CLOSING THE ASSESSMENT FEEDBACK LOOP: THE USE OF A QUALITATIVE FORMATIVE EVALUATION PROCESS AND CHANGES IN A MULTI-YEAR NSF/PENN STATE GK-12 EDUCATION PROJECT.

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Introduction

In this paper[1] we describe some of the changes made as a result of informal feedback gained through qualitative basement techniques in the operation of a three year science, technology, and math education project funded by the National Science Foundation under its GK-12 (Graduate-K-12) program to enhance science, math, engineering, and technology skills and career choices. The Penn State side of the partnership involves graduate and undergraduate science and engineering students at Penn State who are involved with researching and developing HEV (hybrid electric vehicle) technology. On the K-12 side of the partnership are two middle schools and one high school in Pennsylvania.

The three anchors of this joint National Science Foundation-University-School partnership are mentoring, motivation, and manipulatives or M3. The M3 approach was developed by the late Dr. Donald Streit, Penn State. Graduate students from Penn State's Graduate Automotive Technology Education (GATE) Program, which focuses on HEV technologies have been teamed up with 7th, 8th, and 10th grade science classrooms in two middle schools and in one high school that have large proportions of minority students. The graduate fellows participating in the program have been awarded an NSF fellowship. In return, the graduate fellows are teamed with teachers in K-12 classes and visit the schools on a regular basis. In the visits to the science classes the fellows present material on hybrid electric vehicle technology and seek to develop a mentoring relationship with students in the classes.

The second M in the term M3 refers to motivation. Motivation to develop science skills and to consider science and technology-based careers is provided by field visits by the middle school and high school students to the HEV lab facilities at Penn State. Additional motivation is provided by a variety of web-based activities developed for the students by the graduate students and faculty and researchers at the Pennsylvania Transportation Institute. A web-based activity that has become particularly popular with the students is the web-based question of the week. Another web-based activity now under construction is a web based simulation-type game that involves the building of a hybrid electric vehicle.

[1] The authors would like to extend their thanks to Sara Inman, Krishan Bhatia and Nicola Ferralis, all of whom are NSF M3 Fellows and to Jacob George (Pennsylvania Transportation Institute) for their assistance in providing material for this paper.

Manipulatives, the third anchor of the M3 approach, are developed by undergraduate students in the College of Engineering. Manipulatives (also called hands-on activities) are selected or designed to demonstrate basic principles of HEV technology, bringing it out of the textbook (or out of the web page) and into the hands of the students as they build, test, experiment and rebuild/re-test. Three undergraduates per year receive scholarships from NSF and in return are responsible for working with a College of Engineering faculty member to develop low-cost teacher-friendly hands on manipulatives. These manipulatives are based on topics of study in the HEV program and involve focused, hands-on science activities that are used in the target science classrooms and are also introduced to science and technology teachers through a program of teacher workshops.

A program of summer teacher workshops that are open to all K-12 teachers in science and technology classrooms across Pennsylvania has been developed. Graduate fellows, HEV-related faculty, engineering undergrads and outside speakers present HEV-related workshops and seminars in an effort to provide an additional source of inspiration, curriculum ideas, and science updates and refreshers to middle school and high school science teachers. A teacher resource page for all teachers is also being developed on our NSF HEV M3 Penn State project web site. These teacher resource pages will include links and lesson plan suggestions, sources for project materials and the write ups of the manipulative projects. Teachers will also be able to post links, comments and ideas that they have found to the teachers resource pages.

An ongoing, qualitative-based assessment is being carried out for all of these activities. In the balance of this paper we would like to use our various voices to tell some of the ways we have made a variety of "course corrections" to the project as a result of the more immediate impact of informal feed back.

Activities to be discussed

1. Fellows' experiences in the classroom
2. Question of the week
3. Undergrads and the development of the manipulatives
4. Summer teacher workshops
5 The HEV web based game
6. Educational field trips to the HEV center at Penn State

Sara's story

A story I really enjoyed was when I had the opportunity to shadow a quiet and very polite young lady. When we got to the math class she told me, " I really don't like math – I am not very good at it." She had previously informed me that her favorite class was English. In the math class, the teacher was going over geometry of triangles. When he asked a question, she often raised her hand and had the right answer. Afterwards, I told her she was really good at math. She was kind of beaming and just said "well, that stuff is easy." I was surprised to realize that just encouraging students and interacting on a one-on-one basis is so important in helping them feel successful.

Oliver's in-class experience

The 'in-class teaching' is a real challenge for all fellows. Of our program it is the only regular 'one-on-all' activity between fellows and K-12 students. Standing in front of the class and teaching in a way that is easy to understand is tough. Next to that is the initial inability to imagine that not all students are geniuses in math and science, since most of the graduate fellows acquired a strong technical background from early on.

In the beginning of each school year every fellow is assigned to a specific class. After a field trip in which the classes are invited to our university to tour through all laboratories regarding HEV, fellows give science lectures throughout the entire school year. This can be something between a biweekly class and a visit every other month, depending on the location and proximity of the school.

Fortunately, there are multiple topics which can be derived from hybrid electric vehicle technology: Energy conversion concepts, fuel and natural resources, emission with green house gas and acid rain, electric circuit concepts, battery (charge and recharge) to mention only a few.
The key element of each lecture is to convey the message in a "down-to-earth" sense, which gives all class members the opportunity to join the show. We as fellows believe that there are inherently some advantages for us compared to the regular teacher, because we are in a sense a hybrid as well (mixture between a graduate student at the Pennsylvania State University and a part-time teacher for the kids). Therefore the students are able to relate themselves to us, and see directly what might happened to them by choosing an engineering avenue as a career choice. Therefore we found that there is a common team feeling in the classroom and the interest of almost everybody is captured.

Because we had no prior knowledge on how to teach, our goal was to keep the activity level high with at least one hands-on experiment per lecture. Because kids do not necessarily have the ability to answer the question, "Is it difficult or is it easy?", it is our philosophy to emphasize more on the fun level. We found out that children can probably do the hardest things if they have a chance to enjoy doing it. Once the in-class activity provides a healthy mixture between fun (to awaken interest) and content, the ability to retain information and concepts is at a very high level.

Our choice to base our classroom activities on automotive subjects is great for kids. By discussing HEV-problems, all students have real-world examples in mind to which they can relate very easily. Probably they can even go home and discuss certain things with their parents (fuel economy, emission). I had a case, in which a student asked me a question from his parents about car efficiencies (Is it really true that conventional vehicles have a overall efficiency of only 17%, whereas HEV-cars have efficiencies of 30%?).

Also, we all enjoyed giving the students some insight into the difference between science and engineering. The inherent difference is that engineers are producing and applying science concepts and secondly it always involves important secondary design questions and a design objective considering weight, space, cost and environmental impact on the society. We felt that such considerations make it necessary to talk about certain trade-offs, and the existence of gray tones in contrast to a black and white science world.

The biggest compliment I got was from the teacher himself as he wrote to me at the end of the term "it was his most exciting school year in his 20-year career as a teacher".

Nicola's experience with the question of the week

When the Question of the Week site first started, a lot of expectation was present among the fellows. My first concern was to find a question that could have been suitable for a 7th grader: this task was everything but easy. We decided to post for the first week the same question to all the classes involved in the project since the project itself was correlated to the HEV. The question we decided on was "what is an HEV?". We thought that this would have been an occasion for the students to do some of their own research, using encyclopedias, the Internet, and dictionaries.

From the beginning we considered three possible types of questions: "search" questions (like the one just mentioned), intuition ones, and little math ones. From the first question we had to face the fact that a 7th grader has a completely different approach. I remember one girl answering that the HEV is a specific type of Hepatitis: at the beginning we considered this as a joke, but we soon realized that she was correct. We learned that what is obvious for us is not for everybody. For the next question I tried to put the question in the easiest way, so that no possible confusion could have been made. Personally, I preferred to have the kids thinking more than making calculations or doing research.

I believe that after almost two years of working with these questions of the week in this way the students take these thinking questions as games. Sometimes, indeed, having as a result a calculation is too radical, because in that case the answer can be only correct or incorrect with no shades in between. For a thinking question, it is not simply the result that is important but also the way it is explained. Personally I think that sometimes it is better to have a wrong answer nicely described with good arguments, than a badly described but correct answer. The teacher I am working with agreed many times with me on this issue. From a psychological point of view a lot of students can be understood from their approach in answering a question. For example, to the same question about what produces the heat in the brakes when the car is braking, some students answered with just one word: "friction", while some others with two or three sentences, each 9-10 words long, without the word "friction".

The teacher brought this issue to a higher level so that we, the fellows, started working as "psychologists". Specifically we had to face some "special needs students". While normally we considered all the students in the same way, sometimes more attention had to be paid to some students. We designed a way of monitoring those students through a close weekly interaction between the teachers and us. The idea was not to put too much pressure (with negative grades) on these students. The grades were designed as C (correct), PC (partially correct), NC (not correct) in order to allow us to play with the intermediate PC in a quite range of answers, from nearly wrong to almost right. On the other side I monitored some fake answers (parents answering for the students) pointing them out to the teacher.

The first version of the web site (basically a page for the students where they could find the question, and an administration page for us, where we graded the answers), was not accurate enough to provide a complete interaction with the teacher. So I designed, for the class I was assigned to, a daily updated “teacher page” where all the answers were posted with grades and comments. The teacher was so enthusiastic about this page, which she actually printed out in hard-copy, that she cut it up for each student into single splits with answer, date and my comments. In theory my role was just as a grader, but from this interactive weekly appointment, we became, in a sense, mentors. Students got used to us, so when I went in class for some class presentations kids knew me and approached me as a mentor, eventually asking me questions. This teacher page was so successful that it has been implemented for the other class starting Fall 2001.

Eventually this close relation with the students became, in a few occasions, too direct, almost supplanting the teacher herself. To answer a question some students wrote directly to my email address that they found in the class computer rather than answering on the web page. I was worried about the possible problems that would have been raised. In order to resolve this issue, the teacher and I decided that the students with questions would first ask their teachers and then the teachers in turn would pose these questions to the grad fellows. This desire to communicate and ask questions that can help them is in any case a sign of real interest in the program. One time I forgot to post a question on a Monday (the first day of posting for the week) and I had many complaints from the students through the web site. I was surprised that the students were actually waiting for the question, as a fixed weekly appointment that was not a teacher’s idea.

To help the students in answering we implemented the questions to include pointers to some useful websites. In some cases (as for a question about roller coasters, with a suggestion to look at some animated simulations) the suggested website has been considered more interesting by the students than the question itself. Looking for some help for the students, we actually found many resources useful for the teachers, for the students and for us.

The final step for the Question of the week site is the design of an associate portal where the teachers can use the resources of the Question of the week when the actual project will be over. Considering that the site started from zero without any experience from us in education, I hope the most important success of this project will be the fact that it will be used in the future.

The question of the week site right now works in this way. Each of the fellows posts a question before Monday morning. Each question has a specific question ID so it can be stored with the answers, and eventually reused by the other fellows. The students answer by logging on the site. They have to select school and teacher to find the proper question. The fellows log on the administration site and grade the answer for that week. This administration site is available to the teacher so every time they want they can look up and check the progress of the answers during the week. Multiple answers from a single student are treated each as independent. The teacher then can select what to do. Sometimes the same answer (with the same orthographic mistakes) is given by more people: we underline on the comments of the answers that the same answer has been given by some other student. Again, it is the teacher's responsibility to consider what to do.

Last year the teachers asked for a symbolic prize for the students who performed well in the QoW(question of the week). The teachers decided on the name of the prize and we provided some certificates. For the best student a gift certificate to spend at the Creamery at the Penn State main campus. This year a more sophisticated award system has been designed. The prizes include: a Penn State HEV labeled pencil, a T-shirt, and at the end of the year a ride in the PowerLion, an award winning HEV.

Sarah and Krishan's experiences with the Question of the Week

Initially Krishan and I were coming up with QoW based on what we thought the students would understand. The number of responses was very high initially and, as the year progressed, the numbers started decreasing. We were both not sure of the reason behind this, so we e-mailed the teachers for some input. It turns out that they had not yet covered the material we were addressing and the students found the problems too challenging. With input from the teachers on the lessons they were teaching, we could more appropriately gear our questions to what the students were learning. We were very happy to see the number of responses – and more importantly, the correct responses, again increase with our more suitable questions. This teacher feedback and continued teacher/fellow communications has been critical in the success of our question of the week program. We have also found, as we gear questions on a more personal level – such as distance between Penn State and Susquehanna, topics relating to the weather (snow storm), and current areas of interest to their age (we even had a question regarding a race between their science teacher and Harry Potter) we have many more responses. This may be because the students are actually interested in the question and talk about it to their friends. This kind of student input – the number of responses – is our best way to get feedback from the students as to the interest in the questions as well as the difficulty.

Undergrads and the creation of manipulatives

Penn State's NSF-sponsored HEV M3 program is a unique blend of graduate engineering research into the newest vehicle technologies, as well as graduate and undergraduate engineering student outreach to K-12 students and teachers. M3 stands for manipulatives, motivation and mentoring – the three approaches in the program to draw K-12 students of all ability levels to a better understanding of engineering design and research. With hybrid electric vehicle as the core theme of the project, it is very difficult to have large numbers of students at any grade level actually work on HEV engines, motors, controllers, fuel cells and the most advanced battery technology. Therefore, the manipulatives are selected or designed to demonstrate basic principles of HEV technology.

For the 2000-2001 school year, three M3 undergraduate fellows designed, prototyped, field tested and documented three HEV-related manipulatives:

Lemon Battery - http://www.personal.psu.edu/users/c/r/crv108/

Fuel Cell - http://www.personal.psu.edu/users/j/a/jab470/nsf1.htm
Lego Flywheel Car - http://www.personal.psu.edu/users/s/k/skw121/

The undergraduate fellows were given the following guidelines for their "kit" designs:

- Low or minimal cost per kit, with simple but effective learning
- Safety
- Exposure to the fundamental science, chemistry or mechanics of an HEV technology
- Curriculum and assembly instructions in easy-to-use format for teachers, as done in the NSF-supported *Teaching Science with Toys* books[1])
- Support for at least three Pennsylvania Department of Education Science and Technology Standards.

The Lemon Battery and the Fuel Cell Kit included an introduction to basic circuits, with use of a digital multimeter to measure voltage, currents, and resistances. All three kits were tested with a variety of users, including prospective women engineering students, middle school youth, and middle school teachers.

Quantitative as well as qualitative feedback was collected during these field trials to guide the redesign of each manipulative. Specific suggestions included:

Lemon Battery:

- Provide photos as well as line-graphics to show the series and parallel connection of the lemon battery "cells"
- Provide a concise explanation of the chemical reaction at the anode and cathode
- Tie the lemon battery concepts to existing lead-acid battery design and the newest HEV battery designs

Fuel Cell

- Good use of existing experiments with the fuel cell (from the manufacture's website), but add new experiments to address fuel cells in HEV cars…. and the current challenges.
- Provide clear guidelines in how and where to buy the chemical components for cell's hydrogen/oxygen reaction.

Lego-based Flywheel

- Open-ended design challenge for all users (students and teachers), with the instructors having trouble ending this activity!
- Allow ample time for the teams to build the initial "demo" flywheel car, then rebuild at least twice to optimize the flywheel interconnections and to have multiple "runoffs" between cars.

For the 2001-2002 school year, the undergraduate fellows will develop, field test and document two additional HEV-related manipulatives: solar car, and Lego-based gear ratio car. In addition, one undergraduate fellow will work with the M3 NSF webmaster to help develop the teacher resources web page (and hardcopy manual) to include the HEV manipulatives from this NSF program, as well as other HEV-related kits, and HEV websites. As in the first year of the program, student and teacher feedback will be critical to the design and use of the manipulatives for in-class learning.

Summer teacher workshops

Another component of the NSF HEV M3 project is a summer workshop for K-12 science teachers. The first workshop was offered at Penn State's University Park campus in August 2001. Feedback was collected from the teachers who participated in the 2001 workshop, as well as from teachers who elected not to participate. This feedback was used to revise the format and content of the workshop for the summer of 2002.

Of particular concern to Pennsylvania K-12 teachers are two recent acts of legislation: the continuing education requirements of Act 48[2], and Pennsylvania's Chapter 4 science standards[3]. Act 48 requires that all certified educators complete six college credits, six credits of continuing education courses, 180 clock hours of continuing professional education, or any combination of collegiate studies, continuing professional education courses or learning experiences equivalent to 180 hours every five years. Chapter 4 establishes specific standards and assessment for K-12 education; the science and technology standards have only recently been adopted [4].

The first summer teacher workshop was only open to the teachers from the school districts participating in the NSF HEV M3 Penn State project. Three teachers attended, two of whom decided to undertake the optional project offered in association with the workshop in order to obtain graduate credit for the course. The workshop was 3-days long for non-graduate credit participants and 4½-days long for those taking the graduate credit. Each day contained a combination of lecture, hands-on activities, and lab tours. The typical faculty lecture period was 1-hour long and covered technology topics related to the HEV platform (i.e., batteries, ultracapacitors, flywheels, advanced materials, fuel cells, solar panels, and power electronics.) The undergraduate students who developed hands-on manipulatives for batteries, flywheels, and fuel cells as part of the M3 project, presented the activities to the participating teachers. Graduate students provided tours of the laboratories and facilities associated with the HEV technologies. The highlight of the week was when the teachers were given the opportunity to drive a Honda Insight and a Toyota Prius at the Pennsylvania Transportation Institute's test track. The teachers left the workshop with a copy of each of the presentations given and a list of faculty resource people at Penn State, their area of expertise, and methods of contacting them.

Each of the three teachers attending the first workshop agreed that overall it was a positive experience. However, specific issues were raised concerning the time commitment and workshop content. Several teachers said that they would prefer a shorter time commitment (less than three or four days). In particular, they preferred not to stay overnight, regardless of workshop location. These issues were particularly acute for younger teachers who have young children at home.

Most of the teachers are concerned about the implementation of the new Pennsylvania state science standards. The current plan provides for assessments in grades 4, 7, 10, and 12. Some teachers expressed concerns about their basic science knowledge with respect to the standards, and specifically requested assistance in that area. Most would welcome any help that we could provide (both in the other NSF M3 project activities and in the summer teacher workshop) with respect to meeting the new standards.

Some of the teachers expressed a concern that the content of the some of the lectures was too advanced. Because these lectures exceeded their ability to fully understand the topic, they said it would be difficult for them to apply the information in their classrooms.

And finally, as noted earlier, all Pennsylvania K-12 teachers are required to accumulate continuing education credits. The workshop needs to satisfy the requirements of Act 48, and to provide Act 48 credits and/or hours.

In response to this feedback, significant changes were made to both the format and the content of the teacher workshop for summer 2002.

First, to increase participation, the workshop will be open to all Pennsylvania science teachers. A brochure is being prepared, and the workshop will be advertised in the quarterly newsletter of the Pennsylvania Science Teachers' Association and other appropriate media.

Second, the workshop format will be changed to a "smorgasbord" of six short (1- or ½-day) sessions, from which each teacher can choose those in which he or she is most interested. The six sessions will be available with some workshops repeated over a two-day period thus minimizing the need for overnight stays.

Third, the workshop locations and dates are being expanded. Two separate two-day workshops are planned, one at Penn State's University Park campus, and another at a location near Harrisburg, PA . The two workshops will be held approximately one week apart. All six sessions will be available at both locations. The availability of multiple dates and locations should make the workshop more accessible to teachers. This also serves to achieve the outreach goals of the NSF M3 project.

And finally, the workshop content will be revised significantly. Six sessions are planned. In all cases, the technical focus will be on hybrid electric vehicles (the subject of the NSF M3 project). Each session will address Chapter 4 standards and assessment, and Act 48 hours and/or credits will be available to the teachers for all sessions. The following six sessions are planned:

- **HEV "Road Show."** Several hybrid-electric vehicles from Penn State's fleet and from local automobile dealers will be available for inspection/rides/drives by workshop participants. It is anticipated that the following vehicles should be available: two FutureTruck SUV's (GM Suburban, Ford Explorer), a GM EV1, a Toyota Prius, and a Honda Insight. The accompanying discussion will cover fundamental aspects of HEV design, environmental benefits of HEV's, practical considerations, etc.

- **Junior Solar Sprint**. Junior Solar Sprint is a model solar-powered car competition for middle-school students[5]. Kits will be assembled and raced by workshop participants. The accompanying discussion will cover technical aspects of solar cells and electric motors, and how teachers can use the kit vehicle effectively in the classroom as a manipulative for teaching science.

- **Electric Go-Kart**. This is a larger-scale battery-powered electric vehicle capable of carrying one person[6]. A kit will be assembled and driven by workshop participants. The accompanying discussion will cover technical aspects of batteries, electric motors, and vehicle design, and how teachers can use vehicles of this kind effectively in the classroom for teaching science.

- **Fuel Cells/Batteries/Flywheels**. Fundamental operation of fuel cells, batteries and flywheels will be covered, including examples of applications. Manipulatives suitable for classroom instruction will be demonstrated and discussed.

- **Mapping Resources to Standards**. A general overview of available manipulatives and other resources available for K-12 science teachers will be given. The emphasis will be on mapping these resources to the Pennsylvania's Chapter 4 science standards.

- **General Science**. Aspects of general science will be covered for K-12 science teachers, to prepare the teachers for Pennsylvania's Chapter 4 science standards. The focus will be on weak spots in the attending teachers' backgrounds and understanding, which will be identified ahead of time by the participating teachers.

In addition to these six sessions, lunchtime keynote speakers will be invited to the workshop on each day. Prominent candidates are being contacted from the Pennsylvania Department of Education, and from the U.S. Department of Energy Argonne National Laboratory (organizers of the FutureTruck competition).

HEV web-based game

One deliverable of the NSF HEV M3 project is a world-wide-web-based Constructivist Learning Environment (CLE). The CLE is being designed to support different learners and encourage different learning styles. CLE components will support visual and auditory learners using Web-based tools, and tactile learners using manipulatives such as experimental system design, fabrication, and testing activities. The HEV game addresses the former.

A global specification for the CLE software has been written by Dr. Z. Rado of Penn State's Pennsylvania Transportation Institute (PTI). The software will be a WWW-based application of science- and technology-based information and knowledge management with a game-like learning interface that targets students in 6^{th}-8^{th} grades. The application will utilize the building of an HEV as a theme and structure for knowledge introduction and presentation, interactive learning cycles, tests and games, and examination of knowledge acquired. The application has to provide all the essential knowledge information required to complete the tasks in the game. The knowledge base will incorporate audio, video, animation, written and graphical knowledge elements. At the end of the learning curve, a test must be given in the form of an animated race of the student-built HEV against predefined computer models built by HEV experts. The application should also allow for expansion through simple input of new components and of additional science education materials.

To start the game, a new user must register. This is necessary to be able to store information regarding the game (money earned, questions answered, parts purchased, etc.). Registered users can log on and start the game. Users must make an initial selection among three different types of challenges: emissions, towing capability, or performance. The game is a scientific learning structure where the user is presented with challenges, questions, or problems to solve. Money is earned as the user answers the questions, completes tasks, etc. This money can be used to purchase components for a HEV (e.g., engine, drive train, batteries). Once the user has acquired all components necessary for the HEV, the user can test their design by running a vehicle performance simulation: a "race." A race score is calculated and stored, and performance relative to predefined HEV's and compared to other users who have played the game is shown (e.g., similar to the display of top-ten scores in a video arcade game). The user can then re-engage in money-earning games, trade components, purchase new components, etc. The number of times the performance of the HEV can be tested is unlimited.

The scope of the HEV game has been revised considerably from the ambitious design originally proposed. The changes have been made as the developers became more aware of the technical and practical complexities of developing such a game, of the nature of their middle-school-student audience, and of practical access issues (e.g., security). Even with these changes, the HEV game remains an ambitious undertaking.

Originally it was envisioned that Pennsylvania Transportation Institute (PTI) staff would design, develop, implement, and support the game with assistance from NSF M3 graduate fellows. It now is clear that specific professional expertise in web design and implementation is required for a project of this magnitude. Currently it is expected that basic design specification, some of the underlying database structure, and specific database information (e.g., HEV component specifications) will be provided by PTI personnel and the NSF M3 graduate fellows. The actual programming will be contracted out to professionals.

The scope of the game itself also has been toned down. A middle-school student is likely to lose interest if a mouse click or other user action does not elicit a system response within a few seconds. This limits the level of dynamic vehicle simulation that can be carried out interactively. Race results may need to be pre-computed and stored for every possible combination of components that might be selected by a student, for example. And only limited real-time animation of the specific configuration designed by the student may be presented.

Educational field trips to the HEV center at Penn State

One of the M3 project goals is to reach different learners and to encourage different learning styles (tactile, visual, and auditory). What better way to demonstrate the use of science, math, and technology in HEV's than to visit a working research lab, or better yet, several research facilities dealing with HEV technologies? During the first two years of the M3 project, the students from the participating classes in the Bellefonte Area Middle School, the Steelton-

Highspire High School, and the Susquehanna Township Middle School have had the opportunity to spend a day at the University Park campus doing just that.

The first series of educational field trips was conducted during the 2000/2001 academic year. Bellefonte students were the first to visit. Three half-day tour schedules were arranged for the 250 students in an attempt to match the school's lunch period and to accommodate the large number of students in smaller groups. The labs participating included the PTI's HEV Lab, PTI's Truck Driving Simulator, PTI's Test Track, the Diesel Combustion Lab, the Electrochemical Engine Center, and the Learning Factory. Once arriving at Penn State, the students were split into three groups of about 15. One Penn State affiliate and at least one teacher accompanied the student groups. Each of these three groups rotated through the different labs, and was to jointly tour the test track at the end. However, the groups were not able to maintain the time schedule and the test track tour was omitted.

The truck driving simulator experience seemed to be the favorite with the students. After all, as a 7th grade student, how often do you get to operate a full-size Mack truck? The other labs had mixed reviews from the teachers. The most repeated comment was that they didn't know if the experience was worth the time away from the classroom. We then asked the teachers how to improve the experience. One suggestion was to give a brief overview of the trip in the classroom. Another was to have a worksheet or handout for the students to complete. More time at each lab was also necessary—which translated into two options, reduce the number of labs they visit or increase the time each group spends at Penn State.

As a result of these suggestions, two major changes were made before the Susquehanna Township and Steelton-Highspire students visited. The first was the preparation of a PowerPoint presentation covering the activities of each of the labs the students would be visiting and a worksheet requiring the students to pull information from the slide show to fill in the blanks. The second change was to schedule longer periods of time at each lab and to have the Penn State affiliate keep the tour groups on schedule. One additional lab tour was provided in the materials lab. This tour provided demonstrations of how liquid hydrogen changes the properties of bananas, ping pong balls, balloons, etc. This lab proved to be the most popular tour for these groups considering the students were not able to actually operate the truck driving simulator due to conflicts with research projects.

The teachers with the second two tours were pleased with the overall content of the field trips. Additional suggestions included: (1) make the lab tours more interactive for the students, (2) allow more time in each lab, (3) provide more comfortable busing, and (4) allow time for bathroom breaks.

The second year's (2001/2002 academic year) educational field trips were once again modified as a result of teacher feedback, and were better received than those during the first year. The time at each lab was extended. This was made possible by extending the visit to a day-long trip rather than a ½-day trip. For the Harrisburg area schools this meant arrangements for a late bus to take the students home. The facilities toured included PTI's HEV Lab, PTI's Truck Driving Simulator, PTI's Test Track, the Diesel Combustion Lab, the Electrochemical Engine Center, and the Composites Manufacturing Technology Center—replacing the Learning Factory. The tour schedule also included specific times for bathroom breaks. An afternoon visit to the Penn State Creamery was added. Emphasis was placed on encouraging the graduate students to develop some type of hands-on activity in each laboratory.

In general, the teachers' comments regarding this year's educational field trip were very positive. One group of teachers that is not involved in the M3 project, but who must accompany some of the students on the field trip, provided negative feedback such as "How do I relate this to language arts?" or "What does this have to do with history?" The M3 team provided suggestions to tie the trip to those fields such as have the students write a paper on their experience here at Penn State or have the students investigate the history of the automobile. Comments from the teachers participating in the M3 project regarding the second year's trips included the observation that some labs did well with incorporating hands-on activities, while others didn't do as well; and rather than Dixie cups from the creamery the students should be allowed to purchase their choice of creamery delights.

Plans for the 2002 Educational Field Trip are now being developed. With the truck driving simulator and the materials lab activities rating the highest, it is obvious that the activities that engage the students are the most liked and most beneficial experiences. Therefore, plans for the upcoming 2002/2003 academic year include a concentrated effort to generate hands-on activities for each of the labs. If a lab is not prone to this type of interactive presentation, it will be removed from the tour list. In addition, more time will be allotted for bathroom breaks and the creamery stop to accommodate their interest in obtaining their choice of snack. An effort will be made to make connections between the field trip and the educational areas that aren't as directly connected to the HEV technology area (i.e., social studies, history, language arts, etc.).

The ultimate goal is for the schools to want to continue visiting Penn State as part of their yearly curriculum. In order for this to happen, Penn State must provide a tour that engages students and provides a real educational benefit. This can best be achieved by directly responding to teacher feedback.

Conclusion

Here we have the experiences of the fellows, faculty and administrators in using multiple, informal feedback loops to make "real time" corrections in a rather large project that involves over 500 students at three sites. The usefulness of this informal formative feedback activity is driven by the ability of the participants in the project to recognize that informal feedback is coming their way and to absorb the feedback into their own activity system without undue disturbances caused by ego issues. Openness and trust and the ability to establish long term relationships with students and teachers in the schools are crucial to the effectiveness of informal feedback in this project.

References

1. Taylor, B.A.P., Poth, J., Portman, D.J., *Teaching Physics with TOYS, Activities for Grades K-9.* Terrific Science Press, Miami University, Middletown, Ohio, 1995

2. *ACT 48 Professional Education Plan Guidelines*, The Pennsylvania Department of Education, Harrisburg, PA, April 2000 (Revised May 2001).

3. *Title 22, Part I, Chapter 4 of the Pennsylvania Code: Academic Standards and Assessment*, State Board of Education of Pennsylvania, Harrisburg, PA, 1999.
4. *Academic Standards for Science and Technology*, 22 PA Code, Ch. 4, App. B, The Pennsylvania Department of Education, Harrisburg, PA, July 12, 2001.
5. Northeast Sustainable Energy Association, Greenfield, MA. http://www.nesea.org
6. Kango LLC, Macon, GA. http://www.kangoev.com

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