

AN INNOVATIVE INTEGRATED MATHEMATICS, SCIENCE, AND TECHNOLOGY EDUCATION TEACHER CERTIFICATION PROGRAM: CHARACTERISTICS AND FORMATIVE EVALUATION

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INTRODUCTION

The mathematics, science, and technology education communities are undergoing major reform in curriculum design, instructional approaches, and assessment practices. National standards for content, professional development, and assessment have been developed for mathematics, science, and technology education in the United States (National Council of Teachers of Mathematics, 1989, 1991, 1995, 2000; National Research Council, 1996; International Technology Education Association, 2000). Although promoting discipline-specific standards, these reform documents also recognize and recommend connections between and among the disciplines.

It is the union of science, mathematics, and technology that forms the scientific endeavor and that makes it so successful. Although each of these human enterprises has a character and history of its own, each is dependent on and reinforces the others. (American Association for the Advancement of Science, 1993, p. 3)

The science and mathematics are important to the understanding of the processes and meaning of technology. Their integration with the technology education curricula is vital. (American Association for the Advancement of Science, 1989, p. 9)

Given the nature of the reform efforts along with national goals for student achievement in mathematics and science, there is no doubt that we are in a new era where educators in mathematics, science, and technology must find ways to join forces to meet the curricular challenge before them. The consistent message heard across the disciplines emphasizes the need to collaborate, integrate, focus on literacy, facilitate inquiry and problem solving, and provide educational experiences that are of value to all students. To enable teachers to provide an integrated teaching and learning environment, changes in teacher preparation are essential.

Various attempts have been made to integrate science and mathematics methods courses in teacher education programs (Foss & Pinchback, 1998; Haigh & Rehfield, 1995; Lonning & DeFranco, 1994; Miller, Metheny, & Davison, 1997; Stuessy 1993; Watanabe & Huntley, 1998). These courses most often have been targeted at the preparation of preservice elementary or middle school teachers. Very few integrated science and mathematics methods courses have been designed for preservice secondary school teachers (see, for example, Austin, Converse, Sass, & Tomlins, 1992).

The literature associated with teacher preparation and integrated science, mathematics, and technology education is laden with obstacles or barriers including philosophical and epistemological differences, teacher content and pedagogical content knowledge, teacher perceptions and beliefs, school and administrative structures, assessment practices, and appropriate instructional resources (Lehman, 1994; Lehman & McDonald, 1988; Meier, Nicol, & Cobbs, 1998; Pang & Good, 2000; Wicklein & Schell, 1995). In the face of this challenge, however, is a consistent vision of teacher preparation for integrated teaching and learning in middle and secondary school levels that is characterized by peer collaboration and team teaching.

INTEGRATED M. ED. PROGRAM IN MATHEMATICS, SCIENCE, AND TECHNOLOGY EDUCATION (MSAT PROGRAM)

Goals and Objectives

The purpose of the Integrated M. Ed. Program in Mathematics, Science, and Technology Education at The Ohio State University is to provide a comprehensive master's program in mathematics, science, and technology education leading to the following teacher certifications: mathematics, biology, earth science, chemistry, physics, and comprehensive science for grades 7-12; technology education for grades K-12; and integrated math/science for grades 4-9. For admission into the program, applicants must have completed a bachelor's degree with 70 quarter hours of mathematics, science, and/or technology; a 2.7 Grade Point Average (GPA) overall; a 2.7 GPA in the undergraduate major; and a 2.7 GPA in mathematics, science, and technology course work. Consistent with the national standards in mathematics, science, and technology education and state certification requirements, the MSAT students acquire a solid background in content knowledge through their work in both their undergraduate major and graduate M. Ed. program. The courses in the MSAT M. Ed. Program are designed to develop student understanding in educational foundations, cognitive psychology and learning theory, pedagogical content knowledge, assessment, and the use of technology to meet the needs and interests of diverse learners and special populations. Moreover, the MSAT M. Ed. Program identifies and advances connections among the sciences and between mathematics, science, and technology thereby providing a unique academic structure to prepare teachers at middle and secondary school levels. These connections will enable these, traditionally separate discipline areas, to share human, physical, and fiscal resources for a more holistic preparation of teachers and other education-related professionals.

The MSAT Program is a five-quarter program leading to teacher certification and a Master's of Education degree. Two ubiquitous elements of the program are: (1) the integration of science, mathematics, and technology education through specially designed, team-taught content and methods courses and (2) a focus on current theory and research culminating in a student designed and implemented action research project. These elements have guided the development and implementation of the courses and field and clinical experiences for the MSAT M.Ed. Program and serve as a standard by which to monitor, evaluate, and improve the program.

MSAT M.Ed. Program Coursework

The MSAT M. Ed. Program assumes five quarters of full-time registration, beginning in the summer and continuing through the following summer. Students have opportunities to take specialty content courses related to state certification requirements in mathematics, the sciences, or technology education throughout the program. Credit hours in the MSAT M.Ed. Program can range from 63 to 78 quarter hours depending on certification area and previous student coursework.

The schedule of classes, courses titles, and quarter credit hours¹ are as follows:

First Summer Quarter (18 credits)

Integrated Pedagogy I (Standards)	Learning and Cognition
Integrated Content I (Mst) ²	Research Methods
Fundamental Ideas of School Mathematics	Specialty Content Course
Autumn Quarter (18 credits)	
Integrated Pedagogy II (Methods)	Internship (Middle/High School)
Integrated Content II (Smt) ³	Clinical Experience
Fundamental Ideas of School Science	Specialty Content Course

Winter Quarter (18 credits)

Integrated Pedagogy III (Diversity & Equity)	Integrated Content III (Tms) ⁴
Fundamental Ideas of School Technology	Specialty Methods
Internship (Middle/High School; 6 credits)	
<u>Spring Quarter (12 credits)</u>	
Student Teaching (Middle/High School; 10 credits)	Student Teaching Seminar (2 credits)
<u>Second Summer Quarter (12 credits)</u>	
Capstone Seminar	Specialty Content Courses (9 credits)

MSAT M. Ed. Exit Requirements

Students must complete an action research project and a comprehensive examination as exit requirements of the MSAT M. Ed. Program. The action research project must be approved by the student's advisor and a second faculty reader. Upon completion of the capstone seminar, each student submits a complete report of the project. In the final quarter of the program, each student writes a 4-hour examination focused on mathematics, science, and technology education. The examination is typically divided into three parts: (1) Foundations of Education, (2) Curriculum and Instruction, and (3) Candidate's Question Related to Action Research Project.

FORMATIVE EVALUATION OF THE MSAT M. ED. PROGRAM

Formative evaluation of the program includes both quantitative and qualitative data to describe student attitudes and perceptions related to the integration of mathematics, science, and technology education. The results of the qualitative analysis were used to review, modify, and build upon the results of the quantitative analyses so as to develop a more comprehensive understanding of the attitudes and perceptions of the M. Ed. students.

Subjects

Students in the initial three years, 1996-1999, of the MSAT M. Ed. Program participated in the study. The research analysis sample included 79 students (40 females and 39 males) with complete data. Twenty-seven of the students were math majors and 52 of the students were science majors. Since there was only one technology education major in the original sample, his data was omitted from the analysis.

¹All courses are 3 credit hours if not otherwise noted.

²Mst - focus on mathematics content with connections to science and technology content.

³Smt - focus on science content with connections to mathematics and technology content.

⁴Tms - focus on technology content with connections to mathematics and science content.

Instruments

A 20-item, 5-point semantic differential was used to measure student attitudes and perceptions related to the integration of mathematics, science, and technology education (SD-MSAT). A principal components factor analysis with varimax rotation identified two factors or scales. Scale 1: Value consists of 16 items with a range of 16 to 80 and Scale 2: Difficulty consists of 3 items with a range of 3 to 15. Cronbach standardized alpha reliability estimates for the pretest and posttest Value Scale and Difficulty Scale range from .57 to .92. One open-ended, free-response question was administered -- What does the integration of mathematics, science, and technology education mean to you? All instruments were administered prior to the beginning of coursework at the start of the June orientation meeting and then again at the completion of the program at the end of the Capstone Seminar.

Quantitative Analyses and Results

A multivariate analysis of variance was used to identify significant main and interaction effects of gender, major, and trial for the Value and Difficulty Scales associated with student attitudes and

perceptions related to the integration of mathematics, science, and technology education. Table 1 presents the results of the multivariate analysis of variance and followup univariate analyses of variance.

Table 1

Multivariate Analysis of Variance of Gender by Major by Trial Effects for Value and Difficulty Scales Associated With Attitudes and Perceptions Related to the Integration of Mathematics, Science, and Technology Education

Effect	F	DF	p
Gender x Major x Trial	0.52	2,74	.599
Major x Trial	0.36	2,74	.701
Gender x Trial	0.24	2,74	.791
Trial	6.71	2,74	.002*

Univariate Analysis of Variance	MS _E	F	DF	p
Value Scale Trial Effect	56.81	00.23	1,75	.636
Difficulty Scale Trial Effect	3.87	13.57	1,75	.000**

*p<.01. **p<.000

Table 1 indicates that the only significant effect was the main effect of trial, $F(2,74) = 6.71, p = .002$. Univariate analyses were used as a follow-up procedure to consider the effect of trial for each scale. The results of the univariate analyses of variance for student attitudes and perceptions related to the integration of mathematics, science, and technology education reveals that there is a significant difference between student scores on the pretest and posttest for the Difficulty Scale, $F(1,75) = 13.57, p = .000$. Inspection of the means for the Difficulty Scale reveals that student scores on the posttest ($M = 3.56, SD = 2.56$) were significantly higher than on the pretest ($M = 2.44, SD = 2.04$). At the completion of the program, students perceived more difficulty associated with the integration of mathematics, science, and technology education. There was no significant difference between student scores on the pretest ($M=64.72, SD=7.00$) compared to the posttest ($M=64.15, SD=10.04$) for the Value Scale.

Qualitative Analysis and Results

Student responses to the question “What does the integration of mathematics, science, and technology education mean to you?” were subjected to a process of iterative review to identify regularities and emergent patterns associated with student attitudes and perceptions related to the integration of mathematics, science, and technology education. Recurrent statements of interest, importance, and salience to the MSAT M. Ed. Program were identified and coded. Categories were generated to organize the data into manageable units for the purpose of synthesis and explication.

Three categories were identified to construct a parsimonious, but comprehensive, framework for the analysis. Student responses were categorized as curricular, barriers/challenges, or student benefits and examined for consistencies or variations from the onset to the completion of the program.

Curricular patterns Prior to the MSAT M. Ed. Program, students were more likely to note the commonality among the subject areas and the need to provide a cohesive education program through the integration of mathematics, science, and technology education. An example related to this perspective is as follows:

Combining all science, math & technology education so as to make a more integrated and comprehensive education program. (Student 10, Year 1)

Upon completion of the MSAT M. Ed. Program, student perception of the role of integration in the curriculum was less dogmatic and less pervasive. Many students were more comfortable with the term connections and suggested the need for appropriate, “natural” (Student 22, Year 2) integrative

experiences.

Integration means drawing connections between the disciplines and using these connections to build deeper understanding. (Student 10, Year 2)

Barriers/challenges—None of the students mentioned any barriers or challenges in their pre-program statements. This was not the case at the end of the program. Their initial, intuitive comfort with the integration of mathematics, science, and technology education appeared to be idealistic and naïve. After completing the program, student perceptions of the integration of mathematics, science, and technology education were more practical and realistic. They recognized that it was a difficult and complex task to find or develop “appropriate connections” (Student 26, Year 1) and “non-trivial applications” (Student 39, Year 1) and that “research and planning [and] having to think in broader terms” (Student 19, Year 3) was needed. Student 42, Year 1 eloquently captures the perception of integration at the end of the program.

Teaching teachers and teachers-to-be the importance of integrating, connecting, and aligning math, science, and technology in education along with strategies and tactics for such integration. I think we all know that the subjects should be integrated but the difficulty lies in how to integrate and the practicality of the integration in actual school settings.

Student benefits—Responses at the onset and at the completion of the program were similar with regard to student benefits associated with the integration of mathematics, science, and technology education. Support for integration was most frequently couched in the opportunity to provide real world applications for school mathematics, science, and technology. Students perceived these applications as more relevant to students and consequently would benefit student understanding and improve student attitude.

By teaching our students in a setting where the relationships between fields are valued, we create a powerful process in the classroom. These relationships create ties to real-world applications for concepts. (Student 22, Year 2)

Conclusions and Discussion

The results of the quantitative and qualitative analyses indicate that there was no change in student attitudes and perceptions related to their value of the integration of mathematics, science, and technology education. Students clearly valued this integration at the onset and at the completion of the program. However, there was a significant change in student attitudes and perceptions related to difficulty associated with the integration of mathematics, science, and technology education. Upon completion of the program, students perceived integration to be more difficult and identified barriers and challenges, demonstrating a more realistic, practical, and cautious approach to integration. This interpretation is consistent with the results of Lehman (1994) and Lehman & MacDonald (1988) who found that preservice teachers were less knowledgeable and more positive about integration than experienced, practicing teachers. Future research involving subsequent cohort groups in the MSAT M. Ed. Program is planned along with the collection of additional data such as student interviews; student beliefs about the nature of mathematics, science, and technology education; student understanding and implementation of inquiry methods; mentor teacher interviews; and follow-up observations and interviews of graduates.

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