AC 2011-652: TRANSLATING RESEARCH EXPERIENCES INTO CLASSROOM PRACTICE: AN RET PROJECT

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12-13, 2010, CHina; Delivery of the Leslie J. Ford Lecture: Dry Particle Coating Synthesis and Characterization of Engineered Particulates with Tailored Properties, at Particle Technology UK Forum IV, The University of Leeds, Leeds, UK, April 11, 2002; K. S. Fu Award from North American Fuzzy Information Processing Society (NAFIPS), June 1999; Excellence in Research Award (Newark College of Engineering), NJIT, September 2008; Designation as NJIT Master Teacher, September 2008; Harlan Perlis Award for Research, NJIT, 2001; Van Houten Award for Teaching Excellence, NJIT, 2004; Teaching Excellence Award in Category of Upper Undergraduate Level, NJIT, 2003.

Translating Research Experiences into Classroom Practice: An RET Project

Introduction

Most K-12 teachers have not been trained to incorporate engineering and technology topics into their classroom lessons and there is a lack of high-quality curricular materials in these areas [1]. Comprehensive professional development programs are needed for teachers to address the new skills and knowledge needed for improved classroom teaching and learning [2,3] if we expect them to integrate engineering concepts into their classroom practice [4-6]. When teachers are given opportunities to engage in sustained professional learning, and collaboration and to learn from experts and one another, more effective and systematic approaches to supporting, developing skills and knowledge are possible.

Professional development for teachers is considered a key vehicle for educational reform and the need to change and improve classroom instructional practice [2,7,8]. Professional development for teachers should introduce them to technological content and resources that expand their knowledge and their ability to apply new knowledge in the classroom. A long-term professional development program that exposes science teachers to engineering principles and design can lead to the infusion of engineering principles and design into existing science classes that can be continued year after year and last through and beyond the training period [6]. Some of the key factors identified for effective professional development include: engaging teachers in practicing concrete tasks related to teaching, assessment, and observation of learning; drawing upon teachers' questions, inquiry, and experiences; including time for collaboration, sharing and exchange of ideas and practices; building on teachers' current work with students; and providing modeling, coaching, and problem-solving around specific areas of practice.

The planning of professional development programs that effectively lead to desired teaching practices is not a simple process. Too often, short-term training institutes and after school workshops are seen as ends in themselves. "One-shot" approaches to staff development fail to produce lasting changes in teachers' behavior because these teachers are not provided with the opportunity to experience success. Staff development efforts often focus on isolated instructional behaviors, such as cooperative learning, teaching to learning styles, or classroom management skills. One perspective on the features influencing effective professional development outcomes is provided by a Council of Chief State School Officers report [9], in which five features were considered: three core features (active learning, coherence, content focus), and two structural features (duration, and collective participation). With this in mind, the RET program was designed to include each of these five features: 1) **Active Learning**: Teachers were involved in discussion and planning, as well as research, 2) **Coherence**: Activities built on what they were learning, and led to more advanced work, 3) **Content Focus**: Content was designed to improve and enhance teachers' knowledge and skills, 4) **Duration**: Professional development for the teachers extended over 6 weeks during the summer and continued during the school year, and 5) **Collective Participation**: Teachers met in teams as well as a group to discuss strategies and content, and to develop approaches that they presented to their peers.

In addition, a focus is needed on content included in currently available curriculum materials that creates connections between the science used in engineering applications in the real world and science curriculum standards for which teachers and administrators are held accountable [1, 10, 11]. While substantial energy has been devoted to developing standard-based curriculum materials and achievement tests, little is known about lesson planning, implementation, and student activities needed in a standards-based classroom. O'Shea & Kimmel [12] have developed a protocol for standards-based lesson planning that allows teachers to systematically assess learning outcomes that are aligned with state content standards.

Research Experiences for Teachers

Research Experiences for Teachers (RET) have been seen as a vehicle for introducing engineering into secondary school curricula to increase students' interest in engineering, and ultimately increasing enrollment of qualified students in engineering degree programs [13-17]. However, these programs did not report on the use of any systematic process to guide teachers in the development of their lesson plans, and most programs appear to lack follow-up and\or effective evaluation

A RET pilot program at New Jersey Institute of Technology (NJIT) was developed to provide high school science teachers with a professional development program that enhanced their research skills and their knowledge of science and engineering concepts and enabled them to incorporate real-world applications (e.g., pharmaceutical engineering) into their high school science curricula [18]. As part of the program teachers developed instructional modules they could use to integrate engineering principles into their classroom teaching. The current paper describes an expansion of the project which focuses on helping the teachers refine their instructional planning skills while providing them with an effective protocol for developing standards-based lesson plans.

A process was introduced that allowed the development of curriculum modules based on each teacher's research. They start with a statement of their research practice and identify areas in the high school curricula into which the research best fits, then select specific activities to focus on. Program faculty and staff worked with the teachers to develop lessons using standards-based lesson planning and how an outcomes matrix designed to help teachers develop their modules was used. The teachers were also introduced to the basic concepts of experimental design and the appropriate application of relevant statistical methods. The current paper also describes the experiences and evaluation of 13 high school science teachers (7 male and 6 female) who participated during the summer of 2010. Seven of the teachers taught predominately chemistry and\or biology while the others indicated they taught some combination of physics, environmental science, mathematics, general science, advanced science and technology. Teachers were selected based on the subjects they taught and their interest in incorporating pharmaceutical engineering into their courses. Teachers were required to apply in teams of two from the same school. This allowed teachers to support each other when they returned to their classes in the school year.

The Setting

The RET program at NJIT is a collaboration between the Engineering Research Center for Structured Organic Particulate Systems (ERC-SOPS) and the University's Center for Pre-College Programs (CPCP) initiated under an NSF-sponsored four-university project. The goal of the program is to educate high-school teachers in the opportunities and challenges involved with manufacturing of pharmaceutical products, and thus help educate future generations of students, helping create a strong pipeline of talented students interested in pursuing careers in engineering and science.

The ERC-SOPS is a four-university project, involving about 30 faculty, with a central systems-oriented theme of developing a model-predictive, integrated framework for systematically designing materials, composites, and the processes used to manufacture them. The NJIT ERC includes seven faculty members, who mentor research projects aligned with three main research thrusts: 1) A New Manufacturing Science for Structured Organic Particulates, 2) Composite Structuring and Characterization of Organic Particulates, and 3) Particle Formation and Functionalization.

The Center for Pre-College Programs at NJIT has been working with the public school systems in Newark and others across the state of New Jersey for almost 40 years [19]. The mission of the Center includes the planning, development and assessment of STEM education programs, and the development and coordination of academic programs to serve elementary and secondary school teachers. Among the many successful programs at CPCP is the Pre-Engineering Instructional and Outreach Program (Pre-IOP), established to raise awareness about the importance of pre-engineering concepts in science and mathematics curricula [5, 20]. Pre-IOP included the development of pre-engineering curriculum modules (aligned with the New Jersey Core Curriculum Content Standards) for use in secondary mathematics and science classrooms. Teacher professional development programs were established to train teachers how to integrate the pre-engineering curriculum into their classroom teaching as a way for their students to apply classroom lessons to real-life problems. The pre-engineering curriculum in science, mathematics and technology classroom was found to increase students' and teachers' attitudes toward engineering and knowledge of careers in engineering [21, 22]. The RET program at NJIT continued the work of PrE-IOP by incorporating pharmaceutical concepts into the high school science curriculum.

The Research Experience

Success in the RET experience was ensured through both extensive prior preparation and close one-on-one working relationships between research scientists and participating teachers. Each RET experience was structured to include the following components:

1) Collaborative development of agenda, expectations, and goals for the specific research project and overall laboratory experience.
2) Safety training and an overview of the laboratory facilities and equipment.
3) Hands-on experiences in current laboratory techniques and studies being performed by scientists, which could lead to integration of cutting-edge science into inquiry-based learning.
4) Focused research project with mentor scientist.

5) Regular meetings with the range of researchers, including graduate students, postdoctoral fellows, and other faculty members and the teachers to discuss their projects, progress, barriers, and how the various projects are contributing to each other.

This collaboration allowed for the development of inquiry-based lessons in pharmaceutical engineering and instruction for preparation and implementation of the lessons in the classroom that incorporates best educational practices.

Within the ERC, the research focus for the RET participants was Innovative Particle Engineering Techniques for Property Enhancements. The goals within this area of research are to 1) understand the impact of material properties and processing inputs on product structure and performance and 2) use this understanding to design, control and optimize products and their associated manufacturing processes.

Nine research projects were identified for the teachers to consider.

1. Nanomilling of Active Pharmaceutical Ingredients and Cross-linked Polymers in a Wet Stirred Media Mill.
2. Drop-on-demand printing of API on polymer films.
3. Characterization of Effects of Processing on API Polymorphism by Raman Spectroscopy.
4. Nanomaterials synthesis and characterization.
5. Optimization of Formulation of Griseofulvin Nanosuspensions for Long-term Stability.
6. Formation of API loaded films for Oral Drug Delivery.
7. Surface Modification of Pharmaceutical Materials.
8. Fluidized bed coating of API Suspensions on Surface Modified Excipient Particles.
9. Environmentally Benign Mixing of Nano-powders in Dense Carbon Dioxide.

In order to provide a coherent picture of the research program in pharmaceutical engineering, the research projects were selected so as to have a connection among the projects:

- All projects deal with the ERC's mission – making better drug products.
- Project 1 provides materials for projects 6 and 8.
- Project 7 provides material to project 8.
- Projects 3 and 4 deal with characterization of complex drug materials.
- Projects 2, 5, 6, and 8 deal with making drug products.

Teachers were able to select projects relevant to the subjects they teach; i.e. biology, chemistry, physics, and engineering technology. For example, an engineering technology teacher selected a manufacturing problem related to the fact that powdery materials have certain properties that include size, density, and flow. Some powders are composed of very small particles and Van der Waals forces become significant-attraction of particles to one another. The advantage of small particles is that they are easily dispersed in the body; the disadvantage is that manufacturing tablets is difficult. The goal of the research was to improve the manufacturing process by altering the size and components of the components in the drugs: both the API and excipients. Methods included breaking large powders into smaller ones with pressure and adding small excipients like silica to the API to improve flow, a manufacturing concern.

A chemistry teacher chose a project that involved drop-on-demand printing of API on polymer films. There were several other related small projects like viscosity studies of the polymer solutions. The procedure involved precise measurement of the mass of solute and solvent and preparation of the exact concentration of the solution. A viscometer was used to measure the viscosity of solutions after which comparisons of the viscosity of different solutions were made using graph and statistical approach to reach conclusions.

The program included an informal and interactive presentation by a member of the faculty who had extensive industrial experience. The presentation was designed to introduce the teachers to the process of solid dosage form development and manufacture including key concepts and a description of how things usually get done in the pharmaceutical industry.

The Professional Development Experience: From Research To Classroom

The following outcomes were expected as a result of teachers' participation in their research experience:

1. Each teacher was able to enrich his or her own knowledge-base as a STEM education professional by participating as an active member of a research team at NJIT in the area of pharmaceutical engineering.
2. Each teacher was able to gain a better understanding of how scientists and engineers engage in research and how the term "inquiry" is integral to the research process.
3. Each teacher was able to synthesize his or her research experience in order to integrate the acquired content knowledge and skills into a learning module for the high school students, which supplements the school/district curriculum.

Three important components of the professional development experience that helped teachers achieve these outcomes were:

1. Weekly seminars to introduce them to the principles of experimental design and statistical methods that they could apply to their research problem, and bring back to their classroom. Topics included how to develop a research question, data collection, how to select the proper statistical procedure, hypothesis testing and interpretation of the results and use of statistical software because in general, teachers have weak or no background in these topics.
2. An introduction of a systematic process for translating that research experience into classroom content.
3. Guidance in the development of lesson plans that are aligned with content standards.

Translating the Research into Classroom Content

RET teachers are expected to adapt/develop lessons plans based on their research experiences. Lesson plans can provide significant information on a teacher's classroom practice, and the impact of the professional development experience on the teacher. They can complement other aspects of the assessment of the impact of the professional development experience, such as teacher interviews and classroom observations. Since the RET program is heavily content-focused, lesson plans can provide information on how well teachers have acquired the new knowledge and skills and are able to integrate the content into their classroom practice.

The first stage of the professional development for creating/adapting lesson plans involved guiding the teachers in a process to translate their research experiences into classroom content. During one session, teachers formed groups of 2-3 participants based upon discipline. Some groups included teachers working on the same research project while other groups involved teachers working on different projects. The groups were given the assignment to consider their current research project and how they would bring their experiences into the classroom by describing their research, how it relates to their curriculum and the classroom experiences they expect to be able to provide to their students. Some examples follow.

Example 1. Several teams worked on research projects involving the formation and, characterization of suspensions of APIs (Active Pharmaceutical Ingredients). Teams studied the formation of stable nano-suspensions of APIs and cross-linked polymers, and optimization of the formation of the nano-suspensions for long term stability. The latter involved making numerous solutions consisting of polymers and surfactants at various concentration levels, using constant amounts of the API, dissolved in distilled water, in order to find the optimum concentration level. The nano-suspensions were also analyzed to determine particle size and zeta potential in order to assess stability. The study of the effects of particle size and size distribution of both coated and uncoated powders was part of a larger effort to improve flowability of the APIs. The nano-suspensions produced were also used by other groups in their research projects. The formation of API loaded films for drug delivery was studied by taking a hydrophobic drug, making it soluble in water, and coating it evenly in a film. Then the redistribution of the drug is examined when introduced into an aqueous environment.

Key concepts from the research experience fit into a biology or chemistry curriculum as follows:
1. Introducing particle sizes (micro, nano, etc).
2. Crystallization
3. Surface chemistry, cohesion & adhesion.
4. Adsorption & absorption, catalysis.
5. Solutions and mixtures.
6. Dissolution rate.
7. Calculating surface areas.
8. Biological actions of drugs.

Based on these concepts, teachers prepared a list of potential topics for which they could develop lessons, such as:
1. Determine how the concentration of solute effects crystallization of a compound such as sugar, examining the size of the crystals and its uniformity, in addition to the mass of sugar crystals produced.
2. Demonstration of how solids dissolving (or not) in different liquids would allow students to predict which combinations dissolve and which combinations do not.
3. Determine how surface area to volume ratio determines rate of dissolution of solids, and how surface area relates to drug usage in the body.
4. Use titration to investigate % API in various brands of OTC medication.
5. Determine the rate of solubility of a solid based on surface area.
6. Measure volume to surface area ratio to determine bioavailability of a drug (Ice Tea/Kool Aid Lab and Alka-Seltzer vs. Time Release Capsule Lab).

7. Determine how aspirin breaks down into acetic acid and salicylic acid due to temperature and water, as an example of the degradation of aspirin. It can demonstrate the importance of proper storage and disposal of expired pharmaceutical products.
8. Study the chemical properties of catalysts by comparing H_2O_2 decomposition rates when using manganese dioxide in powder form vs. tablet form and explore how the surface area relates to rates of reaction.

Example 2. Mixing of nano-particles offers a variety of opportunities to manufacture new materials with unique electronic, optical, mechanical, and chemical properties, including size, density, and flow among others. Some powders are composed of very small particles and Van der Waals forces become significant-attraction of particles to one another. The advantage of small particles is that they are easily dispersed in the body; the disadvantage is that manufacturing tablets is difficult. The goal of the research was to improve the manufacturing process by altering the size and nature of the components in the drugs. Methods include breaking large powders into smaller ones with pressure and coating the powder with materials, such as nano-silica, to the API to improve flow, a manufacturing concern. Research on drop technology focused on the determination of the properties of drops. Modeling the drug manufacturing technology lead to questions such as:
1. Are all drops the same size?
2. Can we make drops more consistently? What does it mean to be consistent? What is the range for being consistent?
3. What is the mass and volume, of a drop?
4. What is density, and what is the density of a drop?
5. What would we do if we needed half a drop?

Key concepts from the research experience fit into a chemistry, physics, or technology curriculum as follows:
1. Importance of particle size in industrial applications.
2. Importance of proper mixing of substances in industry.

Based on the concepts, teachers determined that they could develop lessons on several topics, including:
1. Analyze the active pharmaceutical ingredient (API) aspirin in different tablets in a batch using acid-base titration and compare the results.
2. Compare the reactivity of different sized Zinc metal with hydrochloric acid solution.
3. Determine how nano-machines are used in Pharmaceutical Industry for Drug Delivery.
4. Use a jello mold with unequally distributed pieces of candy throughout (where the jello mold represents a polymer and candy pieces represent the API to demonstration), to allow student teams to design/engineer a way to equally distribute the candy throughout jello mold.
5. Demonstrate the milling process and the collisions and porosity of milling beads and drug particles, using marbles and Panko bread crumbs in a container. Then, students can design/engineer a way to get smaller/finer breadcrumbs following specific criteria.

Example 3. All the participants expect to use the information learned from the research experience to teach about all aspects of experimentation (hypothesis, testing, data collection, etc.) and the proper way to conduct experiments (close observations during the tests and documentation of it). Student will learn how to create graphs (line, bar, pie charts) with their data and/or given data tables, and read and analyze graphs. They will learn how to Use Excel to analyze data and create graphs.

Standards-Based Lesson Planning

In the instructional process the lesson plan should be the primary organizing structure and serve as a guide to the classroom instruction. While developing and presenting a lesson, a classroom teacher confronts many pedagogical issues and makes choices directed toward assisting students to acquire knowledge, and apply new information to practical activities. Achieving quality in lessons depends not only upon the teacher's ability to present material but also to analyze learning outcomes and assess the pedagogical communication [23].

Preparation of lesson plans is often a challenging experience for teachers, especially when the lessons involve new content they have just learned. Our experience guiding teachers in lesson plan development has shown us that teachers will generally develop instructional strategies first, without realizing the importance of learning objectives for providing direction in the development of lessons [24]. Usually, assessment becomes almost an afterthought in the process.

Many teachers do not even prepare lesson plans. Of those that do prepare lesson plans, many prepare what can be considered very brief, or sketchy, and not designed around learning objectives. For example, the results of the Third International Mathematics and Science Study [25] show that in far too many classrooms, mathematics instruction includes review of the previous lesson's homework assignment, quick delivery of a set of rules and procedures by the teacher, and the rest of the lesson, if there is any time left.

Curricular materials in support of the integration of engineering into science instruction have been made available on the web, as well as through universities and teacher-developed lesson plans. However, only concepts included in state content standards are taught in the classroom, as teachers believe they will only be accountable for what is in the standards [12]. As a result, the only curriculum materials usually considered, let alone implemented, are those that reinforce state content standards, since student achievement (and schools' and districts' achievement) is measured largely by student performance on the statewide assessment tests [26]. So, if teachers are to make engineering principles a part of their instruction for student learning, then engineering principles must be part of the state science standards. Translation into standards-achieving lessons is critical [12]. However, curriculum topics aligned to standards alone is not sufficient [12, 27]. Alignment with standards must also include the assessment of student achievement of the skills and knowledge defined by the standards.

Research suggests that lesson and unit plans are essential and powerful tools for instructional improvement and increased student achievement [27]. When teachers prepare truly standards-based lessons, their teaching is focused on student achievement in relation to specific standards[28]. A protocol for the creation and implementation of standards-based lesson plans has been developed at CPCP and utilized in previous and current professional development programs[12]. The protocol includes identification of measurable learning objectives [29], specification of the corresponding statement from the content standards, adaptation of the activity that provides the student the opportunity to acquire the skill and/or knowledge specified by the learning objective and the expected student performance that provides the evidence that the student has acquired the skill and/or knowledge. The RET participants were introduced to the protocol and a template was developed for use in the development of their instructional modules.

The “outcomes matrix” was developed as a tool for teachers to organize their thoughts into well-defined learning objectives and student learning outcomes, student-focused learning experience, and assessment strategies (assessment tools, and criterion for levels of mastery), that guides them in the development of their instructional module and lesson plans (Figure 1). A module consists of two or more learning activities, or lessons, designed to help students explore specified key concepts to be taught. Each lesson is designed to provide students the opportunity to acquire new skills and knowledge and understanding of the concepts. The outcomes matrix shows how:

- The learning objectives should be linked to the key concepts, and clearly define what students should know and be able to do at the end of the lesson.
- The learning experience is linked to the learning objectives.
- Assessment of students work products that result from the learning experience should be able to demonstrate that students had or had not acquired the skills and knowledge defined by the learning objectives.

The critical components here, and the most difficult aspects of lesson planning for teachers, are the learning objectives and their alignment with the assessment. Once they have been articulated, teachers can then fill in the remainder of the lesson plan, including a detailed instructional strategy for the lesson.

	MODULE	**Lesson**
Topic Title **Brief Description (one sentence)**		
Learning Objective(s)		
Learning Experience **(Instructional Plan - Summary)**		
Student Assessment **(Demonstration of Acquired Skills & Knowledge)**		

Figure 1. Outcomes Matrix Template

One teacher submitted an outcome matrix for a module in which the purpose was for students to analyze the active pharmaceutical ingredients (API) in drugs. The learning objectives and corresponding assessments were:

Objective 1: Students will be able to calculate the amount of aspirin in a tablet by titration.

Assessment: Students will calculate and write the answer for the amount of aspirin in the tablet. They will also write a lab report showing the collected data and calculations.

Objective 2: Students will be able to compare the amount of aspirin from different tablets.

Assessment: Students will draw a graph based on the results of different groups and explain the similarity or variations of aspirin concentrations in different samples.

A technology teacher developed a module of lessons to look at characteristics and flowability of powders and design a prototype machine to measure and alter properties. The learning objectives and corresponding assessments were:

Objective 1: Students will be able to characterize, compare and contrast the properties of two powders, density, color, size, flow and, crystalline/non-crystalline nature.

Assessment: Students will provide a chart comparing the properties of the powders.

Objective 2: Students will differentiate high and low flow powders by their properties.

Assessment: Students will prepare a chart to compare flowability and properties of powers.

Objective 3: Students will be able to design and prototype a machine that will consistently measure the angle of repose.

Assessment: Rubric will be used to examine students' use of design process, and machine's ability to perform assigned tasks, and demonstrate reproducible results.

The "outcomes matrix" served as a guide for the teachers as they prepared their lesson plans. By aligning the expectations of the learning objectives with the expectations of the indicators in the standards, standards-based lesson plans were developed. Thus for the learning objectives for the two lessons given above and the corresponding NJ Core Curriculum Content Standards (NJCCCS) indicators of the standards are:

Objective: Students will be able to calculate the amount of aspirin in a tablet by titration. The standard and indicator for this objective is 5.2.8.A.7 - Determine the relative acidity and reactivity of common acids through a variety of student-designed investigations.

Objective: Students will be able to compare the amount of aspirin from different tablets. The standard and indicator for this objective is 5.1.8.B.2 Gather, evaluate, and represent evidence.

The learning objectives for the lessons developed by the technology teacher and the corresponding indicators of the standards are:

Objective: Students will be able to characterize, compare and contrast the properties of two powders, density, color, size, flow and, crystalline/non-crystalline nature.

Objective: Students will differentiate high and low flow powders by their properties. The standard and indicator for these two objectives is 5.2.8.A.5 - Identify unknown substances based on data regarding their physical and chemical properties.

Objective: Students will be able to design and prototype a machine that will consistently measure the angle of repose. The standard and indicator for this objective is 8.2.8.B.1 Design and create a product that addresses a real-world problem using the design process and working with specific criteria and constraints.

Evaluation

Teachers' Concerns about Incorporating Engineering topics in their Classrooms

Teachers' concerns about incorporating engineering topics into their classroom teaching were measured using The Teachers' Concerns Questionnaire (TCQ) adapted from the Concerns Based Assessment Model (CBAM) [30]. Repeated administrations of the TCQ are used to identify teachers' concerns and track changes in their concerns as they engage in educational reforms[31], focusing on how they progress through seven stages of concern: Awareness, informational, personal, management, consequences, collaboration and refocusing. Teachers completed the TCQ three times; first, several weeks before the beginning of their research experience, second at the end of their summer research experience; and third, several months into the next school year.

Analysis of responses to the TCQ produces a percentile score for each of the seven stages. Graphical displays of the percentile scores make it easy to identify which stages teachers are in at any given time point by examining the peaks (See Figure 2). Examination of the three sets of responses collected from the RET teachers indicates that initially, before the research experience, teachers' concerns focused on increasing their awareness of engineering topics and gathering information about incorporating their research into classroom lessons (the first two stages). By the end of the summer, teachers' concerns had begun shifting toward whether they could help their students learn about engineering through their experiences, expressing fewer personal and management concerns about the time commitments required to develop and implement their modules. After the teachers had returned to school and they had some time to implement their modules in the classroom their responses indicted that they were thinking more about how they could collaborate with other teachers and where shifting into the refocusing stage where teachers begin to think about the benefits of the changes they have made and consider more alternatives.

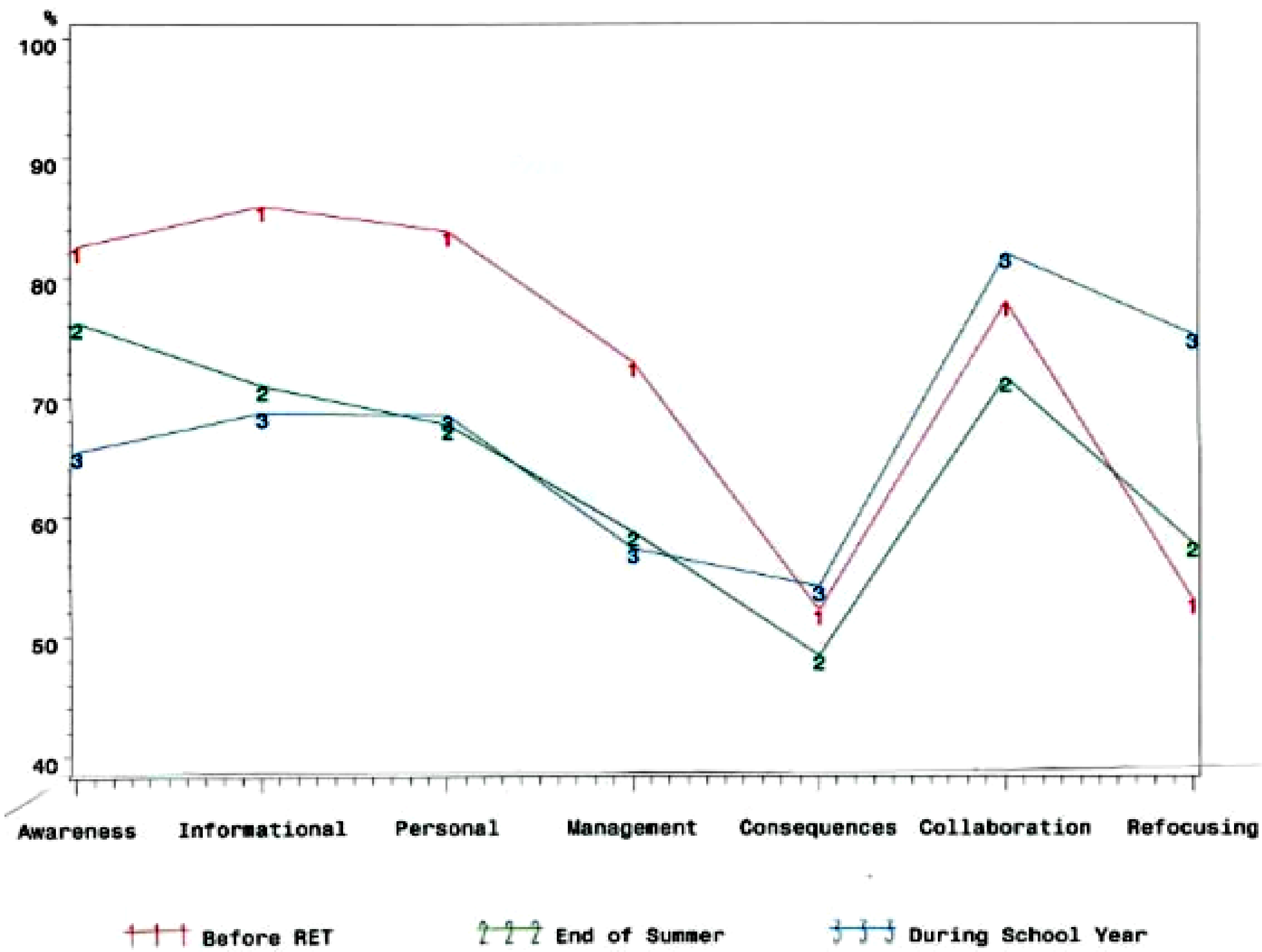

Figure 2: Stages of Concern

Teachers' Readiness to Teach

At the close of their research experience teachers completed a 12-item Readiness to Teach Questionnaire (RTQ). The RTQ (developed as part of a previous research project) [21, 22] requires teachers to indicate how ready they feel they are to teach lessons on the topics or use techniques from their particular learning experience(s) on a scale from 1 to 4 where 1="I would have to start from scratch", 2="I would need more training to teach this topic", 3="I would have to look at my notes to do this", and 4="I can teach a lesson on this topic tomorrow". For example, one item asks 'How ready are you to teach Analysis of experimental data based on a theory?'

Teachers' responses to each individual item averaged from 2.4 to 3.9 with an overall average of 3.3. For all items at least 60% of the responses indicated 3='I would have to look at my notes' or 4='I can teach a lesson on this topic tomorrow. For nine of the ten items this percentage was almost 80%. Only four teachers gave any responses that indicated 1='I would have to start from scratch'. Teachers completed the Readiness to Teach again during the school year after time in the classroom. The overall average responses increased to 3.4, and only three teachers gave any responses that indicated 1='I would have to start from scratch'.

Attitudes to Engineering and Knowledge of Careers in Engineering

Teachers completed the Teachers' Attitude to Engineering Survey (TATE) [21, 22] at the same three time points as the Teachers' Concerns Questionnaire, before the research experience, at the end of the summer research experience and several months into the next school year. The TATE, developed and validated in prior research, has been used extensively[21, 22, 32, 33]. Teacher agree or disagree with statements about engineers (Engineers help make peoples' lives better), mathematics (If one of my students excels in mathematics or science, I suggest engineering as a possible career), engineers or engineering such as "Engineers are nerds", or "My students would have no problem finding a job if they complete a degree in engineering) on a five-point scale where 1 indicates strong disagreement and 5 indicates strong agreement. Teachers are also asked to indicate how well they are prepared to help students pursue careers in engineering by responding to items such as "I know about summer or after school programs to help students prepare for careers in engineering".

Knowledge of Careers in engineering is also measured as part of the TATE by a multiple-part open-ended question that asks teachers to "Name five different types of engineers" and to "give an example of the work done by each type." Each type of engineer is coded "1" for correct and "0" for incorrect. Possible total scores range from zero to five. Each example of the work they do is coded "2" for completely correct, "1" for partly correct, and "0" for incorrect. Possible total scores range from zero to ten.

Attitudes to Engineering: The teachers were actually very positive about engineers and engineering as a career, even before their research experience. All but one indicated that they knew someone who was an engineer. Most agreed that "skills learned in engineering are useful in everyday life" and all but one of them disagreed with the statement "I would not like any of my students to be engineers." Nine of the teachers indicated that they knew at least one of their students was considering studying engineering in college. Teachers' responses to the 27 items on the survey that measure attitudes toward engineering averaged 4.2 before the summer began with a small increase to 4.4 by the end of the summer. Once school started all 13 teachers agreed "If a student excels in mathematics and\or science, I suggest engineering as a possible career."

Engineering Preparation Self-efficacy: Before their research experience began, most teachers were not very well informed about how to help prepare their students to consider engineering as a possible career. Most disagreed with the statement 'I know where to find the necessary information to help their students if they wanted to become engineers'. Only a few indicated they knew of summer programs to help students learn more about careers in engineering. Their average Engineering Preparation score was only 3.6 but it increased significantly to 4.1 by the end of the summer.

Knowledge of Engineering Careers: Only about 50% (n=7) of the teachers were able to correctly identify five different types of engineers before the beginning of the research experience and one of the teachers identified only one type of engineer. By the end of the experience, all but three of them were able to correctly identify five different types of engineers which is a significant increase (See Table 1). Before the beginning of the research experience even the teachers who were able to correctly identify five different types of engineers, but were not able to give correct examples of the kind of work done by all five types. Some gave no examples at all and some gave examples that were only partly correct. By the end of the research experience all of the teachers were able to give at least some partly correct examples of the work done by each type of engineer they identified. About half were able to give correct or partly correct examples for all five types (See Table 1).

TABLE 1: TEACHERS' RESPONSES TO KNOWLEDGE OF ENGINEERING QUESTION
PART 1, NAME FIVE DIFFERENT TYPES OF ENGINEERS - PART 2, EXAMPLES OF THE WORK DONE BY EACH TYPE

	Number Correct Responses				Number of Points			
	0	1-2	3-4	5	0	1-3	4-6	7-8*
Before research experience	0%	15%	31%	54%	23%	46%	23%	8%
After research experience	0%	0%	23%	77%	**0**%	31%	38%	31%

* None of the teachers scored more than 8 points out of a possible 10

Conclusions

The project was successful in achieving the outcomes for the teachers as a result of their participation in the RET project. Their attitudes toward engineering and knowledge about careers in engineering increased as a result of their research experience. The teachers' responses to the Concerns Inventory and the Readiness to Teach questionnaire indicated that they felt confident about their experiences and would be able to incorporate what they had learned into their classroom teaching. Overall:

1. Each teacher was able to enrich their own knowledge-base as a STEM education professional by participating as an active member of a research team at NJIT in the area of pharmaceutical engineering. All the teachers expressed their appreciation for acquiring new skills and knowledge in the area of pharmaceutical engineering. As a result, they were successful in being able to translate their research experiences into course content and develop lesson

plans to implement in their classrooms, where they will be able provide their students with real world applications of their instruction.

2. Each teacher was able to gain a better understanding of how scientists and engineers engage in research and how the term “inquiry” is integral to the research process. All the participants were able to use the information learned from the research experience to include in their lessons various aspects of the scientific inquiry process that involves experimentation (hypothesis, testing, data collection, etc.) and the proper way to conduct experiments (close observations during the tests and documentation of it). The exposure to experimental design and statistical analysis was considered very important as most of them had very little or no prior training or experience in these concepts.
3. Each teacher was able to synthesize their research experience in order to integrate the acquired content knowledge and skills into a learning module for the high school students, which supplements the school/district curriculum. The introduction of a systematic process for translating their research experiences into classroom content and development of lesson plans provided the guidance that the teachers needed to integrate their learning into their classroom practice.

A quote from one teacher expresses the value of this program to all participants. “The experience has been the high point for me as an educator; I entered the RET program having no confidence in the creation of lesson plans, but I left the program after being ‘taught’ for the first time in my career what is necessary to develop effective lesson plans. There is probably no aspect of teaching that is more important, that and the content knowledge. I've learned how to be more effective as a teacher.” The protocols of the RET program allowed experienced teachers become learners once again.

We also learned from the project. In future programs, we will need to place greater emphasis on the alignment of the lesson plans with the standards. This is one area that the teachers are still having difficulties with. In addition, we found that there is a great need for instruction on experimental design and statistics. We plan on expanding this component of the professional development and develop a guide for the teachers in this area. For the research experience part of the program, teachers have indicators that they would like to have more group meetings of the researchers and the RET teachers to discuss the research being conducted. We will work with the research mentors to have more such meetings.

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