Lehigh Valley Partnership for STEM G4-12 Teaching Fellows

Evaluation Report

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Introduction

On June 1, 2003, the National Science Foundation awarded a grant to Lehigh University to establish the Lehigh Valley Partnership for STEM G4-12 Teaching Fellows Program (LVP Program). The project had a dual vision to increase STEM graduate students' awareness of and interest in G4-12 education by partnering them with G4-12 teachers to develop and enhance the STEM curriculum, and to increase the number of women and underrepresented minorities involved in STEM education and careers through exposure to new technologies for inquiry-based learning.

This report is presented in four sections. The first section contains a brief description of the LVP Program for the 2005-06 academic school year. The second section presents the methods used to evaluate all the participant groups. The third section analyzes the information to determine the extent to which the program goals have been met. Finally, there is a brief conclusion section. The report also includes fourteen appendices, which provide in-depth discussions of the various research methods and results, as well as tables containing the figures on which the analyses were based.

Descriptive Evaluation

In addition to the NSF grant, the project received additional funds from the Pennsylvania Information Technology Alliance (PITA), the Office of the Vice Provost for Research, and from the Dean of the P.C. Rossin College of Engineering and Applied Science. The co-directors of the project were Dr. William Pottenger, Assistant Professor of Computer Science and Engineering, and Dr. Henry Odi, Executive Director for Academic Outreach and Special Projects. A leadership team consisting of the co-directors, five faculty team leaders, the consultant from the College of Education, and the evaluator met biweekly to provide direction for the project. The team leaders involved since the start of the program were Dr. William Pottenger, Computer Science and Engineering, Dr. Glenn Blank, Computer Science and Engineering, Dr. Gary DeLeo, Physics, and Dr. Keith Schray, Chemistry. Dr. Jennifer Swann, Biological Sciences, joined the program in 2004, and Dr. Susan Szczepanski, Math, joined in 2005. Both of these faculty members replaced others who withdrew as advisors. Ms. Priyani Jayateleke was a full-time coordinator for the program.

Districts, Schools, and Teams. During the 2005-2006 school year, nine teams worked in seven schools in two school districts serving over 2700 G4-12 students. The program expanded the number of schools involved in the program from five schools to seven in the second year by adding two technology teams - one at Dieruff High School, and one at the Regional Academic Standards Academy. The districts, schools, and teams are listed below along with figures on the ethnicity and socioeconomic status of the student bodies.

Allentown School District

- Harrison Morton Middle School (77% minority, 76% low income)
  - Math Team, 6th grade
  - Science Team, 6th grade
  - Biology Team, 8th grade
  - Technology Team, 6th, 7th, 8th grade
- Dieruff High School (73% minority, 63% low income)
  - Technology Team, 10th, 11th, 12th grade

Bethlehem School District

- Fountain Hill Elementary School (73% minority; 81% low income)
  Spring Garden Elementary School (27% minority; 22% low income)
  - Physics Team, 4th grade
- Regional Academic Standards Academy (70% minority; 82% low income)
  - Technology Team, 5th grade
- Broughal Middle School (82% minority; 85% low income)
  - Technology Team, 6th, 7th, 8th grades
- Freedom High School (31% minority; 25% low income)
  - Chemistry Team, 9th, 11th grades

Recruiting. In the first year, faculty team leaders reviewed applications of incoming graduate students and/or proposed students from their respective departments. Recruiting from other academic institutions was done through an announcement on the project website, brochures, and an ad in a nation-wide bulletin board for women. As fellows left the program, they were replaced with other Lehigh STEM graduate or undergraduate students who were known to the faculty team leaders. Principals, school administrators, or other participating STEM teachers recommended the STEM teachers initially and to replace those who withdrew during the course of the project.

STEM Teaching Fellows. Over the three years of the grant, eleven graduate students served as fellows. Four of them participated in the program all three years; two served for two years, and the remaining five graduate fellows served for a year. There were never more than eight graduate teaching fellows in any one year. Of the graduate fellows, 36% were black, and 36% were women. Two graduate fellows left the LVP Program because they finished their Master's Degrees, and one was not invited back after the first year and a half. Twenty-three undergraduate fellows participated in the program over the three years. Only one undergraduate fellow participated for the entire three years, and four undergraduates served for two full years. The remaining 18 fellows served anywhere from ½ to 1 ½ years. Of these undergraduate fellows, 56% were women; 13% were black; 13% were Hispanic, and 17% were Asian.

STEM Teachers. A total of twenty-one teachers served on LVP Program teams over the three-year period. The first year, there were eleven teachers. This number varied over the following years from 16 to 18. Four teachers did not continue with the program for reasons unrelated to the program. A fifth teacher was assigned to a different class, and sixth withdrew because he did not feel the classes he taught fit the LVP Program's criteria.

Faculty Team Leaders. Eight Lehigh faculty members served as faculty team leaders. One member left the University after the first year, and another withdrew from the program after the second year. Other faculty members replaced them, and the number of faculty advisors remained constant each year at six.

Website. In the first year, a firm was hired to create a website for the project. It can be found at www.lehigh.edu/stem. This website contains sections labeled: Kids in the Classroom, People who Make it Work, Becoming a Teaching Fellow, Documents for the Project, and News about STEM. It includes video clips of various program participants (PIs, team leaders, fellows, and the evaluator) discussing the goals of the program and their individual roles. Interested undergraduate students were able to apply for a fellowship on-line. A brief description of the requirements, responsibilities, and benefits was included. Under the section, Documents for the Project, curricula and/or lessons for five teams are posted; namely, the three Technology Teams at Broughal Middle School, Harrison Morton Middle School, and Dieruff High School, the Physics Team for Spring Garden and Fountain Hill Elementary Schools, and the Math Team at Harrison Morton Middle School.

Workshop. A workshop entitled Becoming a Team and Developing a Unit was held on August 1st and 2nd, 2005. Dr. H. Lynn Columba, Associate Professor of Education and Human Services in Lehigh University's College of Education facilitated the workshop, which was designed using feedback from previous workshops and focus group discussions. Four sessions were held: Discussing Team Successes and Challenges, Updating the Team Charter, Developing a Unit, and Broadening and Sustaining Team Curriculums. Time was scheduled in each session for the individual teams to meet for discussion, and the entire group reconvened to share their conclusions. This was intended to improve synergy among the teams. These sessions were held over a day and a half. In addition, Dr. Columba conducted an orientation session for new fellows. In addition to two hand-outs involving 50 mistakes to avoid when going in a classroom and professional dress guidelines, she was available to answer any questions the first-time fellows might have. Feedback evaluation forms were completed at the end of the workshop, and the results can be found in Appendix 1.

Group Meetings. Twice during the academic year, all the program participants met to inform the other members of their team's progress. Last year, the first meeting was held on Thursday, October 20, 2005. At this meeting, Dr. Henry Odi gave a brief update on program activities, and a buffet dinner was served. Tables were located around the perimeter of the room, and each team had a station where they displayed one or more of the hands-on presentations or activities they developed for the classroom. Attendees were able to browse the various stations and participate in the hands-on activities. The feedback from the program participants who attended this meeting was very positive. The final meeting, held on Thursday, May 18th, was a Closing Awards Dinner. After an overview of the program's successes, all teachers and fellows were given certificates to recognize their contributions. In addition, several teachers and fellows gave testimonies about how their participation in the project affected them. Dr. Henry Odi recognized the corporate partners, and Dr. Glenn Blank discussed the next steps to be included in the proposal to request renewed NSF funding for the program.

Team Activities. Over the years, the number of teams expanded from six in the first year to nine in the most recent school year, 2005-06. Teams were formed concentrating on Physics, Science, Biology, Chemistry, Math, and Technology. There were four technology teams working at different levels in different schools: two teams worked at the middle-school level in Bethlehem and Allentown; one team worked with 5th grade students at the Regional Academic Standards Academy in Bethlehem, and a team operated at a high school in the Allentown School District. The typical team consisted of a faculty team leader, one graduate teaching fellow, one or two undergraduate teaching fellows, and two teachers. Some teams also included representatives from industry who helped develop lessons and presented them to the students.

The teams met outside of the classroom to develop hands-on activities and demonstrations to supplement the content already being taught in the classroom. For some teams, the fellows obtained, delivered, or prepared the supplies or equipment needed for the demonstrations. In addition to presenting the demonstrations or facilitating the hands-on activities, they provided a helping hand in the classroom and co-taught with the teachers. They served as an additional source of expertise in the content area, and they were mentors and role models for the students. Since a number of the fellows were women or were of the same ethnic group as their students, they had a particularly powerful impact. One of the women fellows who worked on the Math Team told of how students with which she worked began to think math was "cool". One of the female fellows noted that the female students tended to ask more questions when she was present. The fellows spent upwards of 2,500 hours in the classroom, and worked with approximately 2,780 students. Almost half of these students had opportunities to work with more than one fellow.

Some of the activities that were developed by the various teams are listed below. Many of these reflect permanent changes in the schools and many have been documented on the website. In addition to this concrete evidence of the program's activities, there are numerous stories of the students' excitement and

enthusiasm for the STEM disciplines. The full impact of this program may not be realized until these young students choose their careers five to eight years from now.

The *Physics Team* developed and implemented an aviation unit for science classes in the 4th grade at Spring Garden and Fountain Hill Elementary Schools. The curriculum will continue to be used in the schools. Over the three year period of the LVP Program, the faculty team leader displayed Timeline: Planet Earth! in the corridors of the two participating schools. Various activities associated with the timeline were available to each grade, from kindergarten to 5th grade. These include hands-on exercises using sand to understand stratification, a chicken skeleton and owl pellets to learn about animal skeletons and to identify the animals eaten by owls, and weather stations to monitor changes in the weather. This display and associated activities have been disseminated to another elementary school in the Bethlehem Area School District. The faculty team leader has also presented various demonstrations at the participating schools and at other schools in the district.

The *Science and Biology Teams* worked together at Harrison-Morton Middle School. The fellows from these two teams worked alongside the teachers to assist with many hands-on activities. The industry sponsor working with these teams, Air Products and Chemicals, sent company representatives to the school on several occasions to offer demonstrations, and the company provided the necessary supplies so that teams of middle-school students could participate in the activities. In the second year of the program, the graduate teaching fellow, Melodie Kent, had an idea to develop an after-school Science Banquet where parents and families could view the students' work. The Science and Biology Teams, along with support from the Math, and Technology Teams, organized banquets in May of 2005 and 2006. The evaluator attended the most recent event, which was held on May 17, 2006. The auditorium was filled with excited student and parents while Dave Smith, a guest speaker from the DaVinci Discover Center, made a presentation on how he became interested in pursuing science as a career. Several students were awarded prizes for excellence in their classes, and all of the students who participated received a backpack and a t-shirt with a logo designed by a 6th grade student as a part of a contest. Each parent received a keepsake keychain or button. In addition, students who attended were given tickets that made them eligible for drawings for a number of science-related prizes that were donated by local businesses. Some of the prizes included a Play Station Portable, a crystal-growing kit, and a Laptop, which was donated by the team's sponsor, Air Products and Chemicals. After an informal meal, students and their families were encouraged to browse the science exhibits by students, teachers, faculty, and industrial sponsor, which were displayed around the school. The excitement and enthusiasm was palpable. In addition to this once-a-year activity, the Science Team established an after-school Science Club that met once a week. The team used this venue to explore various interactive learning websites, such as West Point Bridge Design, 24® online, Discovery Channel classroom activities, and Court TV's forensics in the classroom. The Science/Biology Team faculty advisor also attended several times to support the Forensics unit and provided supplies to dissect frogs to identify bones that the students learned about in the unit.

The *Chemistry Team* developed several presentations to complement the subject matter being taught in the classroom. These presentations have been documented, and many of the supplies needed for them were provided by the team. For example, the team provided a kit for each science teacher at Freedom High School to demonstrate to students how The Periodic Table of the Elements was conceived. In addition to these classroom support activities, the team has been involved in a significant amount of after-school tutoring for students that need extra help. The team also helped plan and facilitate a trip to the Corning Glass Museum to emphasize the scientific aspects of glass making and composition. The students attending this trip were from classes with lower academic functioning. In addition, the Chemistry team reached out to the community at the local Science Fest held in October 2005, which promotes understanding of and interest in science to elementary students and their families. Over 150 individuals were present for a demonstration by the Chemistry Team on the ways in which liquid nitrogen

affects other materials. The presentation ended by making ice cream with liquid nitrogen, which was particularly popular among the students. The Chemistry Team has been associated with Binney & Smith (Crayola), and representatives from the company visited the school three times in the last year to demonstrate fundamental chemical properties applied to everyday solutions that are familiar to the students.

Many of the activities developed by the Math Team to enhance students' learning in various areas of math are documented on the LVP STEM Website. The topics include data analysis and interpretation, number sense, order of operations, fractions, decimals, geometry, early algebra, graphing techniques, and probability and statistics. The Allentown School District imposes a tight calendar for math, because of their concern with improving Pennsylvania System of School Assessment (PSSA) scores. In addition to these activities, in the last year, with support from on of the LVP Program's industrial sponsor, Suntex, and from the Allentown School District, Harrison Morton Middle School was enrolled in the online program "First in Math" Students work online at their own pace to improve their basic math skills, and teachers can monitor their progress. Students could eventually compete against other schools also enrolled in the online program. Another lasting effect of the Math Team's participation with Harrison Morton math teachers are the Smart Boards that were supplied through the team's activities budget. These Smart Boards were used as an interactive tool to teach math and science. This was most helpful with teaching geometric ideas. The students also used them for presentations to help improve their communication skills.

The *Technology Team at Harrison Morton* Middle School provided in-class assistance and technology consulting. Early in the LVP Program, a teacher associated with the Technology Team suggested that the technology classes include robotics. With the help of the team, several robots were constructed, and students were taught simple programming techniques. This eventually led to the construction of the Mars Yard and Mission Control projects. A basement room in the school was transformed to resemble a Martian landscape, which the robots can navigate. An uneven floor, covered in pink-tinted concrete and walls painted to resemble a Martian terrain and horizon add to the authentic appearance of the exhibit. Eventually, the robots will be used to perform various tasks that will provide data for students to analyze. The students can maneuver the robots from classroom computers much like NASA's mission control did for the Mars landing. It is hoped that this remarkable interactive tool will be used in curriculums for science and math in addition to technology. The Mars Yard has been featured in the March 10, 2006 edition of *The Chronicle of Higher Education,* and in the *Lehigh Alumni Bulletin*, Spring 2006. In addition, the American Institute of Physics is creating a video featuring the Mars Yard, and this will be aired in English and Spanish in their nationwide syndicated network. Harrison Morton has also been chosen as a NASA Explorer School, and teachers reported that their partnership with the LVP Program helped them achieve this distinction.

The *Technology Team at the Regional Academic Standards Academy* developed a curriculum for robotics with an associated robotics tutorial that allows students to work at their own pace. The teacher had only a minimal knowledge of robotics before her association with the LVP Program. Although the program made great strides in developing the curriculum for robotics, the team was not able to accomplish the final goal of constructing a miniature of city streets that the robots could navigate. One of the highlights of the program for the teacher was observing two students with attitude and behavior problems as they rose to become the best programmers. For the first time, they were on task, took equal responsibility in their project, and showed great enthusiasm.

The *Broughal Technology Team* developed five new curriculums for the Technology and Industrial Arts classes. Units involving research and preparing reports in avionics, website design and mitosis, and multimedia presentations and technology were developed for the 6th, 7th, and 8th, grade levels. For the 6th and 7th grade Industrial Arts program, the team developed curriculums around bridge design with West

Point Bridge Designer and robotics design and programming. After learning from the fellows, the teachers are now able to teach and enhance the courses, and they will be continued at the school even after the program has ended. Broughal Middle School has also been selected as a NASA Explorer School.

The graduate fellow for the *Dieruff Technology Team*, Sally Moritz, developed a new curriculum to teach Java programming to beginners. It is called "Design First Java" and it focuses on designing a solution to a problem before writing a code. The fellow taught this class for over three semesters, and the teacher from the team learned the material by assisting her with the first class. He will continue to offer this course in Dieruff's Academy of Information Technology. The curriculum has been published in articles in *ACM's SigCSE Journal* (Association for Computing Machinery, Special Interest Group in Computer Science Education), and *ITiCSE* (Innovation and Technology in Computer Science Education international conference). The curriculum and materials are also available on the STEM website. To date, a teacher in the Seattle area used the newly developed materials, and he spoke about his collaboration with the LVP Program at the National Academy Foundation Conference in July. The Technology Team has worked closely with the industrial sponsor, PPL, an electric utilities company. The company provided real-world experiences for these high school students, who wrote résumés and cover letters for a job opening at PPL. The six students who were judged by company personnel to have the best résumés were interviewed in front of the class, and other students observed how a real interview would be carried out and offered critiques. In addition, six students shadowed PPL employees in computer operations, PC support, business analysis, and software development. The company also provided a field trip to their Martins Creek power plant. This association with PPL will continue after the LVP Program has ended.

The highlights mentioned above demonstrate that the LVP for G4-12 STEM Teaching Fellows has had a powerful and lasting impact on the participating schools. In addition to these achievements, the school administrators cite the importance of relationships formed through the collaboration, providing collegiality for often-isolated teachers and role models for students who, otherwise, may not have known of the opportunities for a career in a STEM discipline. The schools also enjoyed the resources provided through the program, including expertise in the classroom, and supplies and equipment that enhance the hands-on exercises developed by the teams. The professional development provided to the teachers allowed them to reflect on and improve their teaching. At the Closing Awards Dinner, one of the teachers with 32 years experience, stated that the LVP Program provided him with the most powerful professional development he ever experienced

Evaluation Methods

The evaluation has been ongoing throughout the project. Evaluation methods included feedback forms, surveys, focus groups, assessments of writing assignments, daily teaching records by fellows, and informal interaction with program participants. The evaluator attended workshops, strategy meetings, large group meetings, and team meetings to discuss the assessment of the G4-12 students. The evaluation elicited information from all project participants: STEM teachers, fellows, G4-12 children, team leaders, school administrators, and industry partners. A description of each method and the results can be found in Appendices 1 through 14. Where quantitative data were collected, the figures on which the text is based are included in a separate Excel file. The evaluation activities for each group are the following:

STEM Teachers

- Feedback on Educational Workshop (Appendix 1)
- Mid-Year STEM Teacher Feedback Form (Appendix 2)
- STEM Teacher End-of-Year Survey (Appendix 3)
- Focus Groups (Appendix 4)
- Assessment of G4-12 Students - 3 times per year (Appendix 8)

Teaching Fellows

- Feedback on Educational Workshop (Appendix 1)
- Focus Groups (Appendix 4)
- Daily Teaching Records (Appendix 5)
- Class Information Sheets (Appendix 6)
- End-of-Year Fellow Survey (Appendix 7)
- Assessment of G4-12 Students - 3 times per year (Appendix 8)
- Team Reports (Appendix 13)
- Fellow Personal Research Reports (Appendix 14)

G4-12 Students

- Assessment of G4-12 Students - at least 3 times per year (Appendix 8)

Team Leaders

- Feedback on Educational Workshop (Appendix 1)
- Focus Group (Appendix 4)
- Assessment of G4-12 Students - 3 times per year (Appendix 8)
- Rating of Fellows by Faculty Team leaders using Rubric (Appendix 9)
- Faculty Team Leader End-of-Year Survey (Appendix 10)

School Administrators

- School Administrator Survey (Appendix 11)

Industrial Partners

- Industrial Partner Survey (Appendix 12)

Analysis

The program's vision is to increase STEM graduate students' awareness of and interest in G4-12 education by partnering them with G4-12 teachers to develop and enhance the STEM curriculum, and to increase the number of women and underrepresented minorities involved in STEM education and careers through exposure to new technologies for inquiry-based learning. Three major goals were proposed to achieve this vision. The first goal was to provide G4-12 teachers with training and resources to incorporate inquiry-based learning methods in STEM education. The second goal was to enhance the educational experience of teaching fellows who serve as a resource in grades 4-12 STEM education. The third goal was to increase interest in STEM disciplines for women and minority G4-12 students. The project vision, goals, program components, and evaluation mechanisms can be found in Figure 1 on page xx, which appeared in the proposal to NSF.

The remainder of this report discusses the extent to which the three major goals were achieved. For each goal, various outcomes are listed that would be consistent with a positive result. Evidence from the evaluation is given to show how each outcome was accomplished, and the appendices that provided the evidence are listed in parentheses at the end of the discussion. The report also lists any negative features of the program that were uncovered through the evaluation process.

Goal 1: Provide G4-12 teachers with training and resources to incorporate inquiry-based learning methods in STEM education.

Positive Evidence

- *Educational Workshop was useful in coordinating team efforts*

The project provided one educational workshop in the past year, which was held on August 1 and 2, 2005. The workshop was entitled "Becoming a Team and Developing a Unit". The teachers found the workshop to be between moderately and extremely useful, especially the sessions that involved working within their teams to develop new units for the upcoming year. They also appreciated the opportunity to hear about the other teams' activities and successes, since these presentations spawned new ideas that were discussed in their own teams' brainstorming sessions. The teachers believed that sharing this information would encourage synergy among the various teams. Presentations by representatives from Suntex on the 24 ® Game and by teachers who attended a NASA workshop were also perceived as very useful. (Appendix 1).

- *Almost every team developed new hands-on projects by mid-year*

By mid year, fourteen of sixteen teachers indicated that the fellows had helped them develop new hands-on lessons. They reported that both graduate and undergraduate fellows were prepared for their demonstrations, communicated to the students at the appropriate level, and were effective tutors. In only two instances, the teachers felt a particular fellow needed more practice before a classroom or more confidence in pedagogy and public speaking. On the whole, the fellows' expertise broadened the teachers' knowledge and led to more efficient teaching strategies. (Appendix 2).

- *Fellows' expertise gave teachers confidence to teach new material*

At the year's end, the teachers indicated that the teaching fellows' expertise and the additional equipment and supplies made available to them were the most important aspects of the LVP Program. Several teachers mentioned that they learned how to search for relevant resources to develop more interactive lessons. They also became more aware of available resources and curriculums offered in other schools through their interaction with other program participants. Several teachers learned topics from the fellows that they would not otherwise have learned. For example, Aileen Wells, a teacher at Broughal Middle School said, "If it wasn't for STEM [LVP Program], I would not be able to teach Flash or Dreamweaver – not at all. I wouldn't even know how to begin." (Appendices 3, 4, and 11).

- *Additional equipment and supplies were very important to classroom activities*

New equipment included Smart Boards, a digital camera and projector, the electronic 24® Game, and supplies for demonstrations. The digital camera allowed a teacher to post on a website photos of fellows conducting in-class science demonstrations. Parents were notified by email, and within two days, eight parents visited the website to view the photos. Harrison Morton Middle School received equipment from Binney & Smith (Crayola) for their Mars Yard exhibit and was in contact with NASA through their appointment as a NASA Explorer School. The teachers believed that the school's partnership with the LVP Program was viewed positively by NASA in their bid to become an explorer school. Another industry partner, PPL, provided employees to help high school technology students practice writing résumés and experience in-class job interviews. Students were also invited to shadow employees for a day, and the company provided a field trip to one of its coal- and gas-fired electric generating facility.

Air Products and Chemicals supplied all the materials needed for nine activities, each of which required 30 distinct small-group experiments. (Appendices 4, 12, 13).

- *Teaching methods changed and new curriculums were developed due to participation in the program*

Teachers found that participation in the LVP Program changed their methods of teaching to a moderate extent. They had more confidence in their own abilities to do demonstrations in the classrooms and to teach new subject matter. They took more risks in learning new programs; they incorporated more hands-on lessons and new technologies in the classroom. They were able to offer labs that would not be funded through the school, and they were more willing to do demonstrations and experiments in the classroom knowing they had an extra pair of hands to assist (Appendix 3).

In several instances, completely new curriculums were developed with the help of the fellows. A novel curriculum with units on aviation was developed by the Physics Team to be applied to elementary science classes at Spring Garden and Fountain Hill Elementary Schools. In developing these units, the team was careful to ensure that all requirements of the science curriculum were included (Appendix 13). Fellows developed a robotics curriculum for The Regional Academic Standards Academy as well as a Flash tutorial that allowed the children to learn at their own pace. The school's principal viewed this as an important development for their students (Appendices 3, 11). Several new curriculums were developed by the Technology Team for Broughal Middle School. These included: Research and Preparing Reports using Avionics, and Bridge Design with West Point Bridge Designer for 6th grade technology and industrial arts classes; Research and Web Site Design for a unit on Mitosis, and Robotics Design and Programming for 7th grade technology and industrial arts classes; and Research and Preparing Multimedia Presentations for the 8th grade technology class (Appendix 13). The Technology Team at Harrison Morton introduced robotics and the Mars Yard into the Technology curriculum. Since the Mars Yard was completed only in the last year, the curriculum is still being developed and formalized. A school administrator from the Allentown School District, while applauding the achievement of this resource, recognizes the challenge of extending this exciting technology education experience to the other middle schools in the district. (Appendices 11 and 13). Finally, Sally Moritz, a fellow from the Technology Team at Dieruff High School, developed, taught, and tested a Java Programming Course as well as Java Programming II. The teacher learned this new material by assisting with the class, and he is now confident enough to teach it. Dieruff's principal saw this new curriculum as an improvement in the Information Technology Academy in their school. (Appendices 11 and 13)

The Math, Science, Biology, and Chemistry Teams all developed hands-on activities and demonstrations that complemented curriculums required by the school and/or the school district. These activities have been documented, and many of them appear on the LVP STEM website. In addition, teachers mentioned improved handouts due to the information supplied by the fellows, and the evaluation activities associated with the program led one teacher to increase use of rubrics in scoring students' work.

- *Program provided professional growth and development*

Teachers were asked how participating in the LVP Program affected their professional development. Their collaborations in the program led to increased strengths as a teacher. One teacher described the experience as "perfect on-the-job training", and another became more proficient at developing useful rubrics. Teacher, Don Stahl, participated in Pennsylvania's Keystone Competition, and he received a Technology Award at the regional level for his essay discussing the Mars Yard; as of May, he was planning to compete at the state level. Several teachers mentioned that their participation in the program taught them how to work with school administrators, as well as individuals from academia and industry to reach a goal. The principal at one of the schools was most impressed at the program's closing dinner by

the testimony of a 32-year veteran of teaching, who stated that the LVP Program provided him with the most powerful professional development he ever experienced. (Appendices 3, 4, and 11).

- *The Program provided opportunities to network with members of the STEM community*

Teachers also reported increased networking with members of the STEM community. Nine of teachers felt that the greatest benefit of the program was their relationship with the fellows. Several teachers mentioned that the LVP Program afforded them an opportunity to share their thoughts with other professionals and to get feedback on new ideas. The school administrators also cited the collegiality engendered by the program between Lehigh University and the school districts. The administrators noted that the Lehigh faculty made several innovative presentations to students, and that the teachers and fellows worked together well, drawing on each other's strengths. One teacher described programs like the LVP Program as a "lifeline in the classroom". Teachers tend to work in isolation, and this program provided an opportunity to develop new ideas with other adults and have a critical friend in the classroom to reflect on what worked and what did not. (Appendices 2, 3, 4, 11, and 13)

- *Teachers shared new techniques and ideas with other teachers*

A number of the participating teachers disseminated the knowledge they gained through the program with nonparticipating teachers. One teacher offered an in-service regarding a topic learned from the fellows, and as a result, other teachers in the school are now better trained. Another teacher traveled with one of the fellows to the American Association of Physics Teachers (AAPT) Conference in Anchorage, Alaska to present on the LVP Program. In addition, one teacher helped develop a course using a hands-on setting. (Appendix 3 and 12).

Negative Features

- *Progress on some newly developed curriculums was slower than hoped*

Teachers were grateful for the curriculums that were developed through the program, but in several instances, they would have liked to see more progress. Several fellows and faculty team leaders also alluded to this issue. Three fellows mentioned the need for better communication methods between and among teams to increase the synergy among the teams; they felt this would lead to more integrated curriculums. The faculty team leaders also wondered how other students could have benefited from the activities developed by the other teams. (Appendices 3, 7, 8, and 10).

- *Time devoted to STEM activities precluded other opportunities for professional development*

One teacher did not feel that the program affected professional development, and another felt that it had a negative impact, because the time that this teacher devoted to STEM activities precluded other opportunities for professional development. The past year was difficult for one teacher; it was felt that the faculty advisor and fellows were not fully committed to the project. (Appendix 3).

- *Factors beyond Program's control affected its impact*

Ten teachers mentioned that there were various problems that were beyond the LVP Program's control. For example, the lack of resources in the school, inflexible curriculums, scheduling conflicts, and short terms for some topics that do not allow enough time to teach the material. Teachers were often too busy to reflect on the demonstrations or were unable to attend meetings sponsored by the program because of scheduling conflicts. (Appendix 4).

Goal 2: Enhance the educational experience of Teaching Fellows who serve as a resource in grades 4-12 STEM education.

Positive Evidence

- *Fellows gained valuable teamwork experience*

The fellows reported being moderately satisfied with the Educational Workshop as a whole. However, they found the session on Team Time: Developing a Unit to be very useful, and several fellows believed that hearing the activities accomplishments of other teams and brainstorming as a group increased the synergy among the teams. In the focus group session, some of the fellows mentioned that working with a team was a valuable aspect of the program. Team meetings were productive and provided opportunities to get direction from the faculty team leaders. From the perspective of the faculty advisors, the fellows received high ratings (4.4 on a scale of 5.0) on their ability to work cooperatively on a team, taking an active role in team meetings, and making useful suggestions. (Appendices 1, 4, and 9)

- *Fellows formed rewarding relationships*

One of the issues discussed in the focus groups involved the relationships formed through participation in the program. Seven of the fellows mentioned how rewarding it was to work with the G4-12 students. The fellows cared about them, and the students reciprocated by showing personal regard for the fellows, greeting them when they were in the school, and asking about them when they were not present. One fellow was invited to watch students perform in an evening band concert. The fellows gained tremendous respect for teachers after spending time with them in the classroom. The impression from the focus groups was that the fellows had excellent rapport with the teachers on their teams. Another aspect of the program that the fellows found very valuable was their interaction with the industrial partners on their team. This program required that the fellows deal with individuals from diverse academic, cultural, and socioeconomic populations. These experiences will serve them well as they embark on their own career paths. (Appendix 4)

- *Fellows had extensive classroom experience*

As a whole, the fellows reported spending over 2500 hours assisting in classroom activities in the 2005-2006 academic year. This averaged to 170 hours per graduate fellow, and 109 hours per undergraduate fellow. Class information sheets provided by the fellows show that they had contact with at least 2,779 students last year. Of these, about 1,400 students had contact with more than one fellow. Teachers confirmed that, on average, fellows spent slightly less than 6 hours per week with them in the classroom, although many fellows worked with more than one teacher. Through this experience, the fellows learned classroom management, including setting boundaries and informing students of the consequences when boundaries are exceeded. The fellows also gained a realistic perspective with regard to learning styles and skills of individuals. They learned how to modify lessons for different academic levels and how to anticipate questions. Whether a fellow pursues an academic career or a career in industry, this experience will enhance their repertoire of people-skills. (Appendices 2, 4, 5, 6, and 7).

- *Program had a positive impact on fellows' academic and research activities*

Besides the various skills that fellows developed through their program activities, several fellows reported that they were able to incorporate the experiences into their research activities or into their classes at

Lehigh. One example is grad fellow Sally Moritz, who worked with other graduate students to develop an Intelligent Tutoring System to help students as they design solutions to beginner-level problems, which builds on the Java Programming curriculum she designed. (Appendices 7 and 14).

- *Fellows received critical evaluations of their teaching and presentation skills*

The fellows felt that their communication skills improved due to their participation in the program. They also received critical feedback from teachers and faculty advisors. For both graduate and undergraduate fellows, the teachers reported that they almost always communicated with the students at the appropriate level. In only two instances, teachers felt that an undergraduate fellow seemed uncomfortable with the students or needed more confidence in pedagogy and public speaking. The teachers also reported that the fellows were superior in their integrity, ethical behavior, and professional conduct, and in meeting the learning needs of the students. Fellows' rated for their communication skills by faculty team leaders were given ratings of 4.3 out of 5, which translates to very good. (Appendices 2, 3, 7, and 9).

- *Fellows learned time-management skills to manage research activities and program participation*

The fellows were required to keep up with their class work and research at Lehigh in addition to spending time developing activities and assisting the teachers in the classroom. By necessity, they had to learn to manage their time to allocate it effectively. Although this was a challenge, several fellows mentioned that the classroom provided an invigorating and welcome break from their academic activities. (Appendices 4 and 7).

- *Fellows reported an increased understanding of K-12 educational issues*

Sixteen of the fellows felt they have a better understanding of the issues regarding K-12 education due to their participation in the program. They were exposed to educational issues at the personal, organizational, and political levels, since they saw the challenges faced by teachers due to the behavior and disparate abilities of the students, scheduling, and standardized testing. Some fellows recognized the importance of involving parents and the community in general education. All but one of the fellows would be willing to volunteer at community schools in the future, and almost three quarters of them believed they would be advocates for education in the future. Participation in the program strengthened the resolve of one undergraduate fellow to pursue a Master's Degree in Education Administration and focus on policy-making. (Appendices 4 and 7).

Negative Features

- *Fellows experienced time pressures due to Program participation*

Several fellows mentioned time pressures they felt due to participation in the program. In one instance, academic and research activities limited the time one fellow could spend with the teachers developing new lessons. Another fellow did not allocate time effectively because of the travel involved in commuting to the school, and another believed that first-year grades would have been better had more time been spent on academics. However, this fellow still performed quite well and believed that the correct choice was made to put the STEM students first. (Appendices 4 and 7).

- *Scheduling conflicts limited time fellows could spend on Program activities*

Two school administrators admitted that scheduling is one of the most challenging aspects of the program. With the schools having rotating schedules, and the fellows needing to attend classes, honest

communication is imperative. One of the teachers felt that the team was not able to meet often enough to discuss activities for the classroom. Another reported that scheduling problems caused the fellow to cancel classroom visits when the teacher was expecting help. Two other teachers felt that the faculty team leader pulled fellows from the classroom to attend to other research activities, and this severely limited their impact. (Appendices 2, 3, and 11).

Goal 3: Increase interest and learning in STEM disciplines for women and minority G4-12 students.

Positive Evidence

- *Students participated more fully when fellows were present*

The teachers felt that the fellows had a moderate impact in the classroom. They pointed out that the students appeared to feel comfortable asking questions of the fellows; they worked harder to find the answers, and eventually came to "own the material". Having the fellows present in the classroom helped the students to recognize that they needed to check numerous resources when looking for answers. The fellows also noted that students actively participated in classroom activities. Between 95% and 100% of the students participated when newly developed projects were presented, and approximately 90% participated in previously developed curriculums. The fellows, too, believed that students were not intimidated to ask questions, and they worked harder to find answers with the fellows' encouragement. (Appendices 2, 3, 4, and 5).

- *Students were more enthusiastic and more interested in STEM topics*

Teachers, fellows, parents, and administrators all commented on the level of enthusiasm exhibited by the students and their increased interest in STEM topics due to the LVP Program. The teachers commented that students look forward to fellows' visits. Their attitudes brightened when the fellows were in the classroom, and they were more interested and excited. The students came to realize that what they were learning actually affected their lives. One of the teachers reported that her students were offered a party as a reward for good behavior, and the students requested a "Science Party", where the fellow did demonstrations and made ice cream using liquid nitrogen. The fellows also felt the students were more enthusiastic and attentive when fellows were in the classroom. One of the fellows reported that after working with the students, they came to view math as "cool". Four teachers reported that parents commented on the LVP Program. They appreciated that their children were able to work with Lehigh students and were given extra attention. Some parents mentioned that their children were excited about science this year, and a number of parents participated in the Science Banquet held by the Science Team at Harrison Morton Middle School. Finally, one of the administrators noted the students' enthusiasm for a scheduled visit with astronaut, Sally Ride. Unfortunately, this visit had to be cancelled because of illness, and the principal noticed how disappointed the students were. (Appendices 2, 3, 4, 5, and 11).

- *Students learned STEM concepts through presentations and demonstrations*

All of the teams assigned several writing assignments to assess whether the newly developed activities and curriculums were successful in teaching the concepts to the students. The assignments were rated using a rubric developed by the team, and the results were discussed with the evaluator at team meetings held at the school three times a year, in November, March, and May. Descriptions that are more detailed can be found in Appendix 8.

Middle-school science students wrote short essays on several topics, which were assessed by the *Biology Team*. The topics included weather cycles and prediction, the importance of chemistry in everyday life,

and presentations given by the team faculty advisor on her research with hamsters. Although all the students tended to be interested in the subject matter and scored reasonably well on content, they scored lower on style and convention. Many students used slang, and spelling was poor, because they wrote phonetically.

The *Chemistry Team* had students write on three subjects: atoms and their charges, lessons they learned from an egg drop experiment and video, and oxygen gas generation, data collection, and analysis. The students performed well enough to infer that they learned the principles being demonstrated, i.e., earning 75% or greater. On the last assignment, most students struggled with a question asking whether oxygen was soluble in water. This was not covered in the lab, but required common sense by considering everyday things. The team was planning to brainstorm to see whether they could improve the responses to this question.

The *Math Team* worked with an accelerated class and several regular classes. For the first assignment, both groups wrote about an activity they witnessed regarding how to insert parentheses into math statements to make them correct. They also performed two math problems. The accelerated classes correctly answered 83% of the assignment, while the regular classes scored 68%. For the second assignment, the accelerated class designed a floor plan, computed the floor space and the cost of the flooring, and converted fractions to percentages. While they did reasonably well on the written portion of the assignment, they did not do as well on the problem-solving portion. Students in the regular classes were asked to describe a manipulation of tanograms and then create shapes. All of the students drew the tessellation correctly, and they averaged 79% of the written portions of the assignment. Most of the problems came from their struggle to write about the process by which they discovered the meaning of tessellation. When answering verbally, the students were able to respond with some thoroughness.

Fourth graders working with the *Physics Team* were given a 3-question pretest at the start of the year. They were asked to explain how a jumbo jet flies, describe what happens to cause a light to go on when you flip a switch, and why lightning is seen before thunder is heard. Fifth graders were asked to explain how animals are classified in the animal kingdom. The students were then given a posttest after the topic was covered in the classroom. Although all the classes had different teachers, the fellows assisted in the activities associated with the test questions. In all of the classes, the students did better on the posttest than they had in the pretest. One class of mediocre students did not do as well as expected, but the fellow believes that this was due to an issue unrelated to the presentation. In both the 4^{th} and 5^{th} grades, the lower performing classes did reasonably well in the posttest, and in the 5^{th} grade, the lower performing students had higher gains in the posttest than the class composed of mid-level students, although their posttest score was still slightly lower.

In trying to improve their writing abilities, the *Science Team* required that the middle-school science students keep a log discussing the science topics covered during the week. Two entries were scored; one involved heat transfer, and the other involved making crystals. In the first assessment, the classes averaged around 71%. Students appeared to have trouble formulating original thoughts, and they struggled to move from their observations to the appropriate conclusions. The fellow believed that this was due to the fact that this was their first exposure to technical writing. There was an improvement in the second assessment, with the students scoring around 81%. Over the year, the advanced and average students demonstrated a real improvement in their writing skills. The slower students struggled with completeness, because they did not push themselves to complete the assignment.

The *Technology Team* at *Broughal* Middle School did assessments of 6^{th} grade Industrial Arts classes and 8^{th} grade multimedia classes. The 6^{th} graders answered questions regarding the West Point Bridge Designer, and in the first session, average scores ranged from 72.5% to 84.2%. More quizzes were given in the following session, and the scores improved greatly, with average scores ranging from 97% to 102%

(exceeding expectations). In the 8th grade multimedia class, the students had to describe how they conducted the research for the assignment and the technology they used. They were also graded for completeness of the assignment. In the first session, the students averaged 82%, even though some of these students had language and learning disabilities. Although they were not rated on completeness in the second session, the overall average was higher in the second session, with an average of 89%.

The *Dieruff Technology Team* assessed the Java Programming Course, a high school level course developed by the graduate teaching fellow. The fellow taught the course for the previous two years in both fall and spring semesters; however, this past spring, the fellow taught a Java Programming II course for interested students who had completed the fall programming course. In the fall, the students averaged between 74% and 87% on the 4 quizzes and 77% on the final exam. The final exam average increased to 80% when one student's score was eliminated; this student missed half of the class sessions and did not complete the programming assignment. Seven students continued to the upper level course, and their quiz scores averaged 94% and 84%. The fellow was pleased with the students' performance.

The *Technology Team* at *Harrison Morton Middle School* offers the technology classes in six sessions throughout the year. Assessments were done in all of the sessions, but were reported for three of them. For the first assessment, students were asked to write about an inter-office memo that they created. Scores ranged from 67% to 92% for the six classes in this session. Many of the deductions from the scores in the lowest classes were due to half-completed responses. In the final two assessments, students provided an overall picture of the entire session, described its purposes, and identified the school district standards addressed in the class. Average scores for the second assessment ranged from 84% to 95%; however, the averages on the final assessment ranged only from 61% to 75%. This drop in scores occurred because the teacher changed the question regarding the school district standards. In earlier sessions, students were asked to select three standards with which they identified, but in the final session, they were asked to elaborate on three ideas that showed how they applied the knowledge they learned in technology class to their other classes. Most students failed to compile complete sentences or ideas.

The *Technology Team* at the *Regional Academics Standards Academy* assessed entries in the 5th grade students' learning logs. The first entry to be scored dealt with whales, and the scores ranged from between 65% to 75%. Students did more poorly on the second assessment regarding the earth's structure. These scores ranged from 42% to 52%. The teacher felt this had more to do with the instructions for the assignment rather than the students' knowledge. For the first assessment, students were asked to write five sentences, while for the second, they were told to write a short essay. The final assessment involved programming a car and presenting their work. The students did very well on this assignment, scoring between 88% and 90%. The team felt that this improvement was due to the fact that the project was hands-on; the team explored new learning styles during the course of the project, and the assessment was made on more than just the students' writing skills. The teacher indicated in the focus group that two students with behavior problems became the best programmers in the class.

As can be seen from the various assessments, the writing abilities of the students hampered their ability to express clearly the concepts they learned. In the focus groups, however, both teachers and fellows mentioned improvements in the students' communication skills over the course of the year. One team felt that the focus on writing for the entire year improved writing skills, and another team saw improved verbal communications when students were required to give presentations using Smart Boards. (Appendix 4).

- *Students received individual attention that they would not have received otherwise*

Teachers indicated that parents appreciated the extra attention that their children were given by the fellows in the LVP Program. Several teachers on the technology teams mentioned that it was easier to

keep the students' attention and interest when the fellows were present to field their questions in a timely manner. Another teacher noted that students with poor self-images attempted activities when fellows were present that they would not have tried without the fellow's support. Two fellows voiced their concern that the discontinuation of NSF funding would leave students without the extra attention that they so sorely needed. (Appendices 3 and 4).

- *Fellows provided positive role models*

The teachers were impressed by the relationships formed between the fellows and the students. One teacher commented that the female fellows provided strong role models for the female students. Teachers felt that the fact that the fellows were closer in age to the students increased the rapport. The fellows also noted that the students related better to them because of their age, and the students were interested in what the fellows were doing in their lives. (Appendices 3 and 4).

- *Students were exposed to various college and career options*

Through the LVP Program, the students in community schools formed relationships with college students and became aware, for the first time, that there are various majors in college, and that people choose to work in STEM careers. The fellows tried to make the students aware of various opportunities, technologies, and careers, and both teachers and administrators confirmed that students showed more interest in STEM disciplines. (Appendices 4, 7, and 11).

Negative Features

- *Established curriculums were too rigid to allow additional activities/projects*

The teachers and fellows pointed out that the effectiveness of the LVP Program was hampered at some schools by the rigid curriculums in place for some disciplines. In particular, the Math Team was limited to developing activities that complemented the current math curriculum, because the administrators and teachers felt the need to prepare the students for the Pennsylvania System of School Assessment (PSSA) tests. The Science Team also lamented that they had to eliminate some activities because the students' math skills were not strong enough to attempt higher-level projects (Appendix 4).

- *Students in these urban schools do not recognize their own potential*

Many of the students served by the LVP Program are from lower income families, and a number of them speak English as a second language. A number of these students lack self-confidence, and this diminishes their interest in learning. They need extra attention to focus on their reading, writing, and math skills before more advanced concepts in STEM can be demonstrated effectively. (Appendix 4).

Conclusion

The LVP Program has made significant progress in reaching the goals that had been set out in the proposal. The program served schools with large percentages of minority and low income students and made concerted efforts to recruit women and minority students as fellows to serve as role models. Almost half of the students who served as fellows over the three years of the grant were women (48.5%), and 40% of the fellows were Black, Hispanic, or Asian.

The STEM teachers expanded their knowledge through the fellows' expertise. Twenty-one teachers served on teams with fellows and faculty team leaders through the course of the grant. They worked with

the team to develop new curriculums or new hands-on activities and demonstrations to enhance STEM classes. Several teachers learned about new topics in their field, which they were now able to teach in their classes and share with other teachers. They gained in confidence and saw the fellows' expertise as a valuable supplement to own curriculums. With the assistance of the fellows, teachers were able to conduct activities that they could not have done due to time constraints, lack of help in the classroom, or lack of resources. The teachers reported professional growth and development in working with a team, and were very appreciative of the relationships formed with fellows, Lehigh faculty, and industrial scientists. This arrangement alleviates the feelings of isolation that many teachers report is inherent in school settings. At the program's closing dinner, a participating teacher, who is a 32-year veteran of teaching, gave a testimonial stating that this was the most powerful professional development he had ever experienced.

The fellows enhanced their educational experience through their participation with the LVP Program by gaining valuable teamwork experience, classroom experience, and time-management abilities. Their classroom experience taught them important skills that can be applied in academe or in industry. In addition, they formed rewarding relationships with students in the community schools, gained respect for teachers, and they increased their awareness of issues affecting K-12 education. Almost to a person, they indicated their interest in becoming advocates for K-12 education in the future. One teaching fellow so enjoyed the outreach experience that she described it as her "best experience at Lehigh".

The K-12 student also gained a great deal through their interaction with the fellows. They increased their enthusiasm for and interest in STEM disciplines, and have come to realize the STEM concepts they learn in school affects their daily lives. The assessments show that the activities are helping the students understand the concepts, and the additional resources provided through the program give them opportunities to learn new technologies and practice presentation skills. These children from urban schools often have little exposure to college and STEM-related careers, let alone aspire to them. The rapport they established with the fellows appeared to give them confidence to express their curiosity and ask questions. Since many of them are from disadvantaged families, they needed the extra attention to raise their expectations of their own abilities.

The school districts benefited through the resources and contacts they gained through participation with the program. Several new curriculums were developed; the electronic 24® game was installed in three schools, and two schools were named NASA Explorer Schools. Harrison Morton Middle School has gained a Martian Landscape and Mission Control Center for students to learn skills in robotics, programming, science, and math.

The negative features of the program were also outlined. Some were inherent to the school systems and were unrelated to the activities of the LVP Program. Other negative features were reported by a small number of the participants. Although this does not lessen their importance, these issues could be handled on an individual basis. There were no major systemic problems that would need to be addressed for the continued success of the program.

Overall, satisfaction levels of all participant groups were very high. The results outlined in this report confirm that this was a very successful venture in integrating higher education and industry to help disadvantaged students in community schools to grow in their knowledge of and appreciation for the STEM disciplines.

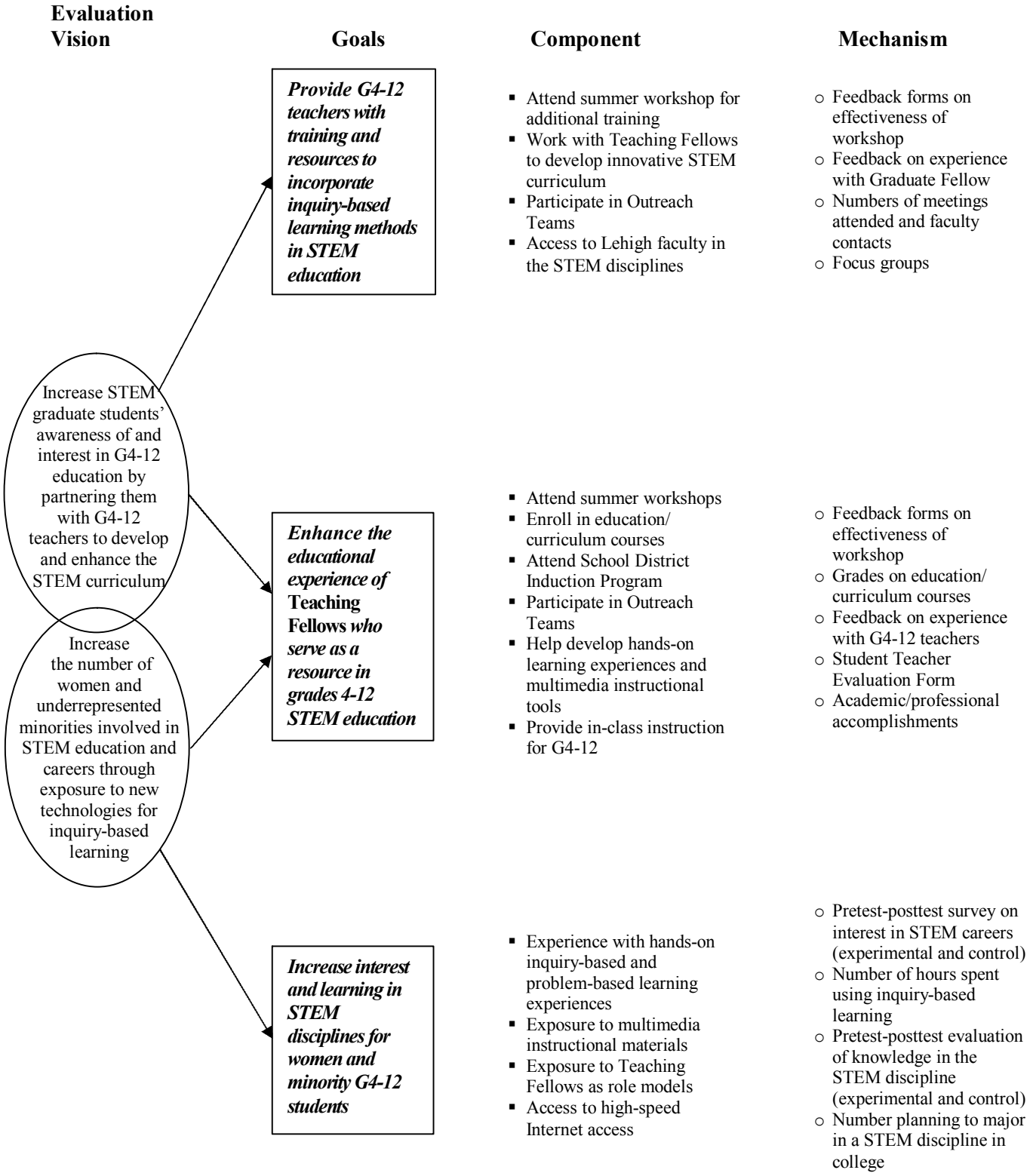

Figure 1: Project Vision, Goals, Program and Evaluation
STEM – Science, Technology, Engineering, and Mathematics