The development of an artificial intelligence based system for scoring biology essays
(RFA Goal 2 – Development)

Significance

Science is an ever-expanding field, so science educators are faced with a particularly
difficult challenge of how to teach large amounts of information in a way in which students
develop deep understanding of the material. Typically, science classrooms utilize passive
learning techniques that do not allow students to integrate their knowledge into a coherent
understanding. Also, learning is assessed using objective tests that tend to support rote versus
meaningful learning, and the form of assessment used inevitably shapes students’ perceptions
of their learning goals during instruction (Fisher, 2000). Rather than continue with this
incremental approach, Bereiter and Scardamalia (1987) argue that writing can lead to
knowledge transformation. A strategy referred to as writing-to-learn may provide a shift in
learning science that is right for this moment in time (Connally, 1989; Hand & Prain, 2002).
During the late 1960s, research on the intersection of language and learning in the
content areas began in the United Kingdom after Britton and colleagues determined that
speech and language play a major role in learning (Keys, 1999). Ordinary speech is the
natural starting place for writing. Young writers’ works, as well as the first drafts of
experienced writers, are considered expressive because they resemble everyday
conversational language. Expressive writing is informal, but still accomplishes the task of
conveying and reflecting on information so that “…the writer may concentrate on making
connections with prior knowledge, clarifying understanding, and otherwise explaining the
matter to oneself” (Britton, 1975). Writing is considered to be a powerful way to associate
concepts with language.

By the late 1970s and 1980s, Britton’s work was absorbed into the Writing Across the
Curriculum (WAC) movement in the United States, especially at the college level (Keys,
1999). Some science and mathematics professors began incorporating writing into their
classrooms to improve content learning. Following this lead, in the mid-1980s, some high
school science educators adopted writing-to-learn strategies for deepening understanding of
science content.

Currently for many pragmatic reasons, typical high school science classes favor quantity
of information over quality (Ferrarro, 2001). Students are taught large amounts of information
but seldom are asked to apply this knowledge or even to fully understand the lessons. The
National Assessment of Education Progress (NAEP) reports that science instruction in the
United States is predominately accomplished by teacher lecturing (Rivard & Straw, 2000).
This passive reception approach to teaching and learning science tends to hinder students
from taking the rudimentary fundamental ideas and organizing them into personally coherent
and well-structured thoughts, a process which can be accomplished through writing. Tishman
not so natural to oral exchanges.” Rivard and Straw (2000) found that analytical writing also
has the potential to increase the retention of science knowledge by students over time. Britton
refers to this as shifting from "spectator" to "participant". The information “sticks” and even
more critical, students can more easily communicate their content knowledge.

The benefits of writing-to-learn may seem like common sense. “Although this idea is
widely accepted, what is common sense is not always common practice.” (DeLorenzo, 1999)
Science educators are hindered by the amount of time that it takes to implement writing-to-
learn strategies in the classroom, including the time-consuming task of reading an abundance of written assignments over the course of the semester.

Implementation of writing-to-learn strategies in science classrooms may take time, but there are frameworks in place to guide educators throughout the process. Between 2000 and 2003, the Reading and Writing About Science (RWS) Project was conducted with support from the National Science Foundation (Miller & Calfee, 2004). The goal of the project was to teach science educators the skills to integrate literacy through implementing reading and writing activities, which would allow students to communicate their thinking and understanding of specific content areas. The framework that is used to change the way educators approached science writing is called the CORE Model of Instruction. The CORE Model incorporates four elements that can be used to design a sequence of instructional writing activities: Connect, Organize, Reflect, and Extend (Miller & Calfee, 2004). By connecting what they already know, organizing multiple sources, reflecting through discussion, and extending the learning after the completion of the project, students’ writing scores and overall understanding of complex science content increased. This is just one method to aid science educators in the task of implementing writing-to-learn strategies in their classrooms that we will incorporate into this project.

Writing in science classrooms also reveals the degree of students’ understanding or perception of the topic, which allows the instructor to more accurately gauge how well the students are able to understand and apply concepts (Berglund & Pakaluk, 2000; Stokstad, 2001). Miller and Calfee (2004) encourage science writing because it benefits the students and the educator. “Through writing, the words and the concepts become truly theirs.” (Yockey, 2001). Students are able to self-assess complex science content and teachers can assess the students on two dimensions, their overall writing ability and their understanding of specific content areas.

In certain situations science writing can serve a heuristic function, meaning that learning takes place through discoveries that result from investigations made by the students (Rivard & Straw, 2000). The situations include (1) when the content is new to students, (2) when the writing task is specifically tailored to the outcome, for instance the teaching of facts and relationships, and (3) when students interpret the task appropriately and respond accordingly. Analytical tasks such as explaining real-world applications of scientific concepts demand that learners connect these into an integrated web of meaning (Rivard & Straw, 2000). Thus, the success of writing-to-learn strategies is in the hands of the classroom science teachers. If they provide appropriate writing tasks and explain the objectives of the task clearly, writing-to-learn can significantly increase the amount of knowledge that students obtain and their ability to apply the knowledge in future classes. Thus, providing science teachers with effective strategies and writing prompts in a convenient handbook are a critical part of this project.

The shift from a passive classroom environment to an active classroom environment, through the implementation of writing-to-learn strategies gives science students the opportunity to develop a personal understanding of difficult science material. An important value-added benefit is that students become more interested in the subject matter AND improve their written communication skills that will serve them well in college and their future workplace.

Knowing the research guided principles for using writing-to-learn strategies in science classrooms is critical but insufficient for making it actually happen in the classroom. Writing software that models and supports these strategies and that makes writing-to-learn easier and
transparent for BOTH students and teachers can serve as a catalyst that will encourage more science teachers to use writing in their classrooms.

Essays are a well-established assessment format well-suited to measuring knowledge integration and conceptual understanding (Fisher, 2000), which are important aspects of meaningful learning of science content. Software that automatically and immediately scores the content of pupils’ essays and provides content specific feedback is an emerging tool for classroom instruction and for assessment in education. Several for-profit companies, including the Educational Testing Service, Pearson, and Vantage Learning, license their branded essay writing products to schools. Although these companies have published numerous reports of success, there has not been a rigorous external evaluation of the learning effectiveness of these products. In addition, for-profit companies focus their products where the return is greatest, in this case, in high-stakes assessment. As a result, these companies have not specifically adapted their essay writing products for high school science instruction.

This 3-year project will support the development of an intervention in high school biology that is an extension of the Vantage Learning web-based writing product called MY Access! software. This software was selected because it supports proven writing-to-learn strategies. Features of the software include: anyplace/anytime online access, easy-to-use interface, writing support tools including a dictionary and thesaurus, longitudinal file archiving and portfolio, teacher report engine, peer-review, and artificial-intelligence essay scoring with individualized immediate feedback. At the end of Year 3, the fully developed project deliverables will consist of (1) the online artificial intelligence software product available form Vantage Learning trained to score 12 unique AP biology essays, (2) a teacher handbook containing research-based writing strategies, essay writing prompts with sample essays and tailored scoring rubrics, and classroom implementation guidelines (available online at no cost in PDF format), and (3) published reports of the results of the project investigations available both online and in peer-reviewed journals.

Research Narrative

Sample

This 3-year project will be conducted in two high schools, one suburban and one urban. The suburban high school is located in a seven-township school district in rural eastern Pennsylvania that is changing from farming to a rural suburban community. Participants will be those students enrolled in the honors biology course for each of three years (300 students per year). These 15- to 18-year olds are mainly middle-class white students (2% minority), with 15.8% who are economically disadvantaged. The urban high school is located in Philadelphia. Participants will be those students enrolled in biology, and are 15- to 18-year olds who are mainly from low-income families (41.5% who are economically disadvantaged) comprised of about 37% white, 32% African-American, 24% Asian, and 7% Latino. Longitudinal participation of the participants in the experimental intervention portion of the study is acceptable since the actual intervention lasts only 3 weeks on two occasions in Year 3. Regarding year-long mortality, the sample size is adequate for establishing the criterion-related validity of the use of MY Access! software.

This project utilizes honors students in Years 1 and 2 because training the artificial intelligence component of the software requires at least 500 quality essays. These students are comparable to the 121,000 students who took the College Board AP Biology examination in 2005. On the essay portion of that examination, only 61.2% produced good essays (i.e.,
scored 3, 4, or 5 on a 1–low to 5–high scale). In Year 3, the addition of an urban student population provides a broader cross-section of participants that allows for greater generalizability of the findings of the project.

**Design**

*Years 1 and 2* – The artificial intelligence component of the *MY Access!* software requires 500 or more human-scored essays per writing prompt to train the system to score that prompt, thus Years 1 and 2 will be used to develop the software. The school year consists of four 9-week periods, and students will write three different essays each 9-week period (12 different essays during the year). Untrained *MY Access!* software is able to score style and grammar and provides support tools including a graphic organizer, dictionary, and thesaurus as well as teacher support features. Students will use untrained *MY Access!* software in Years 1 and 2 to write twelve different 300 to 500-word biology essays online as part of their regular classroom instruction. The 7,200 essays from Years 1 and 2 (e.g., 600 essays x 12 writing prompts) will be used to train the artificial intelligence component of the *MY Access!* software. Biology education graduate assistants will score these essays in a timely fashion and the scores will be used by the teachers for their normal purposes.

During both Years 1 and 2, end-of-year science achievement scores of the students in this course who have used *MY Access!* during the year will be compared with district scores for the same course from previous years. We recognize that this data does not provide causal evidence of the impact of the untrained *MY Access!* writing on student learning outcomes. However, this preliminary data would permit a reasonable evaluation of whether or not the intervention has sufficient potential to merit further investment. (CFD 84.305, p.11). Also, process observation of and interactions with teachers and students will occur throughout all three years. Observations, survey, and interview data will be collected to help explain why things happened as they did.

*Year 3* – In Year 3, the full capability of trained *MY Access!* software will be examined on two separate occasions using a posttest only design with full random assignment in two different high schools, one suburban and one urban. In both schools, at the end of the 2nd 9-week period, and then again at the end of the 3rd 9-week period, all students (N = 300 in each school) will be randomly assigned to one of three treatments (about 100 participants per intervention). The three instructional treatments are: *MY Access!* (trained), *MY Access!* (untrained), and control (using a familiar word processing program). The following research questions will be addressed:

1. **Do participants in the MY Access! (untrained) group outperform the control group on the essay posttest measure (see Measures below)?** This question considers only the efficacy of the support features of *MY ACCESS!* software, such as the peer-review, graphic organizer, thesaurus, dictionary, grammar, and spell check tools, including the human-computer interface and file organization features that allows for ease and transparency of use. The results of this question will complement the findings from Years 1 and 2 above for end-of-year performance effects. The data will be analyzed separately for the urban and the suburban schools.

2. **Do participants in the MY Access! (trained) group outperform the MY Access! (untrained) group and the control group on the essay posttest measure?** This question considers the efficacy of the artificial-intelligence scoring engine relative to the untrained software and to the control. This is an important practical question. Findings will address whether the
benefits of the trained *MY Access!* system is worth the cost required to train the system. If yes, then trained prompts should be developed for other courses such as ecology, physiology and even chemistry, physics, and mathematics. If both the trained and untrained versions are equivalent and better than the control, then the untrained *MY ACCESS!* software “as is” can be reasonably recommended for science courses. If there is no difference between the control and the two interventions, then cost and ease of use become the primary decision factors for science educators. The data will be analyzed separately for the urban and the suburban schools.

3. **Does the instructional effects of writing lesson essays under each of the three interventions transfer to gains in either/or both specific and generalized knowledge as measured by traditional measures of biology content knowledge?** This question considers the affect of writing-to-learn on both specific and general transfer of science content knowledge. The data will be analyzed separately for the urban and the suburban schools.

A sample size of 100 students per treatment should be adequate to reveal any practically significant effects of the interventions and repeating the experiment on the second occasion will increase confidence in the results that are observed.

Following Gay and Airasian (2003), there are a number of threats to internal and external validity in this investigation. Because of the relatively short duration of the experimental treatment occasions (i.e., about 3 to 4 weeks of instruction and then the posttest), the threats to internal validity due to history, maturation, and mortality should be small. Regarding threats due to pre-testing and instrumentation, great care will be used to develop the posttest essay question relative to the lesson essay question, though potential limitations to generalizability will be described in the final report. Because of full random assignment to treatment, statistical regression to the mean should be equivalent in all groups and so not a factor. In addition, a composite score for past essay performance will be used as a covariate to provide a control for both writing ability and general content knowledge. Neither pretest-treatment interaction nor selection-treatment interaction are threats to external validity in this design. Reactive effects should also be minimal, since students have been writing biology essays online for instructional purposes for more than half of the school year.

However, because the experiment is repeated on a second occasion 9 weeks later, there may be multiple treatment interference. The results from the second occasion will be compared to those of the first occasion in order to determine whether the prior treatment affected or interacted with the later treatment, if observed, the limits to the generalizability of the results will be described in the final report. We will minimize possible experimenter effects though preparation and training of the teachers involved, and will monitor these through observations by the evaluation team (Project Director, CO-PI, and graduate assistants) during the intervention. Treatment diffusion may be the greatest threat to external validity, since all classrooms will experience all three treatments at the same time, and it is inevitable that students will talk to other students about their treatment experience. Our intent is that the students will be fully informed participants who, through classroom discussions, understand the experimental requirements and are willing participants in this scientific endeavor. Nevertheless, the evaluation team will observe student interaction and use of their treatment intervention in order to describe possible treatment diffusion effects.
Measures

Posttest measures include a posttest essay scored by human-readers and the traditional end-of-unit examination (e.g., multiple-choice, matching, and fill-in-the-blank questions). The posttest essay cannot be identical to the lesson essay, but should address the same general content. For example, based on a 2005 AP question, we could ask during instruction for the students to write an essay that explains how the immune system responds to a later exposure to the same infectious agent and then on the posttest, to write an essay that explains how the immune system provides an immediate nonspecific immune response. Thus, a lesson and a posttest writing prompt can address the same science concept, but with a different focus.

The validity and reliability of the human-reader essay scores are of critical importance in this investigation. The content validity of the writing prompts will be established by utilizing adaptations of past AP Biology questions by the subject matter expert teachers in this investigation. Two human readers, who are biology content matter expert graduate assistants, will be trained in the scoring rubric used by Vantage Learning and will score all essays. For each set of 300 essays, the inter-rater reliability of the scores will be examined, and when the 2 readers differ by more than 1 point (on a 1 to 6 point scale), those essays will be scored by a third reader. In addition, Vantage Learning will use their in-house essay scoring team to spot check each batch of essays as these are produced in order to determine the quality of the scoring and to advise the team on possible areas of improvement. In Years 1 and 2, the two posttest essay writing prompts that will be used in Year 3 will be pilot tested, and based on the human-reader essay score data, will be modified if necessary to obtain the best possible posttest essays for Year 3. The actual reliability of the Year 3 essay posttest scores will be reported as Cronbach alpha, and this information will inform the discussion section of the final report.

The two traditional end-of-unit examination scores will be separated into two sub-sections. One sub-section will measure performance on those questions that directly align with the lesson essay content, while the second sub-section will measure performance on the remaining questions that do not directly align with the lesson essay content. The two traditional examinations (the first given at the end of the 2nd 9-week period and the second at the end of the 3rd 9-week period) will be field trialed in both Years 1 and 2 in order to improve the validity and reliability of these two tests for the experimental study in Year 3. Specifically, in Years 1 and 2, the items on both tests will be reviewed together by the full team (teachers and evaluators) in order to reach consensus on a set of common test questions that will be used in all classrooms on both occasions. Item analysis will be conducted in both years and poor performing items will be examined and modified or discarded.

In addition, in Year 3, the criterion-related validity of the trained MY Access! software essay scores will be determined using correlation with the human-reader scores across the entire year. In total, there will be 12 writing prompts that will be used to generate 300 essays per prompt at each school. Thus there will be 24 separate and unique direct measures of the criterion-related validity of the MY Access! essay scores, each based on 300 essays scored by multiple human readers.

Further, the Pennsylvania state-wide science assessment should be available beginning in Year 2. As a new test, the test metrics will not be fully established. Thus, in Year 3, correlations between the 12 MY Access! scores, the 12 human reader scores, and the Pennsylvania state-wide science assessment scores will be reported and discussed in order to further examine the criterion-related validity of all of these measures relative to the human-
reader baseline scores. Also, for that subset of students who take the actual College Board AP biology examination, their scores will be correlated with their 12 *MY Access!* scores, human-reader scores, and Pennsylvania state-wide science assessment scores in order to further examine the criterion-related validity of all of these measures relative to the AP Biology examination baseline scores.

**Process Data**

In order to refine the intervention and provide insight into why it does or does not work, and whether it was or was not well implemented, we will collect observational, survey, and interview data as a complement to our quantitative data. We are especially interested in describing the factors that may explain the effectiveness or ineffectiveness of the *MY Access!* software and in identifying those conditions that support or hinder use of the software. The process instruments, interview questions, and approaches will be developed and piloted in Year 1 and then based on these experiences and data, further developed, field trialed, and validated in Year 2. In both Years 1 and 2, the results of the process data will be used to enrich and complement the analysis of the end-of-year achievement data, and all of this information will be used to inform Year 3 data collection activities. These validated survey instruments, interview questions, and approaches will be implemented during Year 3, especially focusing on differences that may be due to the three interventions during the end of the 2nd 9-week period and the 3rd 9-week period.

To address how *MY Access!* software affects the instructional process, we will survey students in the intervention and control groups regarding their perception and use of each tool, and will also interview a sample of these students to confirm and enrich the survey data. We will also interview the teachers to determine their perceptions of the effects of the software, both good and bad, on the instructional process, and on teacher archiving and reporting functions (i.e., does *MY Access!* make it easier to record report card grades).

**Data Analysis**

Data analysis for both the first and second occasion will be identical but separate. Human-reader essay score posttest data will be analyzed by a 1-between analysis of variance (ANOVA). The factor, intervention, has three levels: *MY Access!* (trained), *MY Access!* (untrained), and control (using a familiar word processing program to write the lesson essay). Scheffe’ test will be used to follow-up significant results. The hypothesis-wise error rate will be $p < .05$. A significant difference between the *MY Access!* (untrained) group and the control group would support research question 1, while a significant difference between *MY Access!* (trained) and the *MY Access!* (untrained) would support research question 2.

Traditional posttest score data will be analyzed by a 1-between, 1-within analysis of variance (ANOVA). As above, the factor, intervention, has three levels: *MY Access!* (trained), *MY Access!* (untrained), and control (using a familiar word processing program to write the lesson essay). The within factor, posttest sub-topic score, has two levels, sub-topic score that aligns with the lesson essay content and sub-topic score that does not align with the essay content. Scheffe’ test will be used to follow-up all significant results. The hypothesis-wise error rate will be $p < .05$. This analysis would address possible aspects of research question 3.
Table of activities for each year.

### Year 1 (2006-2007)

<table>
<thead>
<tr>
<th>Period</th>
<th>Activities</th>
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<tbody>
<tr>
<td>July 1 - Aug 15</td>
<td>Planning, select GAs, write portions of teacher Handbook, initial teacher training, set first 3 lesson writing prompts (LP1-LP3)</td>
</tr>
<tr>
<td>1st 9-week period</td>
<td>Implement LP1-LP3 and collect process data, Teachers &amp; Team set next 3 lesson writing prompts (LP4-LP6), set 1st parallel posttest writing prompt, PP6, and traditional posttest TP6</td>
</tr>
<tr>
<td>2nd 9-week period</td>
<td>Implement LP4-LP6 and collect process data, Teachers &amp; Team set next 3 lesson writing prompts (LP7-LP9), set 2nd posttest writing prompt, PP9, and traditional posttest TP9</td>
</tr>
<tr>
<td>3rd 9-week period</td>
<td>Implement LP7-LP9 and collect process data, Teachers &amp; Team set final 3 lesson writing prompts (LP10-LP12)</td>
</tr>
<tr>
<td>4th 9-week period</td>
<td>Implement LP10-LP12 and collect process data, end-of-1st-year data collection, Teachers &amp; Team debriefing</td>
</tr>
<tr>
<td>May 15–June 30</td>
<td>First draft of teacher handbook completed, Data analysis, write for publication, complete and submit 1st year report to IES</td>
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### Year 2 (2007-2008)

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<th>Period</th>
<th>Activities</th>
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<tbody>
<tr>
<td>July 1 - Aug 15</td>
<td>Planning, new teacher training as needed, review LP1-LP3, recruit an urban school for Year 3</td>
</tr>
<tr>
<td>1st 9-week period</td>
<td>Implement LP1-LP3 and collect process data, conduct item analysis on TP6, Teachers &amp; Team review LP4-LP6, PP6, and TP6; rewrite PP6 and TP6 as needed</td>
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<tr>
<td>2nd 9-week period</td>
<td>Implement LP4-LP6 and collect process data, conduct item analysis on TP9, Teachers &amp; Team review LP7-LP9, PP9, and TP9; rewrite PP9 and TP9 as needed</td>
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<tr>
<td>3rd 9-week period</td>
<td>Implement LP7-LP9 and collect process data, Teachers &amp; Team review LP10-LP12</td>
</tr>
<tr>
<td>4th 9-week period</td>
<td>Implement LP10-LP12 and collect process data, End-of-2nd-year data collection, Teachers &amp; Team debriefing</td>
</tr>
<tr>
<td>May 15–June 30</td>
<td>Complete final version of teacher handbook, data analysis, write for publication, complete and submit 2nd year report to IES</td>
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### Year 3 (2008-2009)

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<th>Period</th>
<th>Activities</th>
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<tr>
<td>July 1 - Aug 15</td>
<td>Planning, new teacher training as needed including urban school teachers, review LP1-LP3</td>
</tr>
<tr>
<td>1st 9-week period</td>
<td>Implement LP1-LP3 and collect process data, conduct item analysis on TP6, Teachers &amp; Team review LP4-LP6, PP6, and TP6; rewrite PP6 and TP6 as needed to prepare for the experimental intervention</td>
</tr>
<tr>
<td>2nd 9-week period</td>
<td>Implement LP4-LP6 and collect process data, conduct item analysis on TP9, Teachers &amp; Team review LP7-LP9, PP9, and TP9, rewrite PP9 and TP9 as needed. <em>Conduct the 3-treatment experiment at both schools using LP6 in the lesson and PP6 and TP6 as posttests.</em></td>
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<tr>
<td>3rd 9-week period</td>
<td>Implement LP7-LP9 and collect process data, Teachers &amp; Team review LP10-LP12. <em>Conduct the 3-treatment experiment at both schools using</em></td>
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LP9 in the lesson and PP9 and TP9 as posttests.

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<tr>
<th>4&lt;sup&gt;th&lt;/sup&gt; 9-week period</th>
<th>Implement LP10-LP12 and collect process data, end-of-3&lt;sup&gt;rd&lt;/sup&gt;-year data collection, Teachers &amp; Team debriefing and closure party</th>
</tr>
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<tr>
<td>May 15–June 30</td>
<td>Data analysis, write for publication, complete and submit final report to IES</td>
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*Team – consists of school district liaisons, PI, Co-PI, and GAs.*

**Personnel and Resources**

The **Project Director/Principal Investigator** (PI) has substantial corporate project management experience that demonstrates his capability to manage the project, organize the work, and meet deadlines. For example, the PI was Manager of the Quality Systems Group and also was the Training Program Manager of the 850-person Quality Assurance Division at EG&G Rocky Flats Nuclear weapons facility in Golden, CO, the prime Contractor for the Department of Energy (1990-1991). In 1991-1993, he was an Education Consultant for WICAT Systems, working in 49 schools in Utah, Wyoming, and Colorado developing and implementing multi-year learning improvement plans. While working for Jostens Learning from 1993 to 1996 (now Compass Learning), he was Director of a 15-month long evaluation project conducted in schools in England and Scotland. After returning to the United States (1996-1997) he was Director and lead developer of award-winning web-based curriculum alignment software called **VITAL Tools**, a neural network data mining search engine combined with a lesson planner. He managed all aspects of this $3m software development project. Currently, the PI is a tenured associate professor in instructional systems design at Penn State University. In addition, the PI has a graduate degree in biology and taught biology for 3 years at the high school level, and has conducted (and published in peer-reviewed journals) over 40 experimental studies concerning science, math, and/or technology.

The **Co-Principal Investigator** (Co-PI) has extensive science education grant experience. In the past, she has participated in projects funded by Howard Hughes Medical Institute, the Environmental Protection Agency, and the National Science Foundation, serving varied roles including project manager, co-principal investigator, and research advisor. Presently, the Co-PI is serving as a research advisor to two different NSF projects; one at Queens College, CUNY and the other at the Franklin Institute in Philadelphia. Both projects address equity issues in science education, particularly the shortages of women in science. She also possesses a strong background in the biological sciences, having taught life and environmental science topics in both formal and informal settings with audiences ranging from Pre-K through graduate level.

**Owen J Roberts High School** has an extensive array of networked computer technology with high-speed access to the internet and a full complement of the biology laboratory equipment required for honors biology. Students participating in this study will have ready access to one of the three computer labs for writing their lesson essays.

**The Philadelphia urban high school** will likely be Central High School. The district is interested in participating, and the specific school will be recruited in Year 2 for participation in Year 3. The school selected will be required to have computer and internet resources that are adequate for the purposes of this project.

**The Pennsylvania State University School of Graduate Professional Studies** at Great Valley (about 30 miles west of Philadelphia and half way between the two participating
school districts) will provide office space and resources for the PI and Co-PI and for the graduate assistants enrolled there who will be involved in the project.
Reference List


Yockey, J.A. (2001). A key to science: A simple writing technique helps students to communicate the important science concepts they have learned. Science and Children, 38 (7), 35-41.
Curriculum Vita

Roy B. Clariana (PI and Project Director)
Email: rbc4@psu.edu

SUMMARY
Currently, Dr. Clariana is an Associate Professor of Education in the Instructional Systems program at Penn State University and is coordinator of the Leadership in Technology Integration masters degree emphasis that serves about 100 practicing K-12 teachers in eastern Pennsylvania. He teaches graduate courses in Project Management, Evaluating Learning Outcomes (i.e., using surveys, interviews, observations, traditional posttests, and non-traditional approaches), Integrating Technology in Schools, Instructional Design, and Designing Web-based Instruction. Dr. Clariana has been a faculty member at Penn State for 8 years. He has published over 40 experimental investigations, served as chair on 2 dissertations, and recently completed a Fulbright award at the University of Oulu, Finland. He also serves on the Editorial Review Board for the British Journal of Educational Technology and for the Research Section of Educational Technology Research and Development, and is a Consulting Editor for the Development Section of Educational Technology Research and Development. Also, he is a highly proficient data analyst, using multiple analytic and database software packages including SPSS and knowledge representation software such as Pathfinder networks and multidimensional scaling, and has written two analytical software packages, ALA-Mapper and ALA-Reader.

Before coming to Penn State, Dr. Clariana taught for 9 years in K-12 education, both elementary (5 years) and secondary (4 years) and then worked in the private sector for 10 years in training design, project management and evaluation. Dr. Clariana has extensive experience with multi-site evaluations of software and technology use with K-12 and adult populations, and the development of national survey instruments such as the Distance Learning Profile Instrument.

EDUCATION
- Memphis State University, College of Education, Doctor of Education degree in Instructional Design and Technology with a minor in Science Education, 1990
- University of Central Arkansas, Masters of Science in Biology Education, 1979
- University of Central Arkansas, Bachelors of Science in Biology, 1975

EMPLOYMENT CHRONOLOGY
1997– … Penn State University, College of Education, Associate Professor
1993–1997 Jostens Learning Corporation, San Diego, CA, Project Manager in New Business Development, Project Manager in International Operations (United Kingdom), and Curriculum and Instruction Specialist for National Sales Program
Manager for the Nuclear Resumption Team, and Principal Evaluation Specialist in the Performance-based Training Division

1988 US Peace Corps (Asia Region), Executive Program Assistant in Katmandu, Nepal

1985-1990 Memphis State University, Graduate Assistant (both teaching and research).

1986-1990 St. Anne School, Memphis, TN, School Technology Coordinator

1982-1985 Peace Corps (Africa region), Training Director in Malawi, Assistant Training Director in Kenya, and Technical Trainer in Kenya


1977-1979 University of Central Arkansas, Graduate Assistant

1976-1977 Marvell High School, Marvell, AR, Teacher (math, coach)

RELEVANT PROFESSIONAL EXPERIENCE

Evaluation Consultant, the Council on Addictive Diseases (COAD), West Chester, PA, provided program evaluation services (about 6 consulting days) for a grant pilot to evaluate the impact of a theater drama project on participants and their audience.

Acting Coordinator, Leadership in Technology Integration (LITI) masters degree program, Penn State Great Valley, Malvern, PA, determined the need for teacher technology leadership skills and then worked with the Penn State Instructional Systems program to develop a new program emphasis (LITI) to address this need. He has served for 3 years as acting coordinator of this program.

Project Developer and Lead, Technology Education and Constructivism Hand-in-Hand (TEACHH), Owen J Roberts (OJR) School District, Pottstown, PA, worked with the OJR School District to establish a technology integration certificate delivered by Penn State University to Owen J Roberts teachers onsite and then managed this project during its inception, including course and instructor assessment and quality assurance.

Assessment Software, recently developed two software tools for automatically scoring concept maps (ALA-Mapper) and essays (ALA-Reader) that are available at no charge to researchers and educators.

Project Manager (UK), Jostens Learning Corporation, San Diego, CA, managed the implementation of a 15-month long technology integration and software evaluation project in schools in the United Kingdom under the auspices of the British Educational Communications and Technology Agency (Becta). The traditional schools involved included: Park Junior in Kettering Cedars School in Leicesteir, Montagu High School, Leasowes High School in Dudley, Blantyre High School, Blantyre. The nontraditional schools (Open School) included: Merrydale and Beachaump in Leicesteir, Dartford Hospital School in Dartford, Manamede Tutorial Centre in Plymouth, and Lewisham Tuition Centre in Lewisham.

Education Consultant, WICAT Systems, Orem, UT, worked in numerous schools and school districts establishing and implementing school-wide School Learning Improvement Plans (LIPs) for reading and/or mathematics. Working with the school’s curriculum staff and lead teachers, he developed yearlong action plans, conducted workshops, and then collected,
analyzed, and reported pretest and posttest improvement measures (usually standardized tests or state-wide tests and also teacher questionnaires and interviews). Dr. Clariana has developed and implemented LIPs in the following schools: Henderson Elementary, North Elementary, Northeast Elementary, South Elementary, Southeast Elementary, and Brighton Alternative High School in the Brighton School District 27J, Brighton, Colorado; Skyview High School in the Mapleton School District 1, Thornton, Colorado; Alsup Elementary and Kemp Elementary in the Adams County School District 14, Commerce City, Colorado; James H. Risley Middle School in the Pueblo School District 60, Pueblo, Colorado; Pine Valley Elementary at the Air Force Academy, Colorado Springs, Colorado; Sergeant Elementary in the Sargent School District, Monte Vista, Colorado; Delta Montrose Vocational Center, Delta, Colorado; Park Elementary in the Durango School District 9-R, Durango, Colorado; Book Cliff Elementary, Castledale Elementary, Cleveland Elementary, Cottenwood Elementary, Ferron Elementary, and Huntington Elementary in the Emory School District, multiple towns, Utah; and Park Elementary and Pineview Elementary in Casper Wyoming. In addition, worked with 15 schools in the Denver Public School system in their Title 1 math program. Each school supported about 40 students per year. Dr. Clariana worked closely (10 days per school per year, 150 total days) with these teachers in their own pullout classrooms to integrate technology into their math instruction. He also supported teachers in collecting math performance data monthly and assisted the project director in collecting, interpreting, and reporting the end-of-year achievement results. Dr. Clariana supported the following schools: Amesse Elementary School, Barnum Elementary School, Barrett Elementary, Bryant Webster Elementary, Castro Elementary, Cory Elementary, Eagleton Elementary, Ebert Elementary, Harrington Elementary, Mitchell Elementary, Munroe Elementary, Remington Elementary, Steele Elementary, Valdez Elementary, and Valverde Elementary.

Training Program Manager of the Quality Assurance Division, EG&G Incorporated, Golden, CO, manager of the training and continuing qualification group that served the 850-person Quality Assurance Division. Dr. Clariana and his team were responsible for all aspects of initial and continuing qualification requirements for all personnel in every job classification in the Division. To address a new policy requirement, Dr. Clariana developed and implemented a project to establish the Quality Assurance Division’s qualification procedures and processes. In this high-risk environment, qualification is a yearly rigorous process that involves ongoing training and professional development as well as passing paper-based tests and field observation tests. His team also trained the Division line trainers in developing and delivering these tests.

Training Analysis Manager for the Nuclear Resumption Team, EG&G Incorporated, Golden, CO, responsible for the plant-wide testing of fundamental knowledge related to nuclear resumption. In this capacity, he managed teams that conducted job and task analysis to define fundamental knowledge, and then developed and validated qualification tests of fundamental knowledge for 12 critical resumption job categories impacting about 1,000 employees across numerous Divisions, both Union and nonunion, and then implemented the testing and reporting of the test results to upper management and to the Department of Energy.

Principal Evaluation Specialist in the Performance-based Training Division, EG&G Incorporated, Golden, CO, developed and delivered training programs (both 2-day and 5-day
version) for trainers plant-wide on how to test personnel in job-related knowledge and skills. These tests are used to meet the employees’ yearly re-qualification requirements.

SELECTED PUBLICATIONS (Test related experimental research)

CURRENT AND PENDING GRANTS
Roy Clariana as Co-PI (at 3% effort), Kyle Peck (PI) submitted a $29m grant proposal to the U.S. Department of Education to host the Regional Educational lab at Penn State, with Rutgers, Caliber Associates, and The Metiri Group as partners.
Kathleen Fadigan (Co-PI)
Email: kxf24@psu.edu

EDUCATION
- Temple University, Philadelphia, PA, Doctor of Education degree in Curriculum, Instruction and Technology in Education program with a concentration in science/math education, May 2003.
- Temple University, Philadelphia, PA, Bachelor of Science degree in Biology, May 1993.

PROFESSIONAL EXPERIENCE
Pennsylvania State University, University Park, PA (8/05–present). Assistant Professor–Science Education, teaching undergraduate and graduate level science education courses at the Abington and Great Valley campuses, assisting in the development of the secondary science certification program at Abington, advising students at both locations, conducting scholarly research, and interacting with the local school districts in order to better serve the regional educational community.

Queens College, CUNY, New York, NY (1/04–present). Senior Research Associate in the Equity Studies Research Center conducting research and consulting for the $1 million NSF-funded grant, Sisters in Science in the Community, assisting with initial program development and the design and implementation of a professional development series for urban community youth workers in informal science education settings; also currently in the process of writing additional grant proposals.

Pennsylvania State University, Great Valley, PA (9/04–12/04). Adjunct Professor–Curriculum & Instruction teaching graduate level curriculum courses in the Educational Leadership and Curriculum & Instruction departments, planning interactive sessions, and assisting students with projects.

Association of Science-Technology Centers (ASTC), Washington, DC (4/03–5/05). Consultant for the St. Louis Center for Inquiry in Science Teaching and Learning NSF Grant, Served as a researcher/evaluator for the $10 million NSF-funded grant analyzing the role of informal science centers and their use of inquiry teaching and learning methods with underserved youth by means of multiple site visits, program observations, and interviews with youth and museum staff.

Temple University, Philadelphia, PA (1/04–8/04). Assistant Professor of Science and Mathematics Education, taught both graduate and undergraduate-level sections of elementary science and mathematics methods courses for pre-and in-service teachers, and graduate level technology courses. These courses stress implementing national standards, scientific and mathematical literacy for all, and conceptual understanding through current inquiry-based methods. Mentoring students in the math/science practicum in concert with the School
District of Philadelphia was an additional responsibility of the position, as well as collaborating on writing grant proposals.

Temple University, Philadelphia, PA (9/03–12/03) and Adjunct Professor - Science Education (9/99–5/01). Taught both graduate and undergraduate-level sections of the elementary science methods course for pre-service teachers. The course stresses implementing the National Science Education Standards, scientific literacy for all, and whole science through current inquiry-based methods.

Temple University, Philadelphia, PA (8/02–9/03). Program Coordinator - Sisters in Sport Science Program, managed the year-round planning and implementation of science programs associated with the NSF-funded, science-enrichment program for minority middle school girls. These after-school, Saturday and summer programs used non-traditional sports as a vehicle for teaching physical science concepts. Other duties include hiring and training undergraduate and graduate students, managing the daily finances related to program budget, reporting, grant writing and dissemination through publications and presentations.

Temple University, Philadelphia, PA (9/00–5/02). Graduate Assistant - Sisters in Sport Science After-School Program Coordinator, developed curriculum and assessment, and taught physical science concepts to middle school girls in three different Philadelphia public schools on a weekly basis during the academic year utilizing non-traditional sports such as fencing, golf, and volleyball as a vehicle for presenting the scientific concepts.

Rutgers University, Camden, NJ (Summer 2001 & 2002). Chemistry Co-Instructor, Girls in Engineering, Math, and Science Program, designed and implemented a laboratory-based, cosmetic chemistry curriculum for underserved, high school girls from the Camden City Schools in order to increase the participation of girls in science. Also supervised undergraduate assistants, and designed, conducted, and analyzed the in-house formative evaluation.

Rutgers University, Camden, NJ (1/00 –10/00). Executive Director, Girls in Engineering, Math, and Science Program, coordinated the start-up of an NSF-funded, science-enrichment program for high school girls from the city of Camden, NJ. Duties included curriculum design, recruitment of students, hiring and supervision of research assistants, managing the budget, developing and implementing an evaluation plan, and building relationships with the school principals and staff, students’ families and community members.

Pennsylvania State University, Abington, PA (9/99–5/01). Adjunct Professor–Biological Science, taught one 3-credit Environmental Science course for non-science majors per semester in a lecture hall format. Related duties included developing lecture material, writing and grading exams, and tutoring and advising students.

Temple University, Philadelphia, PA (9/93 12/01). Teaching Assistant, Biology Department, taught general biology laboratories for pre-professional and non-science undergraduates during the academic year; during the 1999 summer session assisted with the teaching,
organization, and logistics for a marine environments course for senior-level biology majors, which included a four-day research field component in Cape Cod.

Youth Build Charter School, Philadelphia, PA (12/99–5/00). Co-Instructor for Science, developed and implemented a hands-on environmental science-based curriculum for at-risk students ages 16-21 who had previously dropped out of school and were returning to earn their diplomas in a one-year work-based program. The majority of activities were taught at the Schuylkill Center for Environmental Education, utilizing the 100+ acre outdoor classroom.

Academy of Natural Sciences, Philadelphia, PA (4/94 –8/99). Special Programs Manager responsible for the coordination, funding acquisition, implementation, administration, and evaluation of more than a half dozen grant funded programs for urban youth, teachers, and families, sponsored by NSF, PEW Charitable Trust, U.S. EPA, and other national funders. Accomplishments included a yearly student excursion to Central America, hosting an AAUW student conference, and creating an improved scientist/student mentoring environment.

PUBLICATIONS

PRESENTATIONS
10/05  Looking longitudinally: Impacts of informal experiences on girls’ interest, engagement and participation in science, presentation, Association of Science-Technology Centers 2005 Annual Conference, Richmond, VA.
4/05  Sport Science in the Community, presentation, National Science Teachers Association National Convention, Dallas, TX
1/04 A Longitudinal Study of the Educational and Career Trajectories of Female Participants of an Urban Informal Science Education Program, presentation, Hawaii International Conference on Education, Honolulu. (session chair)


MEMBERSHIPS, AFFILIATIONS & PROFESSIONAL ACTIVITIES
1/04–pres. National Council of Teachers of Mathematics (NCTM)
3/03–pres. National Association of Research in Science Teaching (NARST)
8/96–pres. American Association of University Women (AAUW); Girls Succeeding in Science, Math & Technology Symposium: Part II Co-Chairperson
1/94–pres. National Science Teachers Association (NSTA)
1/94–pres. George Washington Carver Science Fair Committee, Philadelphia, PA
*Judges Chairperson and Web Master

CURRENT AND PENDING GRANTS
National Science Foundation: The Impact of Informal Science on Girls’ Interest, Engagement, and Participation in Science Communities, Hobbies, and Careers, Research Advisor (2005-2009) $1,180,518 (2 days per month)

National Science Foundation: Sisters in Science in the Community, Research Consultant (2004-2007) $1,288,000 (1 day per month)
### Section C, Form 524

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<tr>
<td><strong>Salaries (Category I)</strong></td>
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<tr>
<td>PI (R. Clariana, 22%)</td>
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<td>16,189</td>
<td>16,756</td>
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<td>Co-PI (K. Fadingan, 11%)</td>
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<td>Graduate Assistant Grade 09</td>
<td>(half-time Fall+Spring)</td>
<td>24,872</td>
<td>25,744</td>
<td>53,288</td>
<td>103,904</td>
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<td><strong>Subtotal</strong></td>
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<td>24,872</td>
<td>25,744</td>
<td>53,288</td>
<td>103,904</td>
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<td><strong>Total Salaries and Wages</strong></td>
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<td><strong>Fringe Benefits</strong> (see budget notes)</td>
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<td>9,941</td>
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<td>2,400</td>
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<td><strong>Domestic Travel (Teachers &amp; PI )</strong></td>
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<td>3,000</td>
<td>3,000</td>
<td>4,000</td>
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<td><strong>Vantage Trainer ($2,500 per day)</strong></td>
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<td></td>
<td>3 days</td>
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<td>2 days</td>
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<td><strong>Vantage Licenses ($36/student/year)</strong></td>
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<td>10,800</td>
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<td><strong>Vantage Prompts ($7,000/prompt)</strong></td>
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<td><strong>Modified Total Direct Costs</strong></td>
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<td>82,388</td>
<td>163,156</td>
<td>130,164</td>
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| INDIRECT COSTS | | | | | |
| **Grad Assistant Tuition Remission** | see budget notes | 23,856 | 26,720 | 59,856 | 110,432 |
| **Teacher Stipends** | ($28/hour x 40 hours each year) | 6,720 | 6,720 | 11,200 | 24,640 |
| | 6 teachers | 6 teachers | 10 teachers | | |
| **TOTAL REQUESTED FROM SPONSOR** | | 135,209 | 240,648 | 236,364 | 612,221 |
Budget Justification

Salary of Project Director/Principal Investigator (PI): Roy B. Clariana, Associate Professor of Education in the Instructional Systems program, brings expertise in project design and management, computer-based instruction and assessment, biology, and science education. Dr. Clariana will be involved in all aspects of the project including budgets, maintaining consultation with all parties, overall project design and management, planning and conducting data analysis, writing final manuscripts for publication and IES reports, and presentations of results. In order to allow the PD/PI adequate time to focus on the project, in each of three years, 22% (2/9\textsuperscript{th} of base) for summer supplementary pay is requested.

Salary of Co-Principal Investigator: Katherine Fadingan, Assistant Professor of Curriculum and Instruction (Science Education), brings expertise in field-based data collection, in science education, and in alternative assessment of science content knowledge. She will supervise the biology graduate assistants, and will assist with the design stages and with field implementation of the project, especially focusing on classroom surveys and interviews. In order to allow Dr. Fadingan adequate time to focus on the project, 11% of her regular academic salary is requested as summer supplementary pay is requested.

Biology Education Graduate Research Assistant (GA): The assistance of two half time biology education graduate assistant is requested for years 1 and 2 and four GAs are requested for year 3. The graduate assistants will be mainly responsible for scoring essays throughout the project, but will also be involved in field interviews, working with biology teachers and students, and other data collection and analyses activities. In order to allow the GAs to focus on the project, the following university estimated rates are requested for each half-time (1/2) graduate assistant, Grade 09 (YR 1 for two GAs $24,872, YR 2 for two GAs $25,743, YR 3 for four GAs $53,287) plus negotiated fringe @14.0% plus Fall/Spring tuition (YR 1 for two GAs $23,856, YR 2 for two GAs $26,719, YR 3 for four GAs $59,850).

Fringe Benefits: Fringe benefits are computed using the rates of 28.2% applicable to Category I Salaries, 14.0% applicable to Category II Graduate Assistants, 8.2% applicable to Category III Salaries and Wages and 0.6% applicable to Category IV Student Wages for the current fiscal year–July 1, 2005 through June 30, 2006. If this proposal is funded, the rates quoted above shall, at the time of funding, be subject to adjustment for any period subsequent to June 30, 2006, if superseding Government approved rates have been established. The fringe benefit rates are negotiated and approved by the Office of Naval Research, Penn State’s cognizant federal agency.

Teachers Stipends: The teacher stipends are calculated at the standard district rate of $28 per hour plus travel to and from the site. Teachers will attend training sessions and project planning meetings in all three years. In order to compensate teachers for the additional training and work required for the project, the following stipends are requested (YR 1 for six teachers for 40 hours $6,720, YR 2 for six teachers for 40 hours $6,720, YR 3 for ten teachers for 40 hours $11,200).
**Vantage Learning:** In order not to jeopardize the objectivity of the evaluation, this project intends to pay the full standard price for the student licenses and the cost of training the artificial intelligence component of the software system to maintain complete autonomy from the vendor. The requested rates for software licenses for each year are (YR 1 for 300 students @ $36 per student $10,800, YR 2 for 300 students @ $36 per student $10,800, YR 3 for 600 students @ $36 per student $21,600). In addition, the standard rate for training the artificial intelligence software is $7,000 per writing prompt. In Year 2, funds are requested to train 12 writing prompts for the amount of $84,000 (12 x $7,000). In exchange, the vendor, Vantage Learning, recognizes the potential benefits (and risks!) of this project to their company, and through the Vantage Learning Foundation, will offer up to 500 accounts of MY Access! annually free of charge (not more than 50 per school) to a total of ten other schools that have a majority of students that are classified as serving low SES students.

**Travel:** All travel will be in accordance with University travel regulations. Travel estimates are based on costs that were incurred on previous projects of a similar nature for federal and state agencies. PI and other team members (Co-PI and GAs) will travel between campuses on regular grant business, also team members will present findings at national and international conference, and to Washington, DC for IES grant-related annual meetings. Teachers will be reimbursed for travel to and from training and project planning events. The following travel monies are requested (YR 1 for $3,000, YR 2 for $3,000, YR 3 for $4,000).

**Materials and Supplies:** Including supplies, equipment, training materials, photocopying, newsprint, markers, long distance charges (including fax transmissions), and courier and mail services between campus sites. A notable cost is contact with parents for IRB signature approval, which includes printing flyers, mailing, and phone calls in all three years (YR 1 for $2,400, YR 2 for $2,200, YR 3 for $4,000).

**Graduate Assistant Tuition** - Computed using the approved tuition charges for a graduate assistant of $5,325 for Fall Semester 2005, and $5,325 for Spring Semester 2006. The charges quoted above are increased by twelve (12.0%) percent for any project period occurring after Summer Session 2006, and each Summer Session thereafter.

**Facilities & Administration (F&A):** F&A rates are negotiated and approved by the Office of Naval Research, Penn State’s cognizant federal agency. Penn State’s current off-campus rate for research is 27% of Modified Total Direct Costs (MTDC) from July 1, 2005 to June 30, 2007. New awards and new competitive segments with an effective date of July 1, 2007 or later shall be subject to adjustment when superseding Government approved rates are established. Per OMB Circular A-21, the actual F&A rates used will be fixed at the time of the initial award for the duration of the competitive segment.