ph.D. Preliminary Examination: To be taken
Research: Examination of student attitude and teacher attitude toward mathematics and its association with student's achievement in mathematics.
Previous positions: Math Teacher, Goleta Valley H.S., Goleta, California, 9/69-6/71
Degree expected: Ph.D., 1973

Trainees not supported by U.S. Office of Education

Dr. Lawerence A. Couvillon, age 33

Education:	Overall GPA	Math GPA
B.S., Louisiana State University, 1968	3.5	3.7
M.A., Louisiana State University, 1964	3.9	4.0
M.S., Louisiana State University, 1967	3.8	3.8
University of Penna. (in program) 1967	3.5	
Ph.D., Louisiana State University, 1970		

Graduate Record Examination:

Scores: 500 Verbal
670 Quantitative
680 Advanced Math

Present Position: Assistant Professor of Mathematics Education, Florida State University

Mr. Nathan Fain, age 42

Education:	Overall GPA	Math GPA
B.S., Knoxville College		
University of Penna (in program) 1967	2.3	4.00

Graduate Record Examination

Scores: Unknown

Language Examinations Passed: None taken
Ph.D. Preliminary Examination: Not taken
Research:
Publications: None
Present Position: Unknown

Miss Julia Gatte[illegible], age 33

Education:	Overall GPA	Math GPA
A.B. Gettysburg College, 1960	3.61	3.82
M.S. Purdue University, 1963	3.07	3.07
University of Penna. (in program)		

Graduate Record Examination: February, 1969

Scores:		
	540 Verbal	Percentile Rank 51
	780 Quantitative	Percentile Rank 99
	740 Advanced Math	Percentile Rank 69

Language Examinations passed: Not taken
Ed.D. Preliminary Examination: Not taken
Research:
Publications: None
Present position: Unknown
Degree: M.A., 1971

Mrs. Julia Hirsh, age 39

Education	Overall GPA	Math GPA
B.A. Middlebury College, 1958	3.82	3.83
M.A. University of Pennsylvania, 1969	3.86	3.86
University of Penna. (in program)		

Graduate Record Examination: ;Not taken
Language Examinations passed: French, 9/66 and German, 10/68
Ph.D. Preliminary Examination: In Mathematics, passed 1969
Research: Maryland Math Project, University of Maryland, assisted with rewriting and evaluating mathematics text for elementary teachers.
Publications: None
Present Position: Student
Degree expected: Ph.D., 1973

Mr. Joseph Kudera, age 32

Education	Overall GPA	Math GPA
B.A. Jersey City State College	3.6	3.6
M.A.T. Harvard University	3.5	
University of Penna. (in program)		

Graduate Record Examination

Scores:	
	520 Verbal
	580 Quantitative
	890 Advanced Math

Language Examinations Passed: None taken
Ph.D. Preliminary Examination: Not taken
Research:
Publications: None
Present Position: Director Computer Services, University of Pennsylvania

Mr. George Luger, age 31

Education:	Overall GPA	Math GPA
B.A. Gonzaga University, 1963	3.1	3.6
M.A. Gonzaga University, 1965	3.6	3.6
M.A. University of Notre Dame, 1969	3.2	3.2
University of Penna. 1969-1970	3.16	

Graduate Record Examination: January, 1967

Scores:		
640 Verbal	Percentile Rank 90	
740 Quantitative	Percentile Rank 99	
640 Advanced Math	Percentile Rank 86	

Language Examinations Passed: French, 10/70
Ph.D. Preliminary Examinations: Passed
Research: Dissertation
Publications: An algorithmic approach to Mathematics: concrete behavioral foundations (with Scandura, J. M.; Durnin, J. H. and Ehrenpreis, W.))
Present Position: Supervisor of Student Teaching, University of Pennsylvania.
Degree expected: Ph.D., 1972

Mrs. Linda Moulton, age 28 (part-time student)

Education:		Overall GPA	Math GPA
A.B. Bryn Mawr College, 1965			
M.A.T. Harvard University, 1966		3.2	2.7
University of Pennsylvania	1967-1968	3.5	3.5
	1968-1969	3.5	3.0
	1969-1970	3.0	

Graduate Record Examination: November, 1964

Scores:		
590 Verbal	Percentile Rank 82	
650 Quantitative	Percentile Rank 94	
600 Advanced Math	Percentile Rank 75	

Language Examinations passed: Not taken
Ed.D. Preliminary Examination: Not taken
Research
Publications: None
Present position: Assistant Professor of Mathematics, Beaver College
Degree expected: Ed.D., on leave

Mr. Gerald Satlow, age 30

Education:	Overall GPA	Math GPA
B.A. Antioch College, 1965	2.9	2.8
M.A.T. Wesleyan University, 1967	3.8	3.75
University of Pennsylvania (in program)		
1967-1968	3.5	
1968-1969	3.5	

Graduate Record Examination: January, 1965

Scores:		
710 Verbal	Percentile Rank	98
760 Quantitative	Percentile Rank	99
650 Advanced Math	Percentile Rank	88

Language Examinations passed: Not taken
Research: Rule generality in the selection of mathematical rules (with F. Endicott). Analysis of current curricular materials for grades K-6.
Publications: An Analysis of existing curricular materials in mathematics phase one (K-6). Philadelphia: Research for Better Schools, Inc., 1968. (with Scandura)
Present position: Assistant Professor of Mathematics and Mathematics Education, Cabrini College

Miss Agnes Rash, age 29 (part-time student)

Educatior	Overall GPA	Math GPA
B.A. Holy Family College, 1963	2.85	3.7
M.S. Notre Dame University, 1966	3.6	3.6
University of Pennsylvania (in program)		
1968-1969	3.5	4.0
University of Pennsylvania (not in program)		
1969-		

Graduate Record Examination: July, 1968

Scores:		
	620 Verbal	Percentile Rank 62
	780 Quantitative	Percentile Rank 99
	840 Advanced Math	Percentile Rank 87

Language Examinations passed:
Ph.D. Preliminary Examination:
Research: Dissertation
Publications: None
Present position: Instructor in Mathematics, St. Joseph's College
Degree expected: Ph.D., 1972

Practicum Training

In the program there were two major areas of research specialization: basic research in structural learning and developmental research in mathematics education. Practicum training in basic research involved theoretical, experimental and analytical investigations into the nature of mathematical and structural learning. Developmental research in mathematics education involved the investigation of mathematical abilities of kindergarten children, the analysis of elementary school curricular materials, the development of teacher education materials and the development of two sets of self instructional materials for teaching basic arithmetic skills, one for children and the other for adults.

An important result of practicum, besides experience, was that the trainees co-authored several publications, presented papers at professional meetings and made recognized contributions to publications of the project director.

Publications coauthored by trainees:

Scandura, J. M., and Satlow, J., An analysis of existing curriculuar materials in mathematics phase one: (K-6) Philadelphia: Research for Better Schools, 1968.

Scandura, J. M. and Durnin, J. H. Extra-scope transfer in learning mathematical strategies. Journal of Educational Psychology, 1968, 59, 350-354.

Scandura, J. M., Barksdale, J., Durnin, H., and McGee, R., An unexpected relationship between failure and subsequent mathematics learning. Psychology in the Schools, 1969, 4, 379-381.

Scandura, J. M., and McGee, R., An exploratory investigation of basic mathematical abilities of kindergarten children. Report No. 51, December 1, 1969, Structural Learning Series. Mathematics Education Research Group, Graduate School of Education, University of Pennsylvania, Philadelphia, Pennsylvania. (Also in Educational Studies in Mathematics, 1972, in press.)

Ehrenpreis, W. and McGee, R. Research implications for the elementary school: From the laboratory to the classroom. Report No. 53, March 1, 1970, Structural Learning Series. Mathematics Education Research Group, Graduate School of Education, University of Pennsylvania, Philadelphia, Pennsylvania.

Scandura, J. M. and Voorhies, D. The role of irrelevant attributes and irrelevant operations in rule learning. Journal of Educational Psychology, 1971, 62, 352-356.

Scandura, J. M., Ehrenpreis, W., Luger, G., and Durnin, J. An algorithmic approach to Mathematics: Concrete behavioral foundations. New York: Harper and Row, 1971.

Scandura, J. M. and Durnin, J. H. Assessing behavior potential: Adequacy of basic theoretical assumptions. Report No. 62, Structural Learning Series. Mathematics Education Research Group, Graduate School of Education, University of Pennsylvania, Philadelphia, Pennsylvania.

Durnin, J. H. and Scandura, J. M. An algorithmic approach to assessing behavior potential: Comparison with item forms and hierarchical analysis. Report No. 63, Structural Learning Series, Mathematics Education Research Group, Graduate School of Education, University of Pennsylvania, Philadelphia, Pennsylvania.

Ehrenpreis, W. and Scandura, J. M. An algorithmic approach to curriculum construction in mathematics: A field test. Report No. 64, Structural Learning Series. Mathematics Education Research Group, Graduate School of Education, University of Pennsylvania, Philadelphia, Pennsylvania.

Lowerre, G. and Scandura, J. M. Conceptually based development of individualized materials for critical thinking based on logical inference. Report No. 65, Structural Learning Series. Mathematics Education Research Group, Graduate School of Education, University of Pennsylvania, Philadelphia, Pennsylvania.

Publications in which trainees obtained practicum experience

Scandura, J. M. Research in psychomathematics. The Mathematics Teacher, 1968, 61, 581-591.

Scandura, J. M. The formulation of research on subject matter learning. Psychology in the Schools, 1968, 5, 330-341.

Scandura, J. M. and Roughead, W. G. "What is learned" in mathematical discovery. Journal of Educational Psychology, 1968, 59, 283-289.

Scandura, J. M. New Directions for theory and research on rule learning: I. A set function language. Acta Psychologica, 1968, 28, 301-321.

Scandura, J. M. A research basis for mathematics education. High School Journal, 1970, 53, 264-280.

Scandura, J. M. The role of rules in behavior: Toward an operational definition of what (rule) is learned. Psychological Review, 1970, 77, 516-533.

Scandura, J. M. A theory of mathematical knowledge: Can rules account for creative behavior? Journal for Research in Mathematics Education, 1971, 2, 103-196.

Scandura, J. M. Deterministic theorizing in structural learning: Three levels of empiricism. Journal of Structural Learning, 1971, 3, 21-53.

Scandura, J. M. What is a rule? Journal of Educational Psychology, 1972, in press.

Scandura, J. M. A plan for the development of a conceptually based mathematics curriculum for disadvantaged children. Instructional Science, 1972, in press.

Scandura, J. M. An algorithmic base for curriculum construction in mathematics (A theory of mathematical knowledge). In Lamon, W. E. (Ed.) Learning and the Nature of Mathematics. Chicago: Science Research Associates, Inc., 1971.

Scandura, J. M. Structural Learning I. The theory and empirical research (with implications for Artificial Intelligence, Education, Linguistics, Logic, and Mathematics as well as Behavioral Science) New York: Gordon and Breach Science Publishers, 1972, in press.

Scandura, J. M. (Ed.) Structural learning II. Issues and approaches. New York: Gordon and Breach Science Publishers, 1972, in press.

Papers presented at professional meetings by trainees (speaker is underlined)

Scandura, J. M. and Durnin, J. H., Rule Generality and Consistency in Mathematics Learning. Annual Meeting of the American Educational Research Association, New York, February, 1967.

Scandura, J. M. and McGee, R. Algorithm Learning and Problem Solving. Annual Meeting of the American Educational Research Association, New York, February, 1967.

Scandura, J. M. and Durnin, J. H. Extra-scope Transfer in Learning Mathematical Rules. Annual Meeting of the American Educational Research Association, Chicago, February, 1968.

Scandura, J. M. and Voorhies, D. The role of irrelevant attributes and irrelevant operations in rule learning. Annual Meeting of the American Educational Research Association, Chicago, March, 1970.

Scandura, J. M. Three Deterministic Theories of Structural Learning: Knowledge Performance and Memory.
with
Durnin, J. H. Performance: Assessing Behavior Potential
Ackler, L. Learning: On combining Higher and Lower Order Rules
Endicott, F. Motivation: Rule Selection
Voorhies, D. Memory: Information Processing Capacity of Humans.
First Annual Meeting on Structural Learning, Philadelphia, April, 1970.

Lowerre, G. Teaching Logic in the Elementary School. Meeting on Teacher Education in Mathematics, University of Pennsylvania, Philadelphia, April, 1970.

Ehrenpreis, W. A Characterization of the Knowledge Underlying Scandura's Mathematics: Concrete Behavioral Foundations. Meeting on Teacher Education in Mathematics, University of Pennsylvania, Philadelphia, April, 1970.

Scandura, J. M. (Chairman), Durnin, J. H., Ehrenpreis, W., Gramick, J. and Lowerre, G. Symposium on Practical Implications of Research in Structural Learning. Pennsylvania Educational Research Association, Philadelphia, October, 1970.

Scandura, J. M. (Chairman), Durnin, J. H., Ehrenpreis, W., Gramick, J. and Lowerre, G. Symposium. Research in Structural Learning: Emperical Research and Practical Implications. Annual Meeting of the American Educational Research Association. New York, February, 1971.

Scandura, J. M. Structural Learning Progress Report
with
Durnin, J. H. Assessing Behavior Potential
Endicott, F. Studies in Rule Selection
Voorhies, D. Information Processing Capability of Human Subjects
Second Annual Meeting on Structural Learning, Philadelphia, April, 1971

Durnin, J. H. and Scandura, J. M. An Algorithmic Approach to Assessing Behavior Potential: Comparison with Item Forms and Hierarchical Analysis. Annual Meeting of the American Educational Research Association, Chicago, April, 1972

Scandura, J. M. and Voorhies, D. Information Processing Capacity of Humans. Annual Meeting of the American Educational Research Association, Chicago, April, 1972.

Scandura, J. M., Ackler, L., Durnin, J., Endicott, F. Problem Solving Under the Memory Free Paradigm. Annual Meeting of the American Educational Research Association, Chicago, April, 1972.

Lowerre, G. Chairman of Session on Empirical Studies in Structural Learning. Annual Meeting of the American Educational Research Association, Chicago, April, 1972.

Requirements for the Ph.D. and Ed. D.

in

MATHEMATICS EDUCATION RESEARCH

GRADUATE SCHOOL OF EDUCATION
UNIVERSITY OF PENNSYLVANIA

GENERAL NATURE OF THE PROGRAM

Ph.D. A minimum of twenty course units and proficiency in two research tools (e.g., modern foreign languages, computer technology) are required for the Ph. D. as outlined in the Graduate School Bulletin.

Ed.D. In general, the Ed.D. in mathematics education is similar to the Ph.D. with: (1) somewhat greater breadth required in education, (2) a minimum of 22 course units, (3) no language requirement, and (4)greater flexibility allowed in the dissertation. Ordinarily, an Ed.D. candidate undertakes a dissertation involving development and/or implementation in mathematics education.

Residency. The program requires a heavy committment and the student should plan to pursue the program on a full-time basis. Typically, the student may expect to complete the requirements for the degree within four full years of study. Although no formal recognition is given to master's degrees, the total time required may be reduced where the previous work has direct relevance to the student's program of study. For example, students entering the program with a strong master's degree in mathematics, logic, formal linguistics, statistics, or experimental psychology may normally expect to complete the requirements for the degree in about three years.

Prerequisites. Students generally are expected to attain or have attained as a minimum level of competency the equivalent of a University of Pennsyl-

vania bachelor's degree in mathematics. In those instances where students take undergraduate courses in mathematics to bring themselves up to this level, the courses taken normally do not count as credit toward the degree.

This requirement may be reduced or eliminated for special students with a strong behavioral background or a strong background in some other area which bears directly on the activities of the program.

Core. All students normally take the full sequence of courses and seminars in mathematics education: Research in Mathematics Education, 729*; Seminar on Innovation in Mathematics Curriculum and Instruction, 820; Seminar on the Psychology of Mathematics Learning, 830; Practicum in Mathematics Education, 830; and Research Seminar in Mathematics Education, 929.

The Research seminar (929) is open to Post-Doctoral students as well as to students in the program.

Generally speaking, students should also expect to complete Proseminar in Educational Psychology, 660, or Proseminar in General Psychology (Psychology 600); Experimental Design, 867 or 871; and a course in Linguistics or Logic as part of the CORE.

Areas of Specialization. There are two major areas of specialization: basic research and development. Current emphases in the former area involve theoretical, experimental, and analytical investigations into the nature of mathematics and structural learning. In the developmental area, the primary emphasis is on teacher education, although considerable attention is also given to school curriculum objectives, measurement and teaching methods.

Within each area of specialization, students will ordinarily elect to emphasize either mathematics or behavioral science.

Mathematical Emphasis: The minimum requirement is for the student to attain the equivalent of a University of Pennsylvania Master's degree in Mathematics, or other mathematical area represented by some Graduate Group in the GSAS. The num-

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*Course numbers on this page refer to courses in the Graduate School of Education unless otherwise specified.

ber of required courses will be contingent upon the student's background, but in any case, students will generally take at least one graduate course in relevant departments in order to develop personal relationships with faculty members.

Behavioral Emphasis: The student will normally take most of his course work (beyond the prerequisites) in the behavioral sciences. In certain cases, a philosophical emphasis may be allowed.

Research Experience. A distinguishing feature of the program is the requirement of active participation in basic research and/or development in mathematics education.

Evaluation. A student is expected to maintain a superior level of performance in his studies. If his grade point average falls below 3.5, at the end of the first year, he must receive special permission to continue in the doctoral program. During the Spring semester of his second year, if a student's work is marginal, he will normally be recommended for a terminal master's degree in mathematics education. In this evaluation, competence in research and/or development and implementation will be weighted most heavily.

Check List of Degree

Requirements with Suggested Deadlines

1.	Evaluation of transfer credits (if applicable)	Spring - 1st year
2.	Preliminary Examination	Fall or Spring - 1st year
*3.	Attain 3.5 G.P.A. in course work by end of first year.	end Spring term - 1st year
4.	Language requirements (preferably completed by end of first year of study)	Summer - 1st year
5.	Satisfactory performance in 1st year research practicum (or other approved activity)	September - 2nd year
*6.	Minor Examinations	Fall or Spring - 2nd year
*7.	Student informed if second year research is unsatisfactory	Spring - 2nd year
8.	Satisfactory completion of second year project	September - 3rd year
*9.	Final Major Examination	End of 3rd year
10.	Satisfactory completion of third year project	September - 4th year
11.	Submit Dissertation proposal	September - 4th year
*12.	Defense of proposal	October - 4th year
*13.	Satisfactory completion of dissertation	Spring - 4th year
14.	Final oral examination	Spring - 4th year (or following Fall)

* Indicates a major step toward the degree.

List of Elective Courses

Math. 365	Foundations of Analysis
Math. 370 - 371	Algebra
Math. 380 - 381	Honors Analysis
Math. 390 - 391	Honors Algebra
Math. 410	Complex Variables
Math. 420	Theory of Differential Equations
Math. 430	Probability
Math. 440	Numerical Analysis
Math. 460	Differential Geometry
Math. 510	Topics in Analysis
Math. 520	Topics in Geometry - Topology
Math. 530	Topics in Algebra
Math. 600	Geometric Analysis
Math. 601	Real Analysis
Math. 602	Algebra (2 Semesters)
Math. 607	General Topology
Math. 609	Complex Analysis
Math. 641	Introduction to Algebraic Topology (Prerequisites, Topology and Algebra)
Math. 691	Theory of Logical Models (2 Semesters)
Educ. 660	Proseminar in Educational Psychology
Educ. 761	The Psychology of Human Learning
Educ. 762	Psychology of Human Development
Educ. 768, 769	Test Construction I, II (2 Semesters)
Educ. 863	Seminar in Educational Psychology
Educ. 867	Experimental Design and Analysis of Variance and Covariance

Educ. 871, 872	Seminar in Experimental Design I, II
Psych. 600, 601	Proseminar in General Psychology
Psych. 710	Developmental Psychology (prerequisite: Proseminar in Psych.)
Psych. 721	Learning Theories (prerequisite: Proseminar in Psych.)
Psych. 725	Verbal Learning and Behavior (prerequisite: Proseminar in Psych.)
Psych. 750	Mathematical Learning Theories (prerequisite: Proseminar in Psych.)
Phil. 436	Introduction to Philosophy of and Logical Foundations of Mathematics
Phil. 524	Problems in Logic and Modern Methods (2 semesters)
Phil. 536	Set Theory
Ling. 602	Formal Linguistics
Ling. 603	Mathematical Systems in Linguistic Structure
Ling. 630	Proseminar in Formal Linguistics
Ling. 642	Mathematical Logic (2 semesters)
Ling. 643	Theory of Recursion (Prerequisite: Mathematical Logic)
Ling. 644	Seminar in Logic (prerequisite: Mathematical Logic)
Ling. 645	Linguistics and Mathematical Logic
Ling. 659	Linguistic Transformations

E.E. 523	Intro. to Digital Comp.: Programming and Logic
E.E. 640	Theory of Automata (prerequisite: Consent of instructor)
E.E. 674	Mechanical Languages (prerequisite: Algebra, Logic, and Programming & Logic or Consent of instructor)
E.E. 675	Programming Languages (prerequisite: Programming and Logic)
Stat. 601	Intermediate Statistics (prerequisite: First course in Statistics)
Stat. 602-I & II	Proseminar in Mathematical Statistics and Statistical decision theory (2 Semesters)
Stat. 623	Design of Experiments and Experimental Optimization (prerequisite: Proseminar in Math. Stat. or equivalent)
Stat. 624	Regression and Variance Analysis (prerequisite: Course in Statistics and consent of instructor)
Stat. 625 I, II	Multivariate Analysis (2 Semesters)

SAMPLE PROGRAMS

Example 1. The program of a student with a bachelors degree in mathematics, which is not at the same level of degree requirement as the University of Pennsylvania's and with no or little background in psychology and who wishes to emphasize mathematics, might look as follows:

First Year

Fall Semester

Educ. 729	Research in Math Educ.	1 c.u.
Educ. 867	Exper. Design & Analysis of Var. and Covar.	1 c.u.
Math. 380	Honors Analysis	1 c.u.
Math. 390	Honors Algebra	1 c.u.

Spring Semester

Educ. 660	Prosem. in Educ. Psychology	1 c.u.
Educ. 839	Practicum in Mathematics Ed.	1 c.u.
Math. 381	Honors Analysis	1 c.u.
Math. 391	Honors Algebra	1 c.u.

Summer Sessions

Preparation for Language Exams

Research Assistance (Continuation of Practicum) or other approved activity

Second Year

Fall Semester		
Educ. 829	Sem. on Innov. in Math. Curr.	1 c.u.
Educ. 999	Independent Study (Research Proj.) or elective course	1 c.u.
Math. 600	Geometric Analysis	1 c.u.
Math. 607	General Topology	1 c.u.
Spring Semester		
Educ. 830	Sem. on Psych. of Math Learning	1 c.u.
Educ. 999	Independent Study (Research Proj.) or elective course	1 c.u.
Math.601	Real Analysis	1 c.u.
Math. 609	Complex Analysis	1 c.u.
Summer Sessions		
	Completion of 2nd year project or an approved activity.	

Third Year

Fall Semester		
Educ. 929	Res. Sem. in Math. Educ.	1 c.u.
Educ. 999	Independent Study	1 c.u.
Ling. 642	Mathematical Logic elective	1 c.u.
	elective	1 c.u.
Spring Semester		
Educ. 929	Res. Sem. in Math. Educ.	1 c.u.
Educ. 999	Independent Study	1 c.u.
Ling. 642	Mathematical Logic elective	1 c.u.
	elective	1 c.u.

Summer Sessions

Completion of 3rd year project

Prepare dissertation topic

Fourth Year

A student will register for Ed. 929 while working on the dissertation.

Example 2. The program of a student with a strong undergraduate degree in mathematics who wishes to emphasize behavioral research might look as follows:

First Year

Fall Semester		
Educ. 729	Research in Math. Educ.	1 c.u.
Educ. 871	Sem. in Experimental Design	1 c.u.
Educ. 761	Psych. of Human Learning	1 c.u.
Psych. 600	Prosem. in Gen. Psych.	1 c.u.
Spring Semester		
Educ. 839	Practicum in Mathematics Ed.	1 c.u.
Educ. 872	Sem. in Experimental Design	1 c.u.
Educ. 999	Independent Study (Research Proj.)	1 c.u.
Psych. 750	Math. Learning Theories	1 c.u.

Summer Sessions

Preparation for Language Exams

Research Assistance (continuation of Practicum)

or other approved activity

Second Year

Fall Semester

Educ. 929	Sem. on Innov. in Math. Curr. & Instr.	1 c.u.
Educ. 999	Independent Study	1 c.u.
Ling. 642	Mathematical Logic	1 c.u.
Psych. 721	Learning Theories	1 c.u.

Spring Semester

Educ. 930	Sem. on Psychology of Math. Learning	1 c.u.
Educ. 999	Independent Study	1 c.u.
Ling. 642	Mathematical Logic	1 c.u.
Psych. 725	Verbal Learning and Behavior	1 c.u.

Summer Sessions

Completion of 2nd year project or approved activity

Third Year

Fall Semester

Educ. 929	Res. Sem. in Math. Educ.	1 c.u.
Educ. 999	Independent Study	1 c.u.
Ling. 643	Recursion Theory	1 c.u.
	elective	1 c.u.

Spring Semester

Educ. 929	Res. Sem. in Math. Educ.	1 c.u.
Educ. 999	Independent Study	1 c.u.
Ling. 644	Seminar in Logic	1 c.u.
	elective	1 c.u.

Summer Sessions

Completion of 3rd year project

Preparing dissertation topic

Fourth Year

A student will register for Ed. 929 while working on his dissertation.

Example 3. The program of a student with a masters degree in mathematics or beyond (equivalent to Univ.of Penn. M.A.), with little psychology background and who wishes to emphasize mathematics, might look as follows:

Second Year

Fall Semester		
Educ. 729	Res. in Math. Educ.	1 c.u.
Educ. 999	Independent Study	1 c.u.
Educ. 867	Exper. Design & Anal. of Var. & Covar.	1 c.u.
Educ. 829	Seminar on Innov.in Math. Curr.	1 c.u.
Spring Semester		
Educ. 839	Practicum in Math. Educ.	1 c.u.
Educ. 999	Independent Study	1 c.u.
Educ 830	Sem. on Psych. of Math. Learning	1 c.u.
Educ. 660	Proseminar in Educ. Psych.	1 c.u.

Summer Sessions

Preparation for Language Exams

Research Project (cont. as Practicum)

Third year

Fall Semester

Educ. 929	Res. Sem. in Math. Educ.	1 c.u.
Educ. 999	Independent Study	1 c.u.
Math. 691	Theory of Logical Models	1 c.u.
Ling. 643	Recursion Theory	1 c.u.

Spring Semester

Educ. 929	Res. Sem. in Math. Educ.	1 c.u.
Educ. 999	Independent Study	1 c.u.
Math. 691	Theory of Logical Models	1 c.u.
	elective	1 c.u.

Summer Sessions

Completion of 3rd year project

Preparation of dissertation topic

Fourth Year

A student will register for Ed. 929 while working on the dissertation.