Integration of Research and Education
Contemporary Research in the Education of Teachers
Full Application
Kansas State University

1. K-State's Vision

Kansas State University encourages all students to become actively involved in research. Our goal for science, engineering *and* science education students at KSU has always been that they understand the intellectual content of their discipline and the process by which that discipline develops new knowledge. While instructional laboratories help students understand the processes of science and engineering, the comprehension that research is an ongoing, complex endeavor only occurs when the student is part of that effort.

In most KSU science and engineering departments, close to 90% of undergraduates participate in research, as do all graduate students. One measure of undergraduate participation in research is the number (about 130) who have appeared as co-authors on research papers over the past five years. Another indicator of the close connection between undergraduate education and research is the success of KSU science and engineering students who have won Rhodes, Marshall, Truman or Goldwater Scholarships and have been actively involved in research. All but one of the 37 KSU science and engineering students who have won Rhodes, Marshall, Truman or Goldwater Scholarships have been actively involved in research.

This vision is strongly influenced by K-State's status as a land-grant university. One of our goals is to produce graduates who understand the ways in which scientific and engineering knowledge impacts modern society and how the sciences and engineering grow and change. Further, as the largest teacher education institution in Kansas, we wield significant influence in improving the form and content of science education. The integration of research and education helps us prepare teachers, citizens, scientists and engineers who will become resources for Kansas and the nation in the twenty-first century.

While the integration of research and education is an important part of our vision for all students, it is an especially critical component for students who will become science teachers and those who are seeking further education while teaching in the elementary and secondary classroom. To be able to teach their students about the way in which scientific knowledge develops, these present and future teachers must understand the research enterprise. Our vision for them is similar to the one for our science and engineering students. However, the research experiences that are a natural part of the science and engineering curricula do not automatically become available to present and future teachers. Thus, the University seeks close ties between its faculty in the College of Education and in the science departments to develop programs that integrate education and research for pre-service and in-service teachers.

When KSU scientists and engineers provide an integrated program for science education students, they also learn about teaching and learning from both the Education faculty and the in-service and pre-service teachers. Thus, our scientists and engineers have become aware of an important body of research-based literature on teaching science and engineering. The results of this research can have direct and immediate impact on the quality of education for all of our students. We encourage faculty in all disciplines – not just the College of Education – to become either active educational researchers or consumers of this research. Both the Department of Physics and the Division of Biology have responded by appointing to their tenured or tenure track faculty specialists in the teaching of the discipline. Thus, for KSU the integration of research and education for pre-service and in-service teachers is a two-way process. It includes bringing research on science teaching as well as research on science into the educational procedures for school teachers and for our faculty. The discussion which follows will focus on how this integration of research and education for present and future teachers has affected KSU, its students, and faculty.

A recent scenario involving the physics courses for education majors and research in both semiconductor devices and physics education exemplifies the KSU vision. During a physics class for elementary education majors one of the students accidentally pointed the remote control of a VCR at a video camera. When he pressed a button on the remote, he noticed that light appeared on the video monitor which was connected to the camera. Thus, he was seeing the infrared light coming from the remote control. The course instructor because intrigued by this process as a way to allow students to detect non-visible light. His interest increased because he had previously noted, in a similar event in a physics course for secondary education students, that ultraviolet light was visible to a video camera. A senior in secondary physics education investigated the response of video cameras to non-visible light further. Her short paper, which was submitted for publication, described the spectral response of some video cameras, and she captured pictures of infrared radiation (IR) from devices such as burners on electric stoves. She also learned that, to determine if a remote control is emitting IR, video repair people use an inexpensive detector which is the size of a business card. This fascinating device became the subject of further study by the Education Research Group in the Physics Department.

With this information the Physics Education Group began developing a lesson that would allow students to complete experiments on the IR detector card and use their results to create an energy level model for the card. They were aided in developing the instructional materials by two research physicists who hold a patent on a material that detects IR by changing its electrical conductivity when exposed to infrared radiation. An energy level model of their material provided insight but was somewhat complex for beginning students. One of these physicists helped adapt the model to one which secondary teachers and students could understand. Using her ideas the Physics Education Group developed a series of experiments that was used in the physics course for future secondary science teachers and helps students build their model of the energy levels and bands in this material. To complete the effort, the Education Group worked with graduate students in Art and Educational Technology to prepare an interactive computer program that enables students to compare their observations with an energy level model of the material in the detector (Figure 1). Thus, the curiosity of students raised questions that required contemporary research to answer, and research in basic physics enhanced the preparation of teachers.

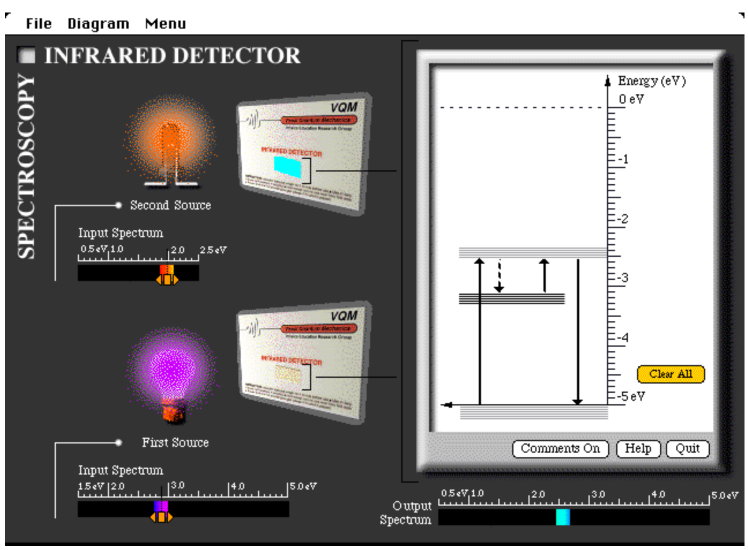

Figure 1: A screen capture of the interactive program which can help students understand how low-energy infrared light is converted into higher energy visible light. Students select the energy of the "pumping" light and of the infrared light. Then, they see if the model allows for visible light to come from the card when IR strikes it. This computer program was created by a collaboration involving both research and education. An interactive on-line version is available at http://bluegiant.phys.ksu.edu/vqm/programs/shockwave.

This type of interaction among introductory and advanced students, faculty who are preparing future teachers, and research science and education faculty is occurring at KSU. An important part of our vision is to increase this type of collaboration and continue to integrate the education of teachers with the research in science, engineering, and pedagogy.

2. Nature and Scope of Activities

The K-State vision related to the education of undergraduates who are preparing for careers as science teachers and graduate students who are already science teachers in schools is most evident in recent projects that were collaborations of research science faculty and education faculty. These collaborations have long supported teacher education based on research and informed by recent research in both science and pedagogy. Three major K-State programs demonstrate our integrated and systemic approach.

- *A Model Science and Mathematics Curriculum for Elementary Education Students* involves faculty from four science departments, mathematics, and the College of Education and incorporates recent scientific research as well as having a component in which the elementary education majors actively engage in research as a way of learning about science, mathematics, and teaching.
- The *Genetics Education Networking and Enhancement* (GENE) Project translates recent research in molecular genetics into laboratory activities for undergraduate students as well as teachers who return for graduate work.
- *Visual Quantum Mechanics* uses computational and visualization research to create lessons to teach quantum mechanics to undergraduate science education majors as well as non-science students.

These programs are representative of the KSU commitment to integration of teaching and research in the sciences, engineering, and the training of science teachers. They include students and faculty from disciplines and colleges across the campus.

Model Elementary Education Curriculum

The program to prepare elementary science teachers was begun in the mid-1980s in response to concerns that science faculty were not sufficiently involved in the education of science teachers. Further, the undergraduates neither understood interrelations among the sciences nor had they any sense or feel for scientific research. In 1989 development of a model curriculum was begun to address these issues.

Faculty involved in this project have appointments in the Division of Biology, and Departments of Chemistry, Geology, Mathematics, Physics, Elementary Education, Secondary Education, and Educational Technology and in the local school district. The group designed a set of courses based on cognitive research on how students learn about science and the problems they encounter when they become teachers of science in elementary schools. Science faculty on the team developed hands-on components that fit into a carefully thought-out structure which emphasized the cumulative nature of scientific knowledge. Working as a multi-disciplinary faculty they developed courses that highlighted connections and relations between the several branches of science.

A capstone course focused on the centrality of research in science and the connections between the sciences. Ecology was selected as the subject for this course because it draws on many fields. In addition, the 9,000 acre Konza Prairie Research Area, operated by the KSU Division of Biology, provides an ideal laboratory for research and education. In the capstone course, students majoring in elementary science and math education were able to use their accumulated knowledge about science, develop hypotheses, and test them through research.

This project continues by developing and testing new modules and incorporating them into the curriculum for all elementary education majors. The result is that both students in elementary education and their students have a new appreciation for the integration of education and research.

Genetics Education Networking and Enhancement

Genetics has changed so rapidly that many science teachers have little up-to-date knowledge about the field and its significance. Until recently, most information came from textbooks. Hands-on activities were considered too complex for high school or early college classrooms.

Beginning in the mid-1980s K-State genetics researchers realized that many of their methods and tools could be converted for use in the science classes. Because their research used simple organisms such as bakers' yeast and flour beetles, the researchers saw an opportunity to have students complete experiments similar to those done in their research laboratories. Thus, they started creating instruments, growing media, and teaching materials that would help teachers learn about the field and provide them with ways of sharing this knowledge with students. Concentrating first on students working on graduate degrees in education during summer school, an interdisciplinary team developed methods of providing basic information as well as research experiences in biology, physics, statistics and biochemistry. These disciplines provide the foundations of molecular genetics.

The interdisciplinary approach to understanding genetics fit well with KSU's overall mission. Since many of our education graduates teach in rural schools, they are responsible for many, and sometimes all, the sciences which are taught in their schools. Thus, an interdisciplinary background provides present and future science teachers in small schools with a means to integrate the courses which they teach.

Networking via e-mail (and now the World Wide Web) has always been part of this project. Acting as researchers, teachers and students in different locations have compared the results of experiments that depend on local environmental variables such as the amount of sunlight available at a particular time. By sharing data this effort shows the way that researchers must cooperate to obtain meaningful results.

Most recently the researchers have turned their attention to reaching undergraduate biology students. This effort involves modifying the materials prepared by the interdisciplinary group for use by second year students in the biological sciences. This activity, supported by the Howard Hughes Medical Institute, is now enabling our biology majors to use research-level techniques at a relatively early stage in their careers.

Videotapes and World Wide Web materials are used locally and distributed across the nation. Creation of these multimedia materials has become a significant research and development effort on our campus and involves faculty from many different disciplines, some far outside the traditional sciences and engineering.

Visual Quantum Mechanics

Quantum mechanics presents challenges to students and teachers at all levels. Many scientists say the subject is too difficult for any but the most advanced undergraduates. However, since the early 1980s the KSU physics faculty has offered a course in contemporary physics research for future secondary science teachers. The students enrolled in this course have not chosen physics as their primary teaching subject; their first area of concentration is another science or mathematics. Because they are likely to be employed in a small, rural school, they will be expected to teach physics as well as their subject of first concentration. This course helps these students to become aware of recent advances in physics and to learn about the way in which physics research progresses.

In recent years this course has changed significantly with the inclusion of visualization tools similar to those utilized by theoretical and experimental scientists. An example of these tools is the scanning tunneling microscope. By combining the basic ideas of quantum tunneling with sophisticated hardware and computer visualization scientists have been able to map the surfaces of many materials and manipulate atoms on those surfaces. The capabilities of these instruments capture the interest of the future teachers. When combined with the possibility of creating nanometer-sized machines, this technology enables students to see not only the value of present research but possible future directions of science and technology.

Scanning tunneling microscopes and other similar devices are far beyond the budget levels of high schools. Thus, we chose to use some state-of-the-art equipment but also use contemporary research results to create simulations and visualizations that enable the students to understand how the research results are obtained. To make these interactive computer materials attractive and to include the latest techniques in interactive design, the physicists in the project work with graduate students and faculty from the Department of Art. The artists are enhancing the visualizations and helping scientists learn about aesthetics and visual communication. At the same time the physicists are developing computational tools for computers that the future teachers are likely to have in their schools. The combination of the visualization and interaction techniques with the computational tools enable the faculty to present concepts of quantum science to students who do not have an understanding of advanced mathematics.

Another level of research that has become part of this project is recent work on some of the fundamental issues and paradoxes in quantum science. For example, within the past year scientists have created superpositions of states of a single atom which are similar to the superposition of the dead and alive states in the famous Schrödinger's Cat paradox. The KSU group is now working with a graduate student in Educational Technology and the Art faculty to create some interactive instructional materials to help students understand the original paradox as well as the recent research development. Because the physics involved in this effort is rather abstract, instructional materials development must be a creative and scholarly activity if it is to communicate with future teachers. Thus, the development of these materials becomes a research effort which focuses on the integration of research and education.

Beginning with the introduction of quantum and visualization research techniques into a single University class, Visual Quantum Mechanics has developed into a major research effort involving several faculty from different disciplines. Drawing on research in computational physics, recent advances in knowledge about quantum physics, and the use of visualization in instruction, this project is developing materials based on the belief that quantum physics can be presented effectively to future teachers, high school students, and college students who are non-science majors. The instructional units are developing new ways to look at quantum physics and challenging researchers to communicate to a broader audience.

These three projects represent the broad scope of the integration efforts as they are applied to the education of teachers. In all of these efforts recent research results were combined with the desire to inform teachers about both science and the process of developing new knowledge. The result has been that the traditional boundary between research and teaching has become blurred.

3. Commitments and Investments

The senior administrators at KSU are committed to supporting the role of research in the education of our future teachers. While faculty initiated each of the projects described above, they have succeeded because of support from the central administration and the Deans of Arts & Sciences and Education. The administration has invested in these projects in many ways, the most important being faculty release time. For each project, the approximate level of support is as follows.

The Model Elementary Education Curriculum involved 18 faculty members from nine departments. During the development phase, KSU contributed $354,973 over six years. Much of this project is now a regular part of our curriculum. By including components of the model into the general elementary education curriculum, the administration continues its support as teaching assignments of the College faculty.

The Genetics Education Networking and Enhancement project involved 10 faculty from five departments. Over ten years, KSU's contribution to this project amounted to $217,742. In addition to the monetary support, the Principal Investigator for this project focused his primary scholarly activities on the transfer of the research techniques to the classroom. He received support for these activities including sufficient space to complete the work and evaluations for merit pay increases based on this effort rather than traditional genetics research.

The Visual Quantum Mechanics project has involved eight faculty from three departments. By the end of the current phase the University will have contributed $223,318 over a six year period. Even prior to the formal start of this project the Physics Department supported the course for future secondary teachers in spite of relatively low enrollments because of the Department's commitment to providing appropriate teacher education concerning contemporary research in physics. The Physics Department treats scholarly work in physics education as one of the department's areas of research. Thus, the faculty involved in this program receive support and evaluations based on this research effort.

External funding of $4,129,033 has supported these three initiatives at Kansas State University. The primary sources of funding for these efforts have been the National Science Foundation and the Howard Hughes Medical Institute. In addition, these programs interacted significantly with other research efforts at the University and were able to take advantage of a variety of resources including the expertise of faculty and the support staff such as electronics, mechanical instrumentation and design personnel who are part of the infrastructure that supports the KSU research efforts.

4. Desired Outcomes and Impacts

Kansas State University became the largest teacher education institution in Kansas by paying closing attention to the education of our future teachers and working closely with in-service teachers who were returning for graduate studies. In the development of teachers their knowledge of content topics and the processes by which new knowledge develops is as important as the understanding of methods for teaching science and knowledge of the discipline. Thus, the education of our teachers is not limited to the faculty in the College of Education. Many faculty in the College of Arts and Sciences must take an active role in this process. This role of the disciplines is most apparent in the development of present and future teachers of science and mathematics.

For teachers to learn the science and mathematics content the discipline faculty must interact with Education faculty to understand the needs of the students. However, KSU's aspirations go far beyond the simple learning of science content; we wish the students to understand the way in which new knowledge in the discipline develops. Thus, we have developed the programs which have integrated research and education of pre-service and in-service teachers.

An important goal for the University is to build the confidence of the students in their ability to teach and learn science. To be able to facilitate active learning as advocated by most science education specialists and the National Science Standards, teachers must have confidence about science *and* science teaching. Thus, our integrated programs emphasize that, as students, teachers cannot learn all they need to know about either the content or process of science. However, they can learn how to learn more and build their confidence so that they will be able to continue to learn about science, sometimes by learning alongside their students.

This effort has had a significant impact on both the students and the KSU faculty. The students have not only learned firsthand how research is important to modern science; they become members of networks of teachers who are involved in communicating this information to their students. The science and mathematics faculty have come to appreciate the needs of teachers and the difficulties that they face. Thus, each group has learned from the other and has enhanced all aspects of the science and mathematics education at KSU.

The value added for the future elementary teachers has become apparent now that they are teachers in the classroom. Even as student teachers their rankings in terms of their development were far above the expectations for individuals at early stages of their careers. (See Evidence of Achievement section below.) In addition to their performance in the classroom these teachers have been actively involved in after school science clubs, sometimes initiating clubs that did not exist in their schools. These clubs represent the equivalent of research activities for K-6 students. Thus, we see that the elementary teachers have also built a confidence in both science knowledge and process and are now relying on that confidence in their teaching.

The faculty and departments involved in the project have also seen a significant impact on other aspects of the KSU curriculum. First, many aspects of this special project have become integrated into the curriculum for all elementary education majors. An even broader influence can be seen in the expanding General Education program at KSU. Courses which meet the General Education requirement must include teaching/learning methods which are consistent with contemporary research on how students learn and information about the process of the disciplines' development as well as basic concepts. The courses that were created for the Model Elementary Education Curriculum have been used as a model for the General Education program.

As the General Education program develops capstone courses will be created for majors. These courses will be similar in nature to the Environmental Education course which was created for the Elementary Education Program. The emphasis on integrating knowledge from a variety of disciplines and the inclusion of research techniques are goals which the University has set for capstone courses for all students. Fortunately, we have a model of this full integration which was created in the Model Elementary Education Curriculum.

Similar impacts have appeared in the genetic project. An increase in teachers' knowledge and confidence leads to a broad impact on their teaching and on the students who come from their classrooms. This result, in turn, has an impact on the science that can be taught at KSU.

The GENE project has also had an impact on undergraduate biology education. With support from the Howard Hughes Medical Institute, the basic concepts and techniques which were developed for the graduate student teachers are now being implemented in an undergraduate biology course on modern genetics. Thus, the integration of research and education has flowed from the research lab to graduate education for in-service teachers to undergraduate education for biology majors.

The impact on the faculty has resulted primarily from their interactions with the present and future teachers. These students, particularly the GENE participants, have taught the faculty much about the needs of classroom teachers and about ways in which to teach. As the GENE project evolved, the KSU science faculty modified its approach based on feedback from the teachers and changed the teaching of other college-level courses in response to their interactions with these teachers.

The Visual Quantum Mechanics project is much earlier in its development than the other two. Therefore, its impact is not as clear at this time. However, the outcome of involving a variety of research faculty in the education process is apparent. For example, an important component of this project is the use of inexpensive solid state devices in the teaching of quantum mechanics. To select the most appropriate devices, the project staff has interacted regularly with faculty whose research is experimental and theoretical solid state physics. These collaborations are resulting in the transfer of very recent research into the undergraduate course for future secondary science teachers. Further, the model established by this project has had an impact on other researchers at KSU. Two recent research proposals - one each in surface physics and cosmology - included components that would translate the basic research to lessons for the undergraduate classroom. If these proposals are funded, they will provide a model that other research universities can emulate in their integration of research and education.

Thus, in establishing the goals for integrating research and education in the teacher education program we have identified several outcomes. A general summary of these outcomes is that we wish teachers who graduate from our program or return for graduate study to have an understanding of the scientific process which enables them to facilitate the learning of their students and the confidence to be able to help students learn science even when the teachers have not studied the science of interest to the students. By integrating research and education for both pre-service and in-service teachers we have created an environment in which these goals can be reached. As discussed above the impact of this integration has gone beyond the curricula for which the courses were created and is affecting both the faculty and the University's general curriculum in a variety of ways.

5. Documentation Efforts

The faculty involved consider all of the projects described in this proposal as scholarly efforts. Therefore, these faculty members have used both traditional and non-traditional means of documenting their results and informing the appropriate communities about their efforts. The traditional documentation includes the presentation of talks at professional meetings, the publication of papers in refereed journals, reports to funding agencies, and the presentation of workshops. Less traditional documentation includes the creation of videotapes about the effort, postings on the World Wide Web and entry of project products in software competitions.

Table 1 displays the number of publications and presentations for each project. Because these projects still have ongoing phases, the number of publications is likely to increase. (Due to space limitations the list of publications is not included in this application but is available on request and can be viewed at http://BlueGiant.phys.ksu.edu/papers/IRE.html.)

	Elementary Education	Genetics Education	Visual Quantum Mechanics
Refereed Papers Published	12	8	
Refereed Papers Submitted	1		5
Presentations at Meetings	60	37	17
Ph.D. Dissertations	5		1*
M.S. Theses	2		2*

*In progress and will be completed by June, 1997.

Table 1: The number of professional publications and presentations that help document the three projects.

At present the institution's documentation for these projects consists of this collection of publications and presentations plus the annual and final reports for each project. While some of the papers simply describe aspects of the project, many of them focus specifically on the impact of the project on the students. Because these efforts are studying the effects of integration of education and research, the impact, particularly on the students, is well documented. Thus, these reports contain information about the outcomes and impacts of each of the projects. The general outcomes and impacts on the faculty were described above. More specific information related to impact on students is contained in the Evidence of Achievement section below.

6. Evidence of Achievement

To describe the evidence for our achievements to date we will concentrate on the GENE and Elementary Education Projects. These two projects have been in operation long enough that a significant amount of data about their effectiveness has been collected. The Visual Quantum Mechanics project is much newer and just starting its initial phase of evaluation and assessment. Because of limited space we will concentrate on a few components of the assessment which are most closely related to this application.

The effects of the integration of research and education on the future teachers in the Model Elementary Education Curriculum have been assessed, in part, by examining their behavior as student teachers in the classroom. When these students were completing their student teaching, a member of the project staff observed their teaching behavior and analyzed it using the Expert Science Teaching Educational Evaluation Model (ESTEEM). This model is used to analyze behavior of teachers with respect to teaching for student conceptual understanding. The analysis is based on a model in which teachers move through five stages of development – novice, advanced beginner, competent, proficient, and expert. Table 2 presents the primary traits observed in each of the stages.

Stage of Development	Traits of the Teacher
Novice	Skill development
Advanced Beginner	Broad skills; Use of sophisticated rules
Competent	Problem solving; Decision making
Proficient	Analytical thinking; Intuitive organization and understanding of tasks
Expert	Maturity; Practical understanding; Automatic and fluent performances

Table 2: The levels of teacher development measured by the evaluation model.

The reliability of this instrument is .91.

One measure of the value of our efforts is a comparison of the behavior of the student teachers in the program with the behavior of student teachers who were not part of the program. The analysis included four major categories of teachers' behaviors:

- Facilitating the Learning Process: A determination of how the student teachers help the students learn in active mode rather than tell them the answers.
- Content Specific Pedagogy: How the teachers vary their style of teaching to match the content of the lesson.
- Contextual knowledge: How the student teachers modify their teaching to match the context in which they are teaching. For example, do they address directly misconceptions that the students state and modify their lesson plan to help students confront the misconceptions.
- Content knowledge: At what level do the student teachers display knowledge of the subject matter that is being taught.

By focusing on a variety of teaching behaviors, ESTEEM enables an investigator to classify the quality of a teacher's work into one of the five categories described in Table 2. Thus, a comparison of the students who completed the program with other students teachers who did not would provide an indication of the value of our effort. Figure 2, on the next page, shows the results of this study.

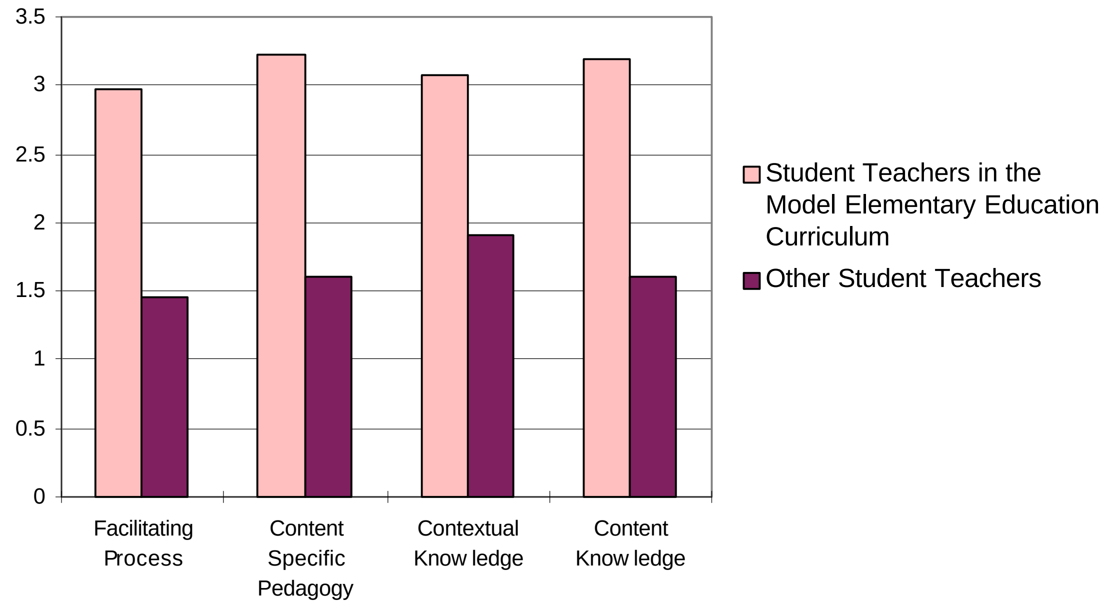

Figure 2: A comparison of teaching skills of student teachers in the Model Elementary Education Curriculum and other student teachers at the same level in their careers.

In creating the ESTEEM system the researchers identified expert teachers and cataloged their levels on the same items. The expert teachers were selected from lists provided by State Boards of Education, faculty in Colleges of Education and other similar sources. Figure 3 shows a comparison of our *student* teachers with these established teachers.

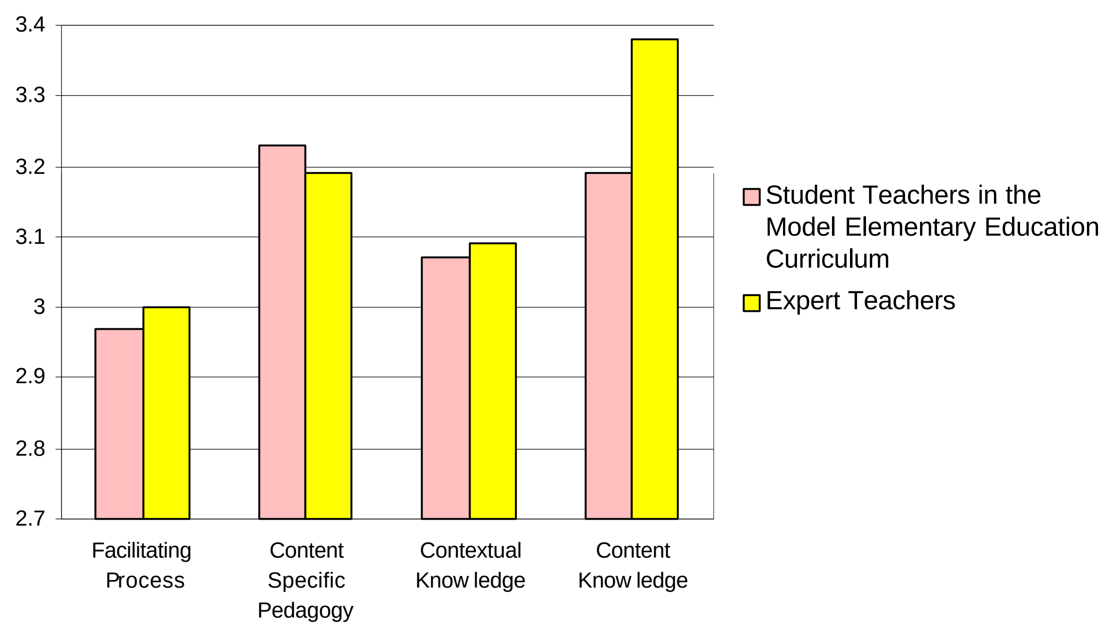

Figure 3: A comparison between our *student* teachers and experienced teachers who have been identified as experts.

The results of these comparisons are quite clear. On behaviors related to conceptual understanding the student teachers in the Model Elementary Education Curriculum performed significantly better than other elementary education students at a similar stage in their careers and were comparable to experienced teachers. Because the teaching of conceptual understanding is an important part of teaching science at any level, we conclude that the initial phase of this program has been effective in meeting its goals.

Other studies of this program and various aspects of its effectiveness have shown similar results. Thus, the integration of education of future elementary teachers and research is showing positive outcomes at KSU.

The professional community has also recognized the value of this program. In 1996 three awards were presented for studies related to the Model Elementary Education Curriculum. The Association for the Education of Teachers in Science presented both the 1996 "Innovations in Teaching Science Teachers" and "Implications of Research for Educational Practice" for work associated with the project. The National Association for Research in Science Teaching presented its 1996 Outstanding M.S. Thesis Award for a study on digital video conducted in the continuation of the physics course which was taken by the students in the Curriculum.

The GENE program has undertaken similar careful analysis of the effects of its program on the students who have been involved in it. Because these students are primarily graduate students who return to KSU only during the summers, much of the evaluation of the effects of the genetics networking program has been completed through mailed questionnaires which are followed by in-depth, structured telephone interviews. By beginning with a set of written responses the telephone interviewers can select items about which they need additional information or wish clarification. Thus, the project is able to collect a large amount of information quickly and with minimum demands on the teachers' time.

The KSU Office of Educational Advancement collaborated in the development of the telephone interview format. The interviewer asked each participant a series of questions, some of which were open-ended and others that asked the participant to rank specific aspects of the program. With information collected in this way we have built profiles of the effects of the GENE program. (Of course, we are aware that all of the conclusions from this assessment are based on self-reported data. Data collection and analysis by an independent evaluator is underway but has not been completed at this time.)

As graduate students these teachers became involved in using research techniques to learn about contemporary genetics, the experimental methods in this field, and methods of teaching with research-level organisms. They then used both the scientific and pedagogical approaches in their own classes. Table 3 displays the number of students in different classes and modes of using the materials over a four year period.

	Elementary School	**Middle School**	**High School**		
			Regular classes	Advanced classes	Independent Study
Number of Students	152	3072	8155	4472	2434
Average Classes/Teacher	3.5	3.3	2.9	2.3	

Table 3: Number of students who used activities from the GENE project during a four year period.

The most striking result in these data is the number of independent study projects completed by the high school students. Over 2,400 students have used real research organisms in independent studies during the four years covered by the survey. These results represent an average of over nine student research projects per teacher per year. Having experienced research quality work in their graduate studies at KSU these teachers, in turn, involved their students in similar efforts. Thus, the integration of teaching and research in the GENE project enabled teachers to include similar activities in their teaching.

An important part of our assessment was to determine how the participants felt that the project had influenced their development as a professional teacher. In response to an open-ended question on that topic the teachers most frequently mentioned

- a sense of accomplishment at being able to complete research-level experiments and understand their results,
- an increase in their confidence to teach the materials and to help students who are interested in going beyond the presentation of the textbook, and
- feeling part of a community of teachers who had a common interest in the way contemporary genetics research is completed and taught.

In ranking aspects of the program on a 0 to 2 scale the sense of accomplishment and the networking with other teachers were both ranked as very important (1.85 and 1.68 respectively.) The interviews have not included confidence building in the ranking questions.

The overall conclusion of our assessment to date is that the involvement in research quality experiments during the summer course as graduate students resulted in the teachers viewing themselves more as professional scholar-teachers. This self image had a definite positive effect on them and their teaching.

Another component of the GENE project is the translation of the yeast genetics instructional materials to the undergraduate biology curriculum. This component of the research-teaching effort should have an effect on the education of future teachers. At this writing the assessment of the effect of this component is not complete.

While the assessment of Visual Quantum Mechanics is just beginning, we are receiving positive feedback from the teaching community. For example, in January two of the software packages developed as part of the program will receive awards from *Computers in Physics*, a publication of the American Institute of Physics, for outstanding educational software. However, analysis of how the program affects students who have completed the materials will need to wait until these students begin their teaching. While we can conclude that the Visual Quantum Mechanics project is on a track to show a definite positive influence on the University, its students and its faculty, the assessment is not yet as carefully documented as the other two projects.

Another indicator that the higher education community views our overall program of integrating research and teaching favorably is a recent award received by Dean Zollman, a co-prinicipal for all three of the projects and co-PI for this award application. The Carnegie Foundation for the Advancement of Teaching and the Council for the Advancement and Support of Education (CASE) have selected Dr. Zollman as the 1996 National Research University Professor of the Year. The documentation for this award included letters from a student who used the Visual Quantum Mechanics materials in a class for undergraduates who plan to be secondary science teachers and from a student who was involved in the Elementary Education Curriculum. Thus, the work related to these projects formed an important component in this selection.

In summary, two of the three projects have completed extensive evaluations of their efforts. We have concluded that both were quite successful in reaching the goals for professional development of present and future teachers. We anticipate that abilities and confidence that have been built by working in an environment that included a combination of research and education will continue to pay dividends for these teachers throughout their careers. As parts of these programs become integrated into the education of all science teachers we expect to see an even greater change in the way our teacher-graduates view science and the enterprise of scientific research.

7. Plans for Use of Award Funds

Funds received from this award will be used to establish the KSU Program for Integrating Education and Research. The primary purpose of this Program will be to document, disseminate and extend our efforts in the integration of research and education. The proposed Program will collect the information needed to document fully all aspects of our efforts, will create methods for dissemination and will provide the motivation and support to enable additional faculty to understand ways in which they can make their research accessible to beginning undergraduate students, particularly those who are planning to be teachers. The Program staff will help faculty see how they can use modern technology and contemporary teaching methods to create understandable materials for a broad range of students. The Program will, thus, build on the success of the three KSU projects described above and enhance the environment in which faculty are encouraged to integrate their research with education, not just for majors, but for all students.

Particularly important in the Program's efforts will be those faculty who are part of a science department but who specialize in research and development related to the discipline. In January, 1997, the Division of Biology will add one such person to its faculty. We anticipate similar appointments in other science and engineering departments during the next few years.

The Program staff will follow a phased operation to complete its initial task. First, complete *documentation* of the existing efforts will be needed. As stated above, many publications have already occurred. However, the process by which the faculty worked to create the instructional materials and the changes that occurred in both the faculty and the University needs further documentation. Working with faculty in the College of Education and the Office of Educational Advancement the Program staff will create documentation for publication and for internal use in both the expansion and dissemination activities.

Once the documentation is well underway, the *dissemination* effort will begin. The Program staff will create a hands-on workshop that describes the process employed in the successful KSU projects. The staff will present workshops at professional meetings in the sciences, mathematics, education and engineering, and at other colleges and universities. The co-principal investigator for this award has significant experience in creating both faculty development workshops and multimedia instructional materials. Thus, he will lead the creation of a multimedia version of the workshop to reach a broader audience than those faculty who attend workshops at professional meetings. The interactive documentation and dissemination effort will be available both on the World Wide Web and CD-ROM.

The final stage of our effort will be *expansion* to include additional faculty and subject areas in science, math, and engineering. We will encourage other faculty to use the model of the GENE, Visual Quantum Mechanics, and Elementary Education projects and transfer their research to introductory courses and to teacher education programs. Because the present integration of research and teaching has occurred with a collaboration of faculty in the Colleges of Arts & Science and Education, we will place particular emphasis on expanding to the Colleges of Agriculture, Engineering, Human Ecology, and Veterinary Medicine which have scientific research programs. Program staff will introduce faculty to teaching strategies used in these programs and the methods by which the conversion from research activity to student-centered instructional materials took place. Faculty will receive assistance to create appropriate materials, to develop visualizations, and to prepare hands-on learning activities. This phase of the effort will allow KSU faculty to include a much broader integration of research into the teacher education and general education programs.

While all activities will occur throughout the Program's lifetime, the emphasis will change as the Program matures. During the beginning of the award period documentation and dissemination will be the major emphasis. A gradual shift to expansion will occur so that during the third year the major emphasis will be expansion of the integration efforts to additional disciplines.

Each of the three activities will receive approximately equal amounts of the award funds. Because a significant portion of the documentation is already complete, we can place a slightly large fraction of the budget on dissemination and expansion. Thus, we estimate that the budget for the three areas will be:

Documentation:	$120,000
Dissemination:	$190,000
Expansion:	$190,000

The University will provide support for the Program with release time for the director, Professor Dean Zollman. The University will also continue the funding for at least two years beyond the Award period to assure that the Program has adequate time to create the atmosphere so that all faculty can have an opportunity to become involved in the integration of research and education.

8. Conclusion

Each of the three programs described in this application represent a different approach to the integration of research and education for our teacher development efforts.

- In the Model Elementary Education Curriculum the faculty used recent research in cognitive sciences to develop appropriate courses and field experiences for elementary education majors with science and mathematics specializations. Then, these students became involved in a research-type experience with a course that enabled them to become active at a major KSU research facility. Thus, starting with the classroom needs faculty integrated research.
- The genetics projects began with a significant quantity of research techniques and results. Fundamental, recent research techniques and research-level organisms were transferred to the classroom so that in-service teachers and biology majors could become familiar with modern genetics and the way knowledge is developed in this field. Thus, beginning with research results and techniques faculty developed an integrated educational program.
- The quantum mechanics project began with the desire to bring contemporary physics concepts and research to future teachers. By using research-level techniques and results of quantum science research which is underway at present, faculty are adapting materials for a setting in which future secondary teachers can learn and be able to transport the ideas to their classrooms. Thus, faculty are continuing to couple contemporary research with the education of teachers.

In all cases the primary goal is to create teachers who are competent in modern scientific concepts and cognizant of the way in which scientific knowledge develops. By integrating their recent research with teacher education our faculty has created research-level opportunities as part of their courses. Further, they develop interactive teaching materials based on their research, and their teaching leads to new research opportunities. Thus, reaching a goal of systemic change in the way present and future teachers are educated requires the combining of both research and education. These and other programs have established an atmosphere in which research and education are not separate but part of a broader scholarly activity. The commitment of the University has enabled this unique integration to flourish.