Integrated Models for Teachers

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The National Science Foundation (NSF)-funded experimental project involving the teaching of physics, mathematics, and technology in collaboration with the Illinois State Board of Education, Department of Adult, Vocational, and Technical Education, Northern Illinois University’s Department of Technology, five industrial partners—Chrysler, General Motors, KineticSystems, Motorola, Woodward Governor, and five northern Illinois schools.

The project goal was to improve high school physics through an integrated curriculum and team delivery. To attain this goal, project staff strove to explore, develop, and field test innovative integrated team teaching methodology, non-traditional delivery models, and integrated physics, mathematics, and technology curricula to create a non-traditional, successful learning environment that would encourage, interest, and motivate average students to reevaluate their attitudes towards enrolling in physics. In working toward their goal, project teachers began to realize that not only was physics going to become stronger, but the mathematics and technology content was going to be strengthened as well. From this point, it seemed that the overall goal had quietly changed; it had become one of improving education across the three disciplines. One discipline did not seem to be any more important than the other.

Furthermore, as the teachers became more knowledgeable about each other, the respect and confidence in each other visibly grew in leaps and bounds. Philosophically, the professional partnership across disciplines grew equally with the time involved in working together.

The project purpose was to enhance physics so that “average” students would be more inclined to enroll in high school physics. Currently, few “average” students (that wide-range middle group of students in IQ or GPA or performance) enroll in physics for a variety of reasons. Often they are discouraged by others as well as themselves. Some feel that average performance is not THE TECHNOLOGY TEACHER. FEBRUARY 1993

acceptable, or that they do not have the ability to pass such a course. Often there are unwritten, sometimes unreasonable and unrealistic prerequisites invisibly barring access to these students. Nevertheless, there is no valid reason for average students not to enroll in physics. If taught in a “real-world” (applied), interesting, and interactive manner, our teams found it possible for them to do quite well. Therefore, the purpose also changed. It became one of enhancing not only the physics content, but the mathematics and technology content as well as to attract average students.

The integration philosophy adopted was one of not only integrated physics, mathematics, and technology curricula, but also team teaching and integrated course delivery. The philosophy also addressed, simultaneously, long-term sustainability. The teachers were adamant that the experimental class teach the same rigorous physics as was normally taught in regular physics classes. They adhered to this commitment throughout the entire study. Five northern Illinois schools representing urban, suburban, and rural locations participated in the project and study. Although NSF was the primary funding source, each school contributed by providing some teacher-subsidiary funds and laboratory-enhancement funds. In regard to ethnic and gender percentages, participating schools reported the following for the experimental (integrated) groups:

- School A—64% minorities and 0% females; School B—8% minorities and 24% females; School C—17% minorities and 44% females; School D—0% minorities and 33% females; and School E—13% minorities and 30% females.

The top priority was to recruit average students who would not have normally enrolled in physics. Each of these schools established a teacher team, which included one physics, one mathematics, and one technology teacher. These teacher teams worked collaboratively to develop non-traditional team-teaching strategies and delivery models. Altogether they developed 45 integrated physics, mathematics, and technology curriculum modules. During the field test year, data were collected to evaluate the success of the curriculum modules and teaching models. The integrated teaching models, curriculum modules, and research outcomes are described in the following sections.

Integrated Teaching and Delivery Models

The integrated delivery models are described below, including their modifications for long-term sustainability. Figure 1, “PHYS-MA-TECH Integration Models,” offers a comparison of the various models ranging from the least integrated to the most integrated.

Model A (Control—Traditional Rotation)

- Physics—1 credit, Mathematics—1 credit, and Technology—1 credit, for traditional time blocks with three separate types of classes. One group of 18 students enrolled in each of the courses mentioned above. These courses were scheduled throughout the school day, not back to back. The teachers were not provided simultaneous preparation time. They coordinated their curriculum and their schedule of delivering content. They were given permission to exchange places throughout the day; in other words, if the mathematics teacher wanted the technology teacher to be part of the discussion in the mathematics classroom, the technology teacher could exchange places with the mathematics teacher for a short period of time. These teachers carefully coordinated the curriculum so that they were all teaching related content on the same days in different ways, and thereby teaching and reinforcing each other’s content. Or, they were teaching different parts that related to the same content broadly. The students were really “tuned in” to the cooperation and collaboration between teachers. The model was “integrated” in a more historical and traditional sense. The integration process was difficult and the teachers worked extremely hard to make it work. The coordination was very successful and integration at this level was successful at integrating information.

This model was successfully implemented across a mathematics classroom, a traditional physics laboratory, and an industrial electronics laboratory. The model was integrated curriculum, not integrated delivery, but interactive and creative delivery allowed for teacher visitation for short time blocks outside their own classroom and group field trips involving all three teachers and groups of students off campus. It was continued a second year and will be sustained long term. This model has been modified to provide teachers with simultaneous preparation time blocks. This school is also planning to develop an integrated science, mathematics, and technology classroom.
technology “track.” Thus, it is planned that there will be a different integrated science, mathematics, and technology course for each of the four high school years. This urban school had an enrollment of 2,300 students. Model B

Physics—1 credit for a 50-minute time block in both traditional physics and technology laboratories. Three teachers team-taught 25 students. Two teachers were assigned to the integrated course; one teacher was assigned a supervisory duty that allowed him to “swing” or exchange places with one of the other teachers when needed. The mathematics teacher was the swing teacher. Collectively, the three teachers assigned the integrated course and the supervision (study hall). They were allowed to work across the two assignments however they felt appropriate. This model was one teacher more expensive than traditional expenditure. These teachers were also provided simultaneous preparation time. The swing position did not reduce the level of interaction or integration among the three teachers. This model was successful, continued a second year, and is being sustained long term with two teachers, physics and technology. The mathematics teacher has also been assigned a non-academic duty, which allows for the swing position when needed. This school also is developing a capstone engineering course to be taken after the integrated physics, mathematics, and technology course. This suburban school had an approximate enrollment of 1,600 students.

Model C

Physics—1 credit for a 50-minute time block in both traditional physics and technology laboratories. Two groups of three teachers team-taught two groups of 25 students each. This group was not assigned simultaneous preparation time and met after school to work together. This model was two teachers more expensive than traditional expenditure for two different classes, equaling four teachers more expensive for the field test year. This model was successful with both classes and was continued a second year. It will be modified to use back-to-back multiple class blocking with multiple course credits as described in Model A for the long term. This urban and somewhat rural school had an approximate enrollment of 2,500 students.

Model D

Physics—1 credit for a 50-minute time block in both traditional physics and technology laboratories. Three teachers team-taught the integrated class. The mathematics teacher, however, used his one-period department- head administrative release to work with the integrated class. This small suburban school was small (750 students) compared to 1,500 to several thousand students in the other schools. This model was successful as well and continued a second year. It will be sustained long term with two teachers assigned to the integrated class, a physics and technology teacher. The mathematics teacher will be available when needed through the swing position. This school has also reorganized structurally so that the science, mathematics, and technology departments share the same unit administration. Because enrollments are up, they have employed an additional teacher. This position has been established as an integrated position, which will work across the three disciplines. Also, this school has initiated a new integrated physical science and technology course for freshmen. The district, including this school, has applied for major grants to help fund continued reform across all schools in their district.

Model E

Physics—1 credit, Mathematics—½ credit, and Technology—½ credit taught for a 2-hour time block in a new, integrated science and technology laboratory. Three teachers team-taught 24 students in this integrated course, making it “one teacher more expensive” than traditional expenditure. This urban school system reallocated locally to renovate a dated industrial lab to a well-designed, integrated physics and technology lab shared equally by both departments. Teachers were provided simultaneous preparation time. This model was successful, was used a second year, and will continue to be sustained long term. It will be modified, however, so that the group of teachers will be assigned a non-academic duty simultaneous with the integrated class, allowing for teachers to “swing” in and exchange places when and as needed. Two teachers will be with the integrated class at all times; one teacher will assume the “duty” position (e.g., study hall, etc.), but the teachers will change places when appropriate. Therefore, three teachers have been assigned three time blocks collectively, maintaining traditional expenditure. This school had begun integration in another area, but as a result of this project is adding another integrated physics, mathematics, and technology class; additional spin-off integrated initiatives have begun as well. This urban school had an approximate enrollment of 2,100 students.

Integrative Curriculum Modules

Forty-five integrated physics, mathematics, and technology curriculum modules were developed, field tested, revised, and packaged for teachers under the title PHYS-MA-TECH. Each module is self-contained with both teacher and student activities. The modules include the following categories: (a) technological framework; (b) purpose; (c) learner outcomes; (d) physics, mathematics and technology concepts; (e) prerequisites; (f) time frame; (g) teaching strategies; (h) teaching methodologies; (i) procedures; (j) materials/equipment; (k) information; (l) mathematics worksheets and data collection instruments; (m) suggestions for further fields of study; and (n) evaluation. These modules were developed to provide a vehicle for integrating physics, mathematics, and technology. They do not represent an entire year of integrated curricula. However, they do establish a viable format, options to use within a program or integrated endeavor so that teachers have access to materials that provide a point of beginning. It might be important for teachers interested in the PHYS-MA-TECH materials to know that these materials were developed by a realistic cross-section of teachers. There were great varieties and levels of talent, background, abilities, motivation, dedication, school economic situations, personalities, teaching and learning styles, etc., across the group of 15 teachers involved. As a group, it was determined important to develop materials from a “typical” perspective, rather than materials that are “great expense, extraordinary ability levels, unrealistic levels of cooperation and support to implement.” Therefore, PHYS-MA-TECH is a mixture of types of modules in sophistication, necessary funding, talent, and cooperation. Hopefully, there are many modules appropriate for any school and teacher situation. They are completely teacher developed, tested, and revised. The following activity modules exemplify the integrated physics, mathematics, and technology curriculum modules: Laser Burglar Alarm, Fiber Optics, and Xerography. These modules and 42 more make up the PHYS-MA-TECH modules. The titles reflect technologically oriented activities. However, the content is drawn from all three disciplines (i.e., physics, mathematics, and technology). For example, the Laser Burglar Alarm module identifies the following concepts: (a) Physics—lasers, reflection, refraction, and index of refraction; (b) Mathematics—acute, right, and obtuse angles as well as use of protractor; and (c) Technology—photocells, transistors, relays, and schematic diagrams.
Each module is treated in the same manner, using technology as both content and methodology. Physics and mathematics are used in this way as well.

Each Phys-Ma-Tech curriculum module includes strategies for instruction. The Phys-Ma-Tech teachers (teams) used a team teaching approach. Initially, each teacher was responsible for his/her content area. However, as time passed and interaction between teachers increased, teachers began to cross disciplines while team teaching. For example, the technology teachers began to feel comfortable teaching physics concepts from their own contextual backgrounds; nevertheless, the content was clearly physics. Even though technology teachers often teach physics content because it is integral to some of our curriculum, conventionally speaking, this was a shift in behavior. It is important to note that all of the teachers in each team began to do the same, i.e., the learning environment became dynamic, and the teachers moved freely across disciplines. This movement better reflected the natural integration of content from a “real-world” perspective. While teaching together, the teachers became more spontaneous over time as well. For example, if lecturing, each would very easily and smoothly take part in the lecture, contributing freely when and as appropriate. In preparing for lectures or discussions, the teams would sometimes assign the lecture to one team member. At other times, each team member would be responsible for “segments”. The teams would deliver the whole learning experience together. Often, the teams would provide opportunity for the students to work in groups. Because there was a lot of “hands-on” activities, a small group format worked well. The small groups sometimes did the same activity; however, often each small group was involved in a different learning activity, and the students rotated through each different activity. Teachers worked together across the small-group activities. What became clear after working in teams for a year, and especially after the second year, was that these teams became exceptionally cohesive educational entities, developing and utilizing a variety of methodologies and styles to team-deliver integrated curricula. Technology education has its own unique content but it can be used as an exemplary technique in teaching as well. Each of the disciplines can be used as a method or tool to “teach” the other, each still maintaining its own integrity as a discipline. The arguments or concerns expressed in the field as to whether technology education content should be used to support or “apply” physics and/or mathematics concepts is considered by some to be a valid issue and by others academic debate. The PHYS-MA-TECH participants felt technology is physics and mathematics while also retaining a unique content base of its own. The goal of the PHYS-MA-TECH project was to improve high school physics for the purpose of increasing enrollment of non-traditional (average) students by utilizing a unique partnership between physics, mathematics, and technology educators. In working toward achieving this goal, the project participants focused on commonalities across the three disciplines, ways of utilizing each others’ expertise, and each as being both content and methodology rather than emphasizing the differences across the respective fields. As a result of their PHYS-MA-TECH experience, the participating teachers feel that each respective discipline is now stronger on its own merit, because the interdisciplinary and team approach not only supports the team and integration activities, but makes possible further growth of individual programs as well. The project participants also felt that individual programs benefited from the positive and supportive professional relationships that developed as the result of learning about each other, thus enabling them to better understand other programs and professional perspectives. Therefore, rather than ask the question, “What does this project do for technology education?” it would not be better if technology educators focused on the results, i.e., (a) long-term and progressive partnerships between physics, mathematics, and technology educators; (b) program improvement, visibility, and growth; (c) enthusiastic reports from teachers about renewal, excitement, and motivation; (d) excited administrators; (e) shared labs and resources; (f) no academic elitism; (g) a better understanding on the part of the physics and mathematics educators about technology and vocational education; and (h) most importantly, the fact that all of the above led to increased local support for technology programs and professionals? To quote one of the physics teachers, “I always thought of you guys [technology educators] as ‘geek-heads.’ I never realized you taught so much!” It seems that the most important consideration is the needs of our students and enhancement of their learning environment. It also seems that we can better address those needs when understanding the potential contribution of each other. Does it really matter which content takes primary or secondary position? Because one discipline manifests itself in another, each is equally important.

Research Outcomes Introduction
As mentioned previously, five schools were chosen to participate in the study, each differing in enrollment, geographic location, and ethnic/racial makeup. The study sought to ensure that the students chosen to participate were “average” high school students rather than advanced placement or “high achievers.” The students in the experimental classes were also students who would not have enrolled in physics normally. Each of the five schools assigned one or more classes of students to enroll in the PHYS-MA-TECH course (integrated approach). In four of the schools, the experimental section was assigned during a class period in which each of the three members of the teaching team (physics, mathematics, and technology teachers) participated together, while in the remaining school, the class rotated among each of the three team members’ classes. At least one section of regular placement physics was selected in each school to serve as a control group. These sections were made up of students who would have normally enrolled in physics.

The regular physics students in the control groups had significantly higher IQs and GPAs compared to the students participating in the experimental integrated physics classes who would not have taken physics normally. Therefore, the experimental groups consisted of students appropriate for establishing whether an integrated methodology and delivery would enhance physics to the point that average students could be successful and encouraged in physics. An interesting point to note is that both groups of students had enrolled in similar science, mathematics, and technology courses prior to participating in the study. The experimental group had lower GPAs, as was expected. This lower success, particularly in science and mathematics, might indicate a reason for students not electing further study in science and mathematics.

Survey data established that students in the PHYS-MA-TECH classes were more interested in technology classes; those in regular physics classes were more interested in mathematics. There were no apparent differences in their interest in science. This was especially interesting. If there is no difference in their perception of science or attitudes toward it, it seems that there is no real reason for the experimental students not to have considered physics. When coupled with the information that these students have similar perceptions about their future (i.e., a high percentage of both groups indicated that they were planning to attend college), this information further confounds the issue of why the experimental students were not planning to enroll in physics. The survey data also established why students enroll in
Students in the control group indicated that their reason for enrolling in physics was that of college preparation. The experimental class indicated that they were recruited (which they were for the purposes of the study). Prior to the study, within the first two weeks of school, all control and experimental students were pretested using the same physics test for both groups. There was no significant difference in achievement across treatment groups; both groups performed similarly on the same physics pretest. This information was used to form a base upon which to judge increases in achievement over the year. The test was adapted from the one developed by the American Association of Physics Teachers and the National Science Teachers Association. The course content for the year was adopted from a course outline established by these organizations as well. The course outline and pretest covered the following categories: Mechanics; Heat and Kinetic Theory; Electricity and Magnetism; Waves, Optics, and Sound; and Modern Physics. Therefore, test validity was assumed; however, the course outline and test were revalidated additionally by five high school physics teachers, one physics graduate student, and a physics professor.

**Research Summary and Conclusions**

Listed below are major conclusions resulting from research data and analysis. The following information is considered the information most important to high school teachers and administrators:

1. **Student perceptions of science changed over the course of the year.** At the pretest stage, there was no difference between groups in interest in science classes. Upon reexamination at the posttest stage, the experimental (integrated) groups showed a higher interest in science than those in the control (regular) physics classes. This shift may indicate a valuable side effect of the PHYS-MA-TECH program.

2. **Students in the experimental (integrated) group showed a higher preference for physics and physical science; the control group showed higher preference for biology and chemistry.**

3. **Students from both groups perceive the difficulty of science classes similarly.** This could also be a valuable side effect of the PHYS-MA-TECH program.

4. **Student reasons for taking physics also shifted over the course of the year.** After the integration experience, significantly higher numbers of the experimental (integrated) students indicated their reason for taking physics was for college preparation. Also, fewer control (regular) students indicated their reason for enrolling in physics as that of college preparation. This positive shift on the part of the experimental group may indicate another valuable side effect of the PHYS-MA-TECH program.

5. **There were no significant differences in achievement scores on the physics posttests.** The experimental students performed equally well in learning the same rigorous high school physics at the same rate as the control students. This indicates that a new population of students might be reached by using the integrated philosophy of team delivery and teaching strategy with an integrated and technologically oriented curriculum.

6. **Although no official data were collected on the issue of mathematics prerequisites for physics, it was found that higher-level mathematics as a prerequisite was not necessary.** The teachers in this study taught the necessary upper-level mathematics skills simultaneously when needed. Upon formal evaluation, the mathematics teachers themselves determined that the mathematics teachers were not needed as often as originally established. They usually became the “swing” position in the models, because less mathematics was needed as integral content than originally thought.

**Summary**

Historically, long-term sustainability of integrated curricula has rarely occurred. There is usually too much theoretical content, too many technological requirements (especially in the technical hardware and software arena), and too much time required for one teacher to continue long term. Using a cross section of teachers, laboratories, technologies, and field experiences, integration has the potential to be maintained successfully on a long-term basis. However, this means rethinking traditional delivery, resource allocation, and priorities. Reallocation of time, resources, facilities, schedules, and reprioritization is a must for committed educational reform. New and additional funding is not always the answer. Systemic change involves rethinking not only the program and curriculum, but teacher, staff, and administrative roles in addition to non-traditional scheduling and delivery. With a real commitment to long-term reform and non-traditional delivery, improved academic content and enhanced learning environments can result from integrating across disciplines. PHYS-MA-TECH outcomes provide supportive evidence for rethinking how physics is taught and delivered. The outcomes also provide evidence that new partnerships can reduce barriers, increase access, and open physics, mathematics, and technology courses to non-traditional (average) students. In addition, study results indicated that interdisciplinary integration served average students well as a method for learning.
Figure 3. School integration models and levels of integration.