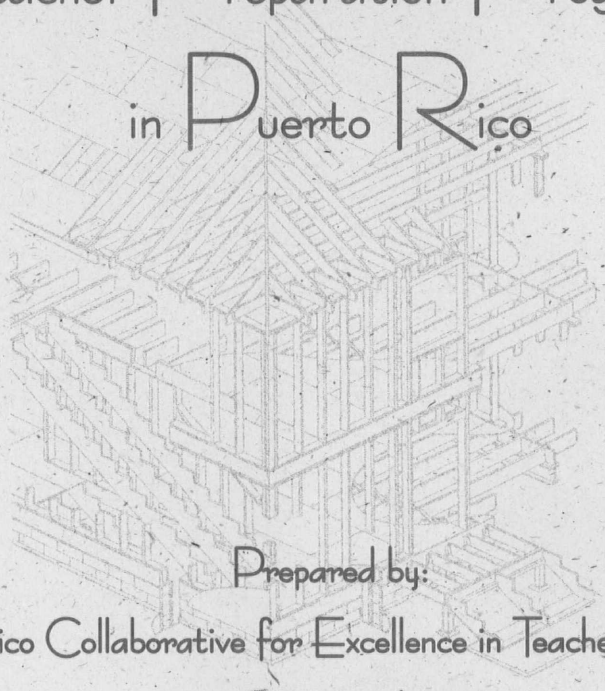
Blueprint for the Reform of K-12 Science and Mathematics Teacher Preparation Programs in Puerto Rico



Prepared by:

Puerto Rico Collaborative for Excellence in Teacher Preparation

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TABLE OF CONTENTS

Blueprint for the Reform of K-12 Science and Mathematics Teacher Preparation Programs in Puerto Rico

Preface- The Systemic Reform of Science and Mathematics Education in Puerto Rico.

The educational system in Puerto Rico is undertaking a systemic reform of science and mathematics education to provide all students on the Island with high quality opportunities to achieve standards of excellence. An essential part of this systemic reform is the transformation of the teacher preparation programs to ensure that all future teachers are well prepared to teach in alignment with the educational vision set forth through the reform. The preparation of future teachers is the responsibility of multiple sectors working in collaboration, not of a single department or school working in isolation. Hence the reform of the teacher preparation programs requires the joint effort of all key sectors in this enterprise. The overall purpose of the Blueprint is to offer general guidelines that will stimulate and facilitate collaboration among all the sectors involved in teacher preparation, so as to bridge the gap between where we are now and where we want to be in relation to the preparation of all science and mathematics teachers in Puerto Rico.

The design of the Blueprint is the result of a collaborative process sponsored by the *National Science Foundation's Collaboratives for Excellence in Teacher Preparation (CETP) Program,* through which Science and Mathematics Teacher Preparation (SMTP) faculty members, academic administrators, K-12 teachers who are leaders in the educational reform, the Puerto Rico Department of Education (PRDE), and the Resource Center for Science and Engineering (RCSE) staff, formed an interinstitutional team to assess the major areas of need for the reform, and the fundamental changes needed to align SMTP programs with the local and national standards and with the K-12 systemic reform, and outlined the major strategies to achieve the objectives of the reform. The universities joined in the development of the Blueprint range from small four-year colleges to large graduate centers which share a tradition of collaboration in the improvement of teacher preparation in Puerto Rico, as members of the Resource Center for Science and Engineering (RCSE) Consortium. Since 1980, the RCSE has served as a broker, joining institutions throughout the Island to undertake major projects for the improvement of science, mathematics and engineering education and research, and tapping on the best resources available in both natural sciences and education faculties. Two of these major initiatives are the Puerto Rico Statewide Initiative (PR-SSI) which is spearheading the reform of K-12 education, and the Puerto Rico Alliance for Minority Participation the (PR-AMP) which is promoting the systemic reform of science, mathematics, engineering and technology (SMET) education at the undergraduate level.

Five of the six universities participating in the elaboration of this Blueprint have a long-standing history in the successful development of in-service science and mathematics teacher enhancement programs funded by Dwight D. Eisenhower-Title II of the U.S. Department of Education, The National Aeronautics and Space Administration (NASA), and NSF among others. The sixth institution is new and is building its offerings following the Puerto Rico Alliance Minority Program (PRAMP) curricular principles. These universities have developed three different models of SMTP programs: 1) those that offer BA degrees in K-6 and in Science and Mathematics Education; 2) those that offer education courses required for teacher certification to students graduating with a BS degree in Natural Sciences; and 3) those that offer BS degrees in

Natural Sciences with a concentration in Science Education. The collaborating institutions serve over 70% of the total annual enrollment in K-6 teacher preparation programs and over 95% of enrollment in all secondary science and mathematics teacher programs on the Island, as of 1996-97. The Collaborating Institutions in the PRCETP are:

- The Río Piedras Campus, University of Puerto Rico, offers BA degrees in Elementary Education (K-6), in General Science Education (7-9) and Secondary Education in Biology, Chemistry, Physics and Mathematics (10-12).
- The Mayagüez Campus, University of Puerto Rico, the Land Grant Institution specializing in Agricultural Sciences & Engineering offers BS degrees in Sciences and Mathematics with an option in education for certification to teach at the secondary level;
- The Cayey University College, University of Puerto Rico, offers a a four year College with mission to prepare teachers; offers BA degrees in Elementary Education (K-6) in General Science Education (7-9) and Secondary Education in Mathematics (10-12)
- The Interamerican University of Puerto Rico System, the main private university on the Island, offers BA degree in Elementary Education (K-6), in General Science Education in (7-9) and Secondary Education in Biology and Mathematics (10-12)
- Pontifical Catholic University offers a BA degree in Elementary Education (K-6) and General Science and Mathematics Education (7-9)
- The University College of the East, Ana G. Méndez University System, will begin a BS in Elementary (4-6) and Intermediate (7-9) Science Education in 1998-99.

The Resource Center for Science and Engineering (RCSE), a special unit of the Central Administration, Office of the President of the University of Puerto Rico, served as a facilitator and coordinator for the planning process and the elaboration of the Blueprint.

A central partner in the development of the Blueprint is the **Puerto Rico Department of Education (PRDE)**. The PRDE is undertaking a major reform to decentralize the school system which started in 1993, through the implementation of site-based management, establishing all schools as community schools. The PRDE is undertaking the reform of K-12 education to promote that all students achieve high standards through Goals 2000 and is implementing the PRSSI with the RCSE to achieve excellence in science and mathematics education. PR-SSI schools that have been developed into **Regional Professional Development Centers** (RPDCs) have actively collaborated in the elaboration of the Blueprint. These Centers are exemplars of standards-based, inquiry-centered teaching/learning environments where teams of empowered teachers and SMTP faculty provide professional development programs throughout the Island to scale-up the PRSSI reform.

The Blueprint is therefore, the product of a broad collaboration endeavor that builds upon and incorporates prior and current developments, integrating them to propel a critical component of the systemic reform, the islandwide reform of science and mathematics teacher preparation to produce a new generation of teachers who are empowered to meet the standards of excellence.

Acknowledgements

The Blueprint for the Reform of K-12 Science and Mathematics Teacher Preparation Programs in Puerto Rico was sponsored through a planning grant from the Collaboratives for Excellence in Teacher Preparation Program of the National Science Foundation (Grant Number: DUE 9653975) implemented by the Puerto Rico Resource Center for Science and Engineering. A group of natural sciences and science and mathematics education faculty from the leading universities that prepare science and mathematics teachers in Puerto Rico and K-12 leader teachers participating in the systemic reform of K-12 education formed an interinstitutional committee. This committee analyzed the major issues in the reform of teacher preparation programs, and reached a consensus on the vision and the major directions to spearhead the reform which became the basis for the Blueprint.

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Introduction

The emergence of the knowledge-based society requires the development of human resources and citizens who possess a high level of scientific literacy and the capability to perform as lifelong proactive learners within a global community. Based on the above assumption, since 1990, Puerto Rico has engaged in the systemic reform of science and mathematics education, starting at the undergraduate level through the Puerto Rico Alliance for Minority Participation Program, followed by the Puerto Rico Statewide Systemic Initiative to reform K-12 education in 1992. Both initiatives, now in their second 5- year phase sponsored by the National Science Foundation, are focusing on the scaling up of efforts at the islandwide level and the institutionalization of the improvements achieved. These initiatives both provide the foundation for, and require the reform of future science and mathematics teachers. If universities are to receive high school graduates who successfully complete undergraduate studies in sciences, mathematics, engineering and technology (SMET) fields, they need to be involved in the preparation of high quality K-12 teachers. The K-12 reform requires the reform, teacher preparation programs to ensure that all future generations of teachers are well prepared to sustain the reform in alignment with the standards of the National Research Council (NRC), National Council of Mathematics Teachers (NCTM) and Benchmarks 2061 of the American Association for the Advancement of Science (AAAS).

The major universities that prepare teachers in Puerto Rico, have played a major role in the K-16 reform in science and mathematics. These universities have joined efforts to undertake a comprehensive project to align K-12 SMTP programs with the standards-based systemic reform spearheaded through the PRSSI, and face the challenge of providing the future science and mathematics teaching workforce with learning experiences that will optimally prepare them to fulfill the demands and sustain the achievements of the reformed educational system. The common goal of the PRCETP is to promote teacher preparation programs that prepare teachers who are: committed to standards-based education for all students; strong in conceptual understanding of the subject they teach and in the integration of knowledge across disciplines; competent in the use of inquiry-based, content specific teaching methods and authentic assessment; effective in the use of multiple educational technologies in their teaching practices; empowered to adapt and design high quality standards-based curricular materials to meet the diverse learning needs of their students within the context of their daily experiences; knowledgeable of the principles of scientific research; and members of communities of lifelong learners who are engaged in the continuous improvement of their practice through active research efforts. The main sources of information tapped upon by collaborating universities to elaborate the blueprint for the reform of science and mathematics teachers include:

- local and national standards for science and for mathematics education, and standards for science and mathematics assessment;

- the PRSSI Professional Standards for Science and Mathematics Teachers, which are aligned with local and national standards;

- the professional development needs expressed by PRSSI teachers, and the curricular changes taking place in the teaching/learning process promoted through the PRSSI whole school-based strategy;

- the reports of the National Commission on Teaching and America's Future (1996), the Mathematical Sciences Education Board (1996) and the National Research Council (1997) on the preparation of science and mathematics teachers;

- the present needs, barriers and windows of opportunity for the reform of SMTP Programs found in the participating institutions.

The PRDE content standards for science and for mathematics completed in 1995, and the assessment standards completed in 1998, as well as the PRSSI Professional Standards for Science and Mathematics Teachers (1994) were developed by commissions formed through the PRSSI, joining the efforts of SME faculty and K-12 teachers. The content standards for science and for mathematics are both aligned with national standards, including those of the National Research Council, the National Council of Mathematics Teachers Standards, and the 2061 Benchmarks. The seven science standards established by the PRDE are based on the following unifying themes: nature of science; structure and levels of organization of matter; energy; systems and models; interactions; conservation and change; and science, technology and society. The six content standards for mathematics emphasize the following major themes: numeration, operations, geometry, measurement, relations and functions, and probability and statistics. The PRSSI curricular principles establish that all science disciplines and areas of mathematics are to be taught in each grade through a spiral progression of conceptual abstraction, promoting the integration of knowledge within and between the different fields of knowledge. It is critical that the path towards the achievement of these standards and principles be carefully developed and that we create the vehicles that will enable us to progress towards our goals through teacher preparation programs of excellence.

Part I: Vision of the Science and Mathematics Teacher in Puerto Rico

In 1994, through the PRSSI, a group of science and mathematics educators from all over the Island and all levels of the educational system worked together to elaborate the Professional Standards for Science and Mathematics Teachers. These standards, created as a key component of the vision for the systemic reform in science and mathematics education in Puerto Rico, reflect the national trends in education of science and mathematics and are aligned with the major national standards. Each standard is described including the implications therefor the teacher preparation and continued education programs. The following are the Professional Standards, which are adopted in the PRCETP Blueprint as the core of the vision that will guide the reform of teacher preparation programs in Puerto Rico:

PRSSI Professional Standards for Science and Mathematics Teachers

Teachers master the concepts, processes and skills of the science and mathematics discipline they teach.

Teachers possess the basic skills for scientific and mathematics research that allow their students to develop these effectively;

Teachers are effective communicators that facilitate learning and the adequate use of scientific and mathematics language at their students level.

Teachers know their students, understand them, respect them and create an environment that propitiates active learning, social interaction and self-motivation;

Teachers select and design teaching strategies that promote the development of simple and complex cognitive skills.

Teachers propitiate the integration of concepts within and among the natural sciences and mathematics, at the same time they promote the development of connections with other disciplines and with the students' experiences.

Teachers select, adapt, and use materials and instructional equipment and create their own resources so as to stimulate exploration, understanding and application of science and mathematics.

Teachers use a variety of instructional resources including human and physical resources from the community and field experiences that underscore the relevance of science and mathematics in our world.

Teachers are able to interest students in science and mathematics, and to participate, regularly and actively, in different educational activities.

Teachers gather, organize and interpret information that facilitate reflection on their students' learning process and allows them to make judgements on their performance.

Teachers establish links with parents or the students' custodians and the community to construct educational experiences that are pertinent to the students.

Teachers continuously analyze the effectiveness of the learning experiences they provide to improve their educational practice.

Teachers value their profession and keep updated in their discipline and in new educational developments.

Chapter 1: Elements of an Effective Teacher Preparation Program

The systemic reform of K-12 science and mathematics education requires that teacher preparation programs become aligned with the Professional Standards for Science and Mathematics Teachers in Puerto Rico and the local and national science and mathematics education standards. These teacher preparation programs must provide a comprehensive and coherent spectrum of learning experiences that will ensure the effective development of the fundamental knowledge, attitudes, and skills that every teacher needs to fulfill the professional standards. The PRCETP Blueprint provides a profile of the key elements that should be addressed by effective teacher preparation programs to develop highly competent teachers. In developing this profile, the PRCETP group embraces the following vision statements formulated by the National Research Council for

the preparation of science and mathematics teachers as presented in their report **Science Teacher Preparation in an Era of Standards-Based Reform by (1997)**:

#1 All Teacher Preparation Program science [and mathematics] faculty will recognize their role as educators.

#2 All science [and mathematics] faculty members will structure the content, pedagogy and assessment strategies in their courses, especially in the lower division, to optimize student learning, thereby providing future teachers with the knowledge, understanding, and skills necessary to teach in accordance with the national and local standards;

#3 All science [and mathematics] educators will consider issues of teacher preparation program and curriculum design in light of the standards;

#4 The Teacher Preparation Programs will develop and implement mechanisms that encourage collaboration among departments, among the postsecondary institutions and among the postsecondary institutions and K-12 schools;

#5 The Teacher Preparation Programs will attract and retain students of high quality from diverse backgrounds;

#6 The Teacher Preparation Programs will provide future teachers with an integrated education, that includes and interweaves a strong content area component and an applications-based methodology component with current educational research;

#7 Each Teacher Preparation Program will have the appropriate mechanism to have accessible for their faculties a body of research about the effectiveness of various models for teacher preparation, will draw on that research to improve existing science and mathematics teacher preparation programs, and will contribute to that body of knowledge as part of the teacher preparation program design.

The following constitute the major elements of the Teacher Preparation Program envisioned by the PRCETP:

Articulation between Content and Method, and between Theory and Practice: Among the major barriers to the effective preparation of science and mathematics teachers are the structural gaps in teacher preparation programs that disconnect science/mathematics content and teaching methodology, and teaching-learning theory from teaching-learning practice. The content and pedagogical components of the teacher preparation programs are separately provided by the schools of science and education respectively, with little coordination or collaboration between the faculty from both schools. This fragmentation does not allow for the integration of content matter with pedagogical knowledge required for effective learning. The second gap is found between pedagogical theory and methodology courses, as well as between these courses and the practicum, creating a cognitive gap that curtails the student's ability to effectively transfer theory to practice as well as build their own knowledge from experience. Finally, there is a gap between the

practicum component and the actual K-12 reform, as students are not systematically exposed and involved in exemplary schools where they can directly experience the reform. Teacher Preparation Programs must promote stronger articulation among these components. The current state of teacher preparation programs with its major gaps is presented in Diagram A, whereas the ideal situation where the gaps are bridged is illustrated in Diagram B.

The Process of Preparing Teachers is Structured as a Coherent Developmental Continuum: The preparation of future teachers should begin at recruitment and continue through induction into teaching courses during the first years as a professional in the classroom. All the components of the process must be clearly integrated and sequenced so as to provide students with a coherent learning experience (See Diagram C).

Collaboration Among Natural Sciences and Education Faculties and K-12 Teachers: To ensure that future teachers develop strong content knowledge as well as strong content-specific pedagogical knowledge, it is fundamental for the natural sciences and education faculty to develop collegial relations and work together in the design and implementation of the teacher preparation programs. Collegial collaboration between university faculty and K-12 teachers is essential to promote stronger articulation between the theory and practice of teaching.

Faculty Model Effective Teaching Methods: One of the strongest influences in the way teachers learn to teach is the way in which they are taught rather than the ways in which they are told to teach. Faculty from both natural sciences and education must keep up-to date in cognitive research developments and implement effective research-based teaching strategies that focus on inquiry so as to model these methods for future teachers.

Institutional Policies Support Faculty Development and Teacher Preparation Programs: It is necessary for the academic administrators to foster an institutional culture that recognizes, encourages and actively supports faculty development and the institutionalization of faculty development programs.

Faculty Development through Communities of Learners: Faculty development opportunities must be available to stimulate faculty to continually improve their teaching practice according to high standards of quality, and faculty should engage in their own professional development by forming communities of learners integrating members from the different disciplines through which experiences in teaching and innovations are shared and supported.

Academic Offerings Based on Standards: The curricular configuration of teacher preparation programs must be clearly aligned with the educational standards in science and mathematics, and each course should be designed to ensure that students are well prepared as future teaches to promote the achievement of standards among students.

Diagram A

From Theory to Practice, the Cognitive Gap

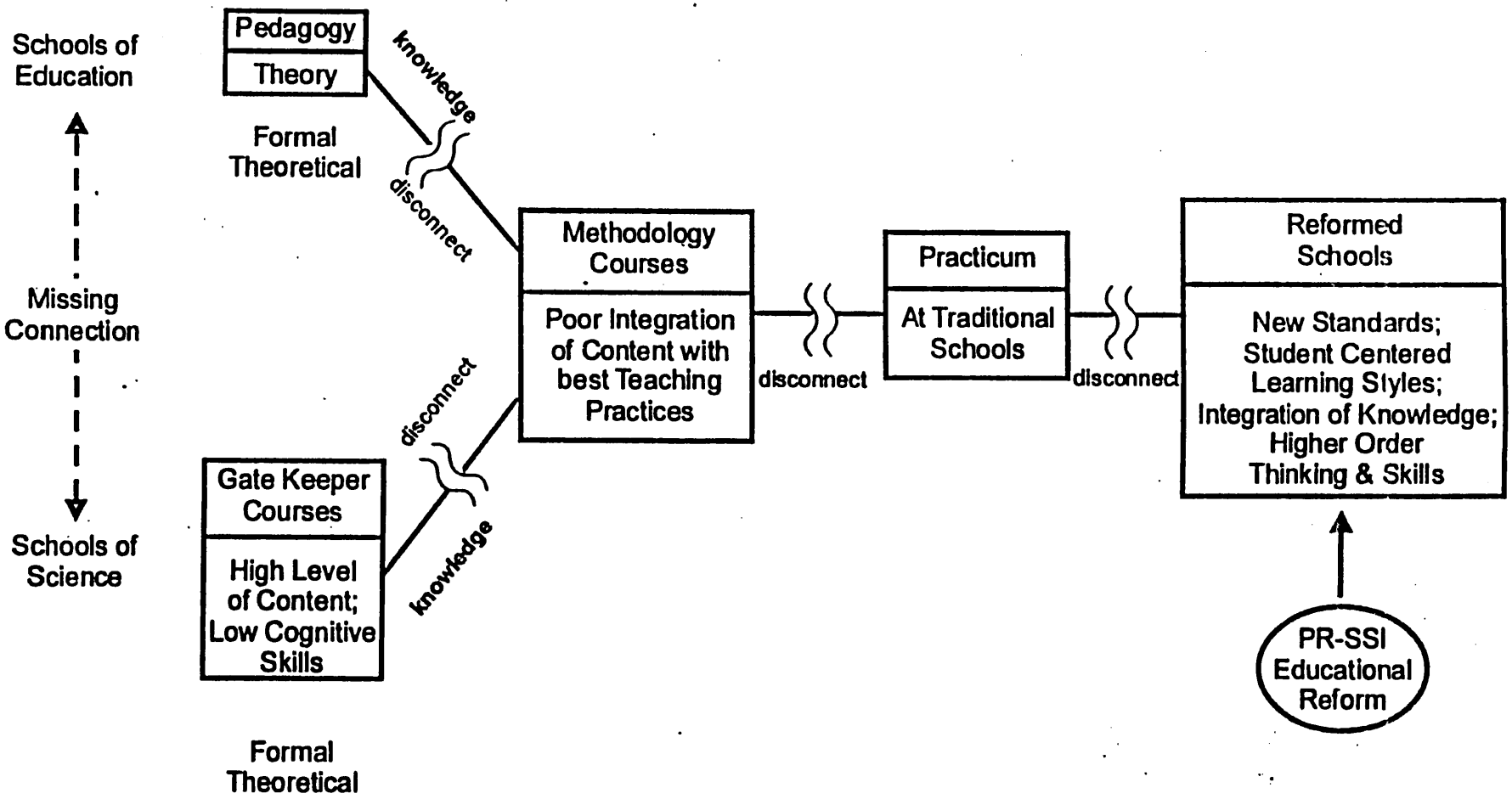


Diagram B

From Theory to Practice: A Constructivist and Integrated Approach to Connect Effectively with Reformed Schools

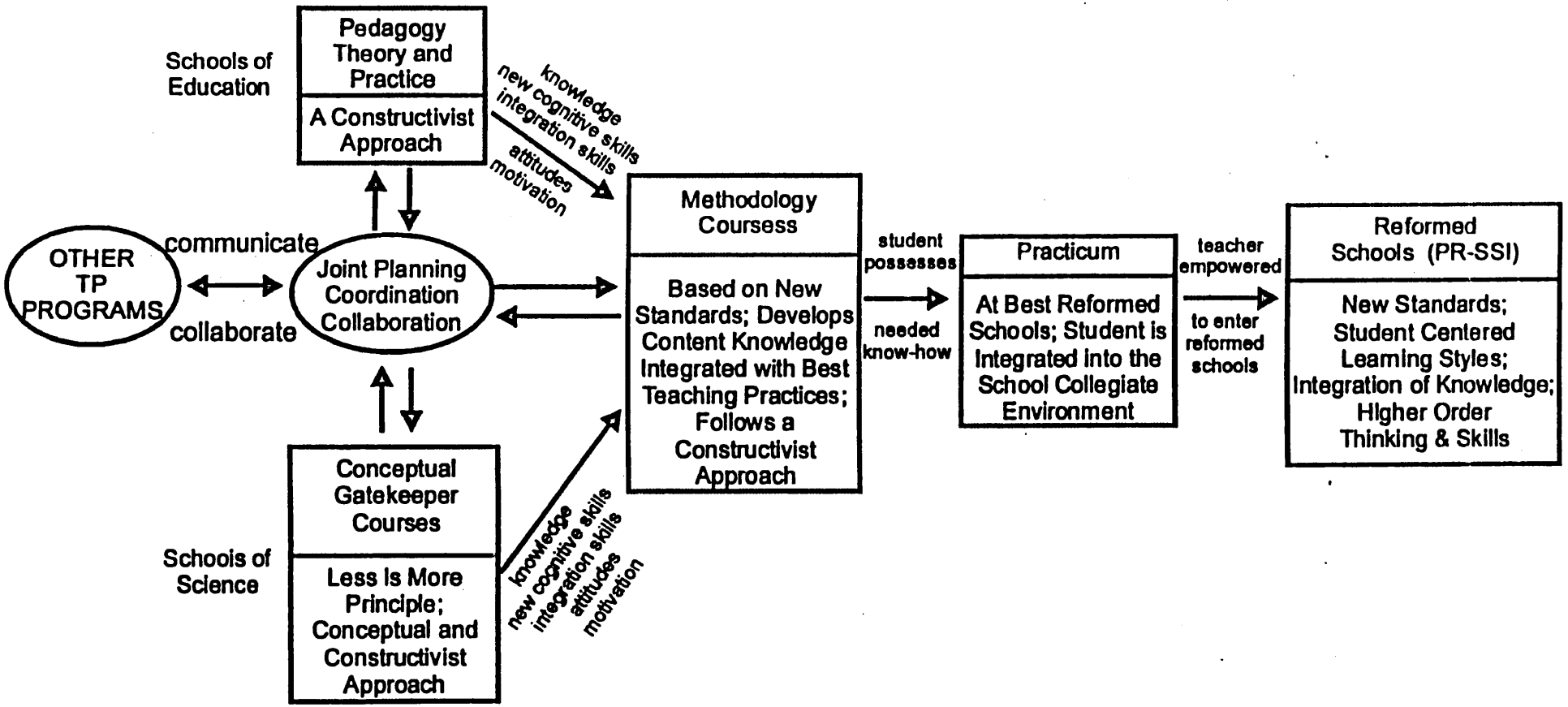
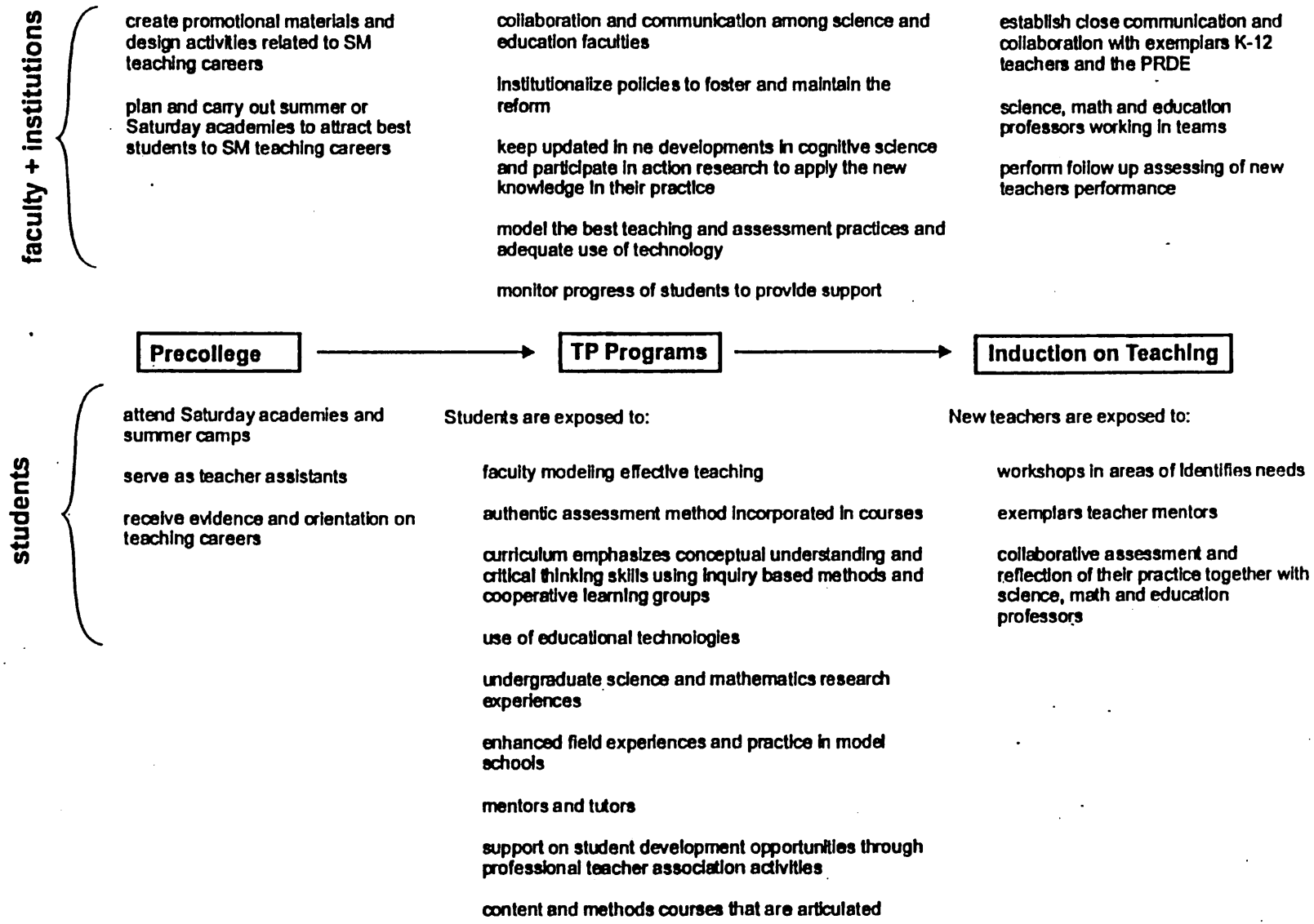


Diagram C

PR COLLABORATIVE FOR EXCELLENCE IN TEACHER PREPARATION
Seamless continuous from recruitment to induction into Teaching



Field Experiences Extend Throughout the Teacher Preparation Process : Field Experiences in a variety of schools as well as in non-traditional settings such as: "El Yunque Rainforest", "The Camuy Caverns" the "Arecibo Observatory", industry, and others that are resources for K-12 education should be strengthened and begin early during early teacher preparation programs to provide students with multiple opportunities to become involved in the practice of education.

Educational Technologies is Infused throughout the Teacher Preparation Curriculum: Tools such as computers, graphing calculators, telecommunications, and others are essential to improve learning among future teachers, as well as to prepare them to incorporate technology in their own practice.

Future Teachers Participate in Educational and Scientific Research: Participation in the research process is a fundamental experience in the development of knowledge, both scientific and educational, and promotes students to develop an understanding of the scientific enterprise, develop skills in teaching the scientific method and inquiry, and in using research to improve their own teaching practice.

Student Assessment Reflects Standards and is Integrated into the Learning Process: The assessment of student learning must be designed to assess learning in alignment with the standards. These methods should effectively assess what students know and are capable of doing, and provide students with an opportunity to reflect on their own learning process. The methods by which students are assessed should be congruent with those they are prepared to incorporate in their practice as future teachers.

Recruit Excellent Students: Proactive efforts must be made to attract and support students who have the potential to become excellent teachers through recruitment during the high school and early university years. Students with potential to become good teachers must be actively sought, encouraged as a valued resource and provided with opportunities to explore the positive experiences of teaching. More intensive efforts must be made in the areas of Chemistry, Physics and Mathematics which are the areas of teacher shortage in Puerto Rico.

Induction into Teaching: Research shows that beginning teachers who have had the continuous support of a skilled mentor are more likely to stay in the profession and to get beyond classroom management concerns to focus on student learning. Graduates should be provided with a program that promotes an effective induction into teaching and continues its professional development with emphasis on the areas of need that arise in the initial stages of the teaching career.

Students' Communities of Learners: Future teachers need to identify themselves as part of a professional community and become involved in the process of lifelong continued education as part of a community of learners. To promote this involvement, faculty and institutions should encourage, invite and facilitate students' participation in professional societies meetings and promote the presentation of their research efforts at such meetings.

Chapter 2: Academic Offerings

The curriculum of an Effective Teacher Preparation Program must provide for students to develop a strong and broad base of knowledge in content matter in alignment with the national and local curricular standards. It must also develop-content specific pedagogical knowledge based on a constructivist framework that focuses on active learning methodologies, cooperative learning and authentic assessment.

The academic offerings of an effective teacher preparation program should take into account the following:

- Course content should focus on the basic ideas of science and mathematics and should be aligned with local and national content standards. The local content science standards are based on seven unifying themes: the nature of science, structure and levels of organization of matter; energy; systems and models; interactions; conservation and change; and science, technology and society. The mathematics standards emphasize the following themes: numeration, operations, geometry, measurement; relations and functions, and probability and statistics. Key concepts in content courses should be presented in relation to these unifying or major themes highlighting the connections among concepts.

- The amount of material included in these courses must be revised to allow more time to the in-depth discussion of the fundamental concepts. This may require less emphasis on certain topics and more emphasis on others, to promote depth of understanding of the key concepts. These courses must emphasize conceptual understanding of key concepts, and the development of higher order thinking and science process skills.

- Courses should incorporate an interdisciplinary approach that focuses on the interrelation and connections between disciplines as well as between science and mathematics. The Puerto Rico content standards for science and mathematics are based on unifying themes that cut across the traditional disciplinary boundaries. Future teachers must be able to understand these themes through an interdisciplinary lens that underscores the inter-relationships among science, mathematics, technology, and society. Science, mathematics, and education faculty should work together to structure the sequence of courses in ways that help students understand the conceptual connections within and across disciplines. Case studies that provide for the integration of multiple disciplines should be used throughout the curriculum.

- Concepts should be learned within the context of concrete situations of our daily life and in direct contact with our local context by means of field experiences.

- Emphasis on student-centered learning must be promoted where conferences are minimized and substituted with active inquiry activities, interactive demonstrations and cooperative learning. Classes must also provide activities to engage all type of students and allow time for them to self-assess and reflect on their own learning. These methods actively engage students in the learning process, promote depth of understanding and the development of higher order cognitive skills. Class discussions are central to promote student participation,

focusing on the formulation of questions that engage students in higher order thinking processes. For example, students can be required to work in groups in the design of research projects.

Scientific research experiences

- It is critical for future teachers to develop knowledge of the scientific approach and habits of mind called for in the national and local standards. To understand the true nature of science, preservice teachers must have meaningful undergraduate experiences participating in scientific research projects. Scientific research is the main process by which scientists develop their knowledge. Therefore, students must be exposed to specific experiences in scientific research through courses and involvement in actual scientific and mathematics research groups.

Pedagogy courses

- Learning theory courses should develop understanding of how students with diverse interests, abilities, and experiences make sense of scientific ideas and what a teacher needs to do to support and guide learning for all students;

- Students need to be involved in evaluating curricular materials, instructional and assessment approaches for congruence with the Standards.

- All methodology and assessment courses should be aligned with national and local standards, modeling and providing conceptual understanding for the key teaching and assessment methods that have proven to be effective according to educational research.

Field experiences

- Field Experiences should begin early and extend throughout the teacher preparation process, so that students have real experiences that serve as a testing ground for educational theory and ideas about practice.

- Future teachers should be provided with extensive experiences in exemplary schools where they may interact with teachers who model the best practices in inquiry-based teaching.

- Teacher Preparation Programs should prepare and support cooperating teachers so that they become excellent resources and partners in the teacher education process.

- Exposure to a diversity of field experiences is important to provide students with multiple opportunities to learn about the teaching of key concepts in their real context, such as industries, laboratories, natural settings, and others.

Faculty in teacher preparation programs should adopt clear guidelines for curricular development to ensure that academic offerings are addressing the critical aspects of an effective

teacher preparation program. One example of such guideline is the Framework for Analyzing Syllabi provided by the AAAS in their book *Resources for Science Literacy, professional Development Project 2061.*

- Is each topic or concept within a topic treated in adequate depth to realistically expect students to learn it?

- Is attention called to appropriate connections among concepts presented in the course? in other courses?

- Does the course attempt to address student misconceptions?

- Is the course structured to make possible the collection of evidence on student understanding of the concepts targeted? Is the evidence used to revise the course?

- Are students engaged in activities that give them first-hand experiences with the concepts and then given opportunities to reflect on their activities?

- Are opportunities provided for students to apply their knowledge in varied contexts-e.g., explaining everyday phenomena or considering alternative solutions to practical problems?

Chapter 3: Educational Technology

The integration of educational technology into teacher preparation programs is fundamental for optimizing the learning process of future teachers as well as for preparing them to incorporate technology as an educational instrument in their future teaching practices. The use of technology should be infused throughout the teacher preparation curriculum, not limited to a course on this topic. The following should be taken into account in the incorporation of educational technology.

- Future teachers require learning experiences that incorporate the use of educational technologies, including the computer, Internet, CD ROMs, calculators, Calculator-Based Laboratory (CBL™), telecommunications, distance learning and video players in their TP courses.

- Prospective teachers need to be prepared to make informed decisions about the appropriate use of specific technology in K-12 instruction.

- Faculty should incorporate and model the effective use of educational technology in their courses. Professional development should be provided for faculty to incorporate multiple educational technology in all facets of the overall institutional program for teacher preparation.

- Institutions must develop the facilities and resources required for faculty to incorporate the use of multiple educational technologies into the preparation and assessment of future teachers.

- Faculty must be encouraged to create and disseminate curriculum materials that use educational technology in science, mathematics and education courses.

- Educational technology should be used as an effective instrument to strengthen connections between science and mathematics.

- Discussion groups and faculty development strategies based on the use of educational technology as a curricular innovation need to be fostered.

- The use of multimedia instruction in teacher preparation courses, particularly in teaching methods courses, should be expanded and its effectiveness assessed.

Chapter 4: Educational Research

Future teachers need to be actively involved as contributors in building the educational research knowledge-base on effective teaching-learning practices. They must also learn to be critical users of these developments in the improvement of their educational practice. The participation of future teachers in educational research experiences is fundamental to foster the self-directed and ongoing professional development of teachers. For this, they need experiences in research that can prepare them to critically examine the effectiveness of alternative teaching methods and approaches. Future teachers should keep abreast of the emerging research developments on the effectiveness of reform and on educational trends and innovations. It is therefore important to provide future teachers the opportunity to develop as scholars. Research projects can be incorporated into the different teacher preparation courses and students can participate in educational research projects by enrolling in specific courses with the purpose of joining research with or teams to carry out research without receiving academic credit. The results of student research should be presented and published in local, national, and international forums.

Research in education should focus on quantitative and qualitative classroom research in areas that will provide useful results to the improvement of the teaching learning process from K-16. Research projects that team up professors of education with professors of science and mathematics as well as K-12 teachers and education students should be supported.

Areas of educational research that need to be emphasized in Puerto Rico include:

- Ways to implement and assess the impact of recent educational research results in actual teaching-learning contexts.

- Building stronger connections among the natural sciences, mathematics, education, language and social sciences as well as the design of activities and its effective implementation in the curriculum.

- The process of "understanding" fundamental scientific and mathematical concepts such as heat, energy, force, patterns and graphs at the different grade levels.

- Methods to help students develop understanding of symbolic representations of physical phenomena.

- The process of developing graphing skills and the relationship between producing and interpreting them. How technology like graphing calculators and computers affect the development of knowledge and skills.

- Methods to help students build and use models to understand scientific concepts.

- What scientific and mathematical misconceptions prevail at the college and university level.

- The misconceptions science and mathematics teachers have about the subject they teach and how these can be corrected.

- How well a given assessment method measures students' understanding of SM concepts and how to develop better assessment methods.

- What effect does the experience with university professors as role models have on the prospective teachers' ideas and beliefs about their teaching practices?

- How do manipulatives affect student's understanding of scientific and mathematical concepts?

- What is the effectiveness of using CBLs (Calculator-Based Laboratory ™) to develop understanding of scientific and mathematical concepts and a better comprehension of the interrelationship between math and science?

- How does vocabulary knowledge affect the comprehension of scientific and mathematical concepts?

Chapter 5: Student Assessment

The alignment of assessment methods with educational standards and inquiry-based teaching methods is necessary to optimize the teaching-learning process. Assessment methods that are congruent with the educational standards need to be incorporated into TP Programs as a tool to assess the learning of future teachers and to provide them with an important part of the knowledge base to be developed by future teachers. Effective assessment must also be used to inform the instructional practices of faculty.

- Effective assessment methods need to be modeled in TP courses for students to learn as future teachers. In teaching future teachers about alternative assessment, linkages among content, teaching methods and assessment strategies must be clearly established.

- Future teachers need to become knowledgeable of alternative and performance-based assessment methods which promote active learning and depth of understanding, integration of knowledge, and the development of higher order cognitive skills. Examples of these assessment methods are portfolios, open ended questions, problem solving projects, higher order multiple choice questions, performance tasks, reflexive diaries, and group research projects;

- It is important to ensure that future teachers understand the different purposes of each type of assessment method and how to incorporate them effectively into the classroom. Additionally, future teachers need to develop knowledge of scoring rubrics as an important component of performance assessment, as rubrics articulate the criteria against which the quality of student work is evaluated.

- TP Programs need to provide future teachers with experiences that involve them in the design and implementation of assessment strategies. These experiences should allow adequate time to work through the issues and problems associated with accurate assessment of students' knowledge and achievement.

Part II: How to get there-The Reform Process

To achieve excellence in the teacher preparation programs, a systemic reform is required that promotes changes through the articulation of all components of the teacher preparation system and their alignment with local and national standards instead of focusing on the isolated modification of each component. Currently, the different components of the teacher preparation system are not effectively articulated, and communication and feedback channels among them are not well established, resulting in the overall fragmentation of the teacher preparation process. The transformation of the current piecemeal structure into a highly integrated system will require a substantial increase in intra-and interinstitutional interaction and collaboration among the multiple components of the teacher preparation process. Within institutions, a two-pronged strategy needs to be followed with integration of top-down and bottom-up strategies connecting the efforts at the systemwide level with those at the local and grassroots level. The systemic reform efforts need to focus on the key pressure points or critical components of the system, including:

- Faculty development and the building of communities of learners among the faculties of Natural Sciences and Education, and K-12 teachers.

- Transforming institutional culture, increasing administrative support, and establishing policies.

- Developing Institutional Assessment to measure progress toward goals.

- Building Partnerships among key players.

Chapter 6: Faculty Development through Communities of Learners among Science, Mathematics and Education Faculty and K-12 Teachers

For faculty to be effective models of inquiry-based teaching methods and design standards-based curriculum and assessment methods, access to and active participation in an on-going faculty development program is vital. One of the most important means to promote faculty development as part of a reform process is to establish "communities of learners". A community of learners is defined as a group of individuals or units of change that self-organized to learn new skills and behavioral patterns in a systematic and coherent manner within a collegial environment (Gómez & Dávila, 1992). In building a community of learners it is necessary to establish an environment of trust and respect within and between departments and faculty and administrators. When working with faculty from different disciplines it must be remembered that everyone is an expert in a different area and that differing ideas need to be valued. To support faculty development, institutions may:

- Identify and disseminate the best practices through multiple means such as workshops, and electronic discussion on innovations;
- Disseminate materials on exemplary SMTP programs and research in cognitive sciences related to learning science and mathematics;
- Offer workshops on the effective use of educational technology in SMTP courses;
- Offer workshops to promote the articulation of content, methods and assessment throughout the SMTP curricula;
- Sponsor faculty advisors to provide support and share expertise for the implementation of innovations in the classroom;
- Promote visits to exemplary K-12 classrooms and practicum sites to keep abreast about the implementation of the reform;
- Provide workshops and seminars on inquiry-based learning methodology, critical-thinking skills development, concept-mapping, performance-based assessment methods, and cooperative learning, among other;
- Sponsor travelling lecturers to present best teaching practices and stimulate discussion and explore key issues related to innovation;
- Establish a Resource Bank of faculty mentors to offer assistance in the development and implementation of curricular innovations;

- Foster networking among faculty through electronic discussion groups and conference calls;
- Provide adequate library facilities and access to the Internet for all SMTP professors and students;
- Encourage faculty to visit each others classroom and to provide feedback on the implementation of innovations;
- Design strategies to attract faculty who are interested but not yet committed or involved in the improvement of teacher preparation programs
- Sponsor collaborative action research in science and mathematics education to promote joint development among SMTP faculty, K-12 teachers and students in building a knowledge base in areas of priority in science and mathematics education.

Chapter 7: Institutional Policies and Organizational/Administrative Support

Academic and administrative officials play a fundamental leadership role in promoting a favorable institutional climate for reform by providing the incentives, facilitating administrative flexibility, and allocating the resources necessary to successfully effect and sustain changes at the institutional level. Their authority is needed to build an organizational culture that recognizes and values teacher preparation as a priority of the institutional mission, and to create spaces for collaboration, to develop and to implement innovations.

The universities academic administrators can adopt a central role through the following:

- Establish excellence in the preparation of future teachers as a prime item on the institutional agenda;
- Support and provide incentives for faculty involved in the improvement of teacher preparation curriculum, including released time. Incorporate faculty commitment to excellence in teacher preparation as a criterion for recruitment, promotion and tenure;
- Foster collaboration among the natural science and education faculty to sustain a unified professional development community, and interdepartmental initiatives and innovations in interdisciplinary team teaching, including colloquia on the redesign of courses and assessment methods, peer coaching, mentoring new faculty, joint publications in professional journals and joint presentations in local and national conferences;
- Value, reward, and foster broad recognition of faculty achievements and the broad dissemination of best teaching and assessment practices;

- Create faculty development programs that provide faculty opportunities to incorporate inquiry-based teaching methods and assessment into their courses;

- Develop strategies and activities that target faculty who traditionally are not interested in teacher preparation, and to involve researchers in curricular revision and student mentoring;

- Organize regular faculty meetings to present progress in curricular developments, and to promote discussion of issues in the implementation, dissemination, and institutionalization of change;

- Require the design of interdepartmental plans for collaboration of faculty in the curricular design and testing process to promote integration of the disciplines in the teaching of science content, including the offering of interdepartmental courses and team- teaching;

- Require the presentation of departmental reports on the effectiveness of curricular redesign efforts to improve student achievement and incorporate teacher preparation as a priority in the development of departmental plans;

- Lobby for and expedite the official approval of the curricular revisions proven effective in enhancing teacher preparation;

- Intensify efforts to obtain resources that support the participation of science and mathematics education students in research activities, and promote their recruitment as teaching assistants in science/mathematics courses;

- Reward the best students with activities such as scholarships, deferred tuition payment, and sponsor participation in professional meetings;

- Sponsor faculty collaboration with K-12 teachers, including as co-teachers, teacher mentors, and advisors, particularly for beginning teachers, to enhance faculty's understanding of the needs of science and mathematics teachers and to strengthen the teaching of fundamental concepts in K-12;

- Promote interinstitutional collaboration by sponsoring joint committees, task forces, conferences, and sharing resources.

Chapter 8: Institutional Assessment of Program Effectiveness

To ensure the effectiveness of the reform strategies, Teacher Preparation Programs must establish clear quantitative and qualitative benchmarks, and develop multiple valid institutional metrics and assessment mechanisms. These benchmarks will enable to measure progress in achieving the goals of the reform efforts towards standards of excellence and to promote

accountability for outcomes/products and quality control in teacher preparation programs. The assessment process should be a participative and ongoing one to promote ownership and increase the effectiveness of the assessment as well as the analysis and use of the information produced to further improve and guide enhancement efforts. The documentation of the value-added by reform efforts to enhance the preparation of future teachers will provide institutions with a solid foundation for continuous strategic planning and for the development of institutional policies to sustain the reform, as well as to disseminate the efforts to other institutions at the local and national level. Ideally, such a process should provide the basis for the development of an organizational learning process. Institutional assessment of teacher preparation programs should document the progress of institutions in addressing the critical issues set forth in this Blueprint including:

- The level of collaboration among science, mathematics and education faculty and K-12 teachers in revising, testing and assessing curriculum;
- Academic progress of students, including their GPA in gatekeeper and bottleneck courses, the average number of times students take courses before passing them, and the development of knowledge, skills and attitudes aligned with professional standards;
- Enrollment trends by area/field, retention and graduation rates, average number of years to graduate by cohort;
- Productivity of scholarly educational research, number of research projects, publications and presentations by faculty and students in recognized forums;
- Effectiveness of professional development opportunities for faculty in helping to develop and implement curricular change;
- The extent to which support policies have been developed and effectively implemented;
- The establishment of practicum sites and diverse field experiences in exemplary schools and other non-traditional settings;
- Opportunities for future teachers to be involved in scientific research as well as classroom-based research;
- The degree of alignment of teacher preparation curricula with national and local standards;
- Incorporation of authentic assessment into the curricula;
- Degree of infusion of educational technology throughout the teacher preparation curricula;
- Level of collaboration of all major partners in the improvement of teacher preparation programs;
- The scores of graduates from teacher preparation programs in certification exams;

- The degree in which graduates are certified and employed;
- Retention of beginning teachers and effectiveness of mentoring and induction activities;
- The profile of the students being recruited as future teachers and;
- The number of students recruited for, and completing degrees in areas of identified shortage-physics, chemistry and mathematics.

Chapter 9: Partnerships- Interinstitutional Collaboration among Universities, Department of Education, Industry, Community and Others

Among Universities

- Each university has particular strengths as well as areas that need to be strengthened. By pooling resources and uniting efforts, universities can reach mutual goals for teacher preparation more effectively;

Among Universities and K-12 Schools

- Universities and schools need to share knowledge about the effectiveness of the reform efforts, collaborating in the assessment of K-12 education and the preparation of future teachers, and ensuring the alignment of these two processes;

Department of Education

- Develop effective authentic assessment mechanisms to determine the effectiveness of beginning teachers according to certification requirements and standards;
- Collaborate with the universities in the professional development and certification of cooperating teachers who are exemplary of the reform vision and standards based teaching;
- Promote the establishment of professional development schools and other exemplary sites as laboratories and sites for the practicum experience;
- Collaborate with universities in the development of induction into teaching programs and the development of mentor teachers who can provide support to beginning teachers;
- Strengthen incentives and career ladders for teachers;

Industry

- Cooperate with universities and the Puerto Rico Department of Education in establishing the requirements of future teachers in the preparation of scientifically literate workforce,

designating representatives to participate in curricular revision teams for teacher preparation programs, and in the design and development of curricular activities and materials;

- Provide internships for future teachers in industry to expose them to environments where applications of science and technology are demonstrated;

- Provide the time of employees to participate as speakers in curricular and extra-curricular activities for the preparation of future teachers, as well as to serve as mentors for future teachers;

- Provide scholarships, awards and other support and resources to develop innovative educational experiences for future teachers;

- Donate materials and equipment to enrich the preparation of science and mathematics teachers such as computers, projectors, calculators, and laboratory equipment and others and;

- Co-sponsor and participate in symposia on educational research.

National Organizations and Other CETPs

- Expertise at the national level, studies and position papers should be used as resources to improve local efforts;

- Promote communication and collaboration with the NSF-Funded Collaboratives for Excellence in Teacher Preparation, focusing on the exchange of ideas about common interests and information about what has worked and what has not to reform the preparation of teachers.

Others (professional organizations-educational and scientific- College Board, Research Programs)

- Professional organizations, in education as well as scientific, can provide development opportunities for future teachers, encourage them to participate in professional activities and mentor them as part of the professional community;

- The College Board can work with universities in studying and identifying the areas of needs in the preparation of future teachers by examining data on certification exams;

- Research Programs such as EPSCoR, Minority Access to Research Careers (MARC), Minority Biomedical Research (MBRS), Research Experiences for Undergraduate (REU) and Howard Hughes could be tapped on to strengthen opportunities for future teachers to participate in scientific research.

Part III: Recommendations for Next Steps

The achievement of excellence in science and mathematics teacher preparation programs in Puerto Rico poses the challenge of deeply transforming the way we "do business", both within our specific areas of responsibility as well as in the way we relate to each other in the teacher preparation process. To effectively undertake this transformation, we propose that universities engage in institutional strategic planning to implement the reform of teacher preparation programs through a broad based interinstitutional collaborative process to analyze current situations at each institution, areas of strength that can be tapped on, and to design a specific workplan with goals, objectives, activities, benchmarks, and resources needed to carry out the reform. The Resource Center for Science and Engineering, with its longstanding commitment to joining the different sectors in the improvement of science and mathematic educations, can play a central role in facilitating interinstitutional collaboration to achieve our mutual goals for excellence in teacher preparation in Puerto Rico, fostering its articulation with the PR-SSI and the PR-AMP.

The following are a few recommendations of actions that can serve to launch the reform:

- The analysis of existing strengths that will serve to accelerate the reform. Numerous ongoing efforts that can be built upon, include the PRSSI, the PRAMP with its Teacher Preparation Component, Dwight D. Eisenhower-Title II teacher enhancement efforts, research programs such as EPSCoR, and other institutional reform efforts that have been developed at the collaborating universities.

- Incorporation of the curricular reform already advanced through the PRSSI and PRAMP of methodology and practicum courses and introductory science and mathematics courses based on inquiry teaching methods and authentic assessment methods.

- Implement a faculty-needs assessment as well as develop a resource bank of faculty and K-12 exemplary teachers to design and implement an islandwide professional development program.

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