Using Performance Assessments in Traditional Physics Classes

by
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Focus Statement

Duval County has four levels of Physics instruction: Physics I Standard, Physics I Honors, AP Physics without calculus and AP Physics with calculus. The last two courses have a curriculum specified by the Educational Testing Service. The Physics I Honors curriculum has changed only a little over the last two decades. In the honors course, students complete most or all of the book (depending on the teacher), mostly in order of the chapters. Physics I Standard has two approved curricula. The first, referred to as the "traditional curriculum" is basically "Physics I Honors Lite", because the two courses use the same book and the same curriculum with the addition of "Honors Extensions" for the more advanced class. Honors extensions are topics and methods that various teachers use to distinguish between the two courses. The second, which is called the inquiry curriculum, uses the Active Physics series from It's About Time, Inc. Active Physics teaches using a thematic design with overarching questions for entire units and performance assessments that are part of completing the extended investigations.

Duval County Public Schools has been collecting data on whether the traditional or the inquiry physics curriculum is superior at producing learning that endures past the end of the course. Without reference to this data, I have reached the conclusion from my own work with Honors classes and with Standard classes that were taught the traditionally and others that were taught through inquiry that there needs to be a third way. To produce the best physics class, the traditional and the inquiry approaches must be blended to a much greater extent than can be easily done under the limitations imposed by the two approved curriculum.

Research Question

The eventual goal of my research is to discover how to add more meaningful inquiry activities to the traditional curriculum and how to add more mathematical and textual analysis to the inquiry curriculum. To this end, I decided to try to answer the question: What activities and resources are needed in the traditional physics curriculum to allow those students to be able to complete the same performance assessment with the same level of success as the students using the inquiry curriculum?

Review of Literature

In order to accomplish this, I needed to find the answers to four questions. First, what is inquiry, how is it done and why should it be done? Second, what is the proper depth and scope of a high school physics course? The deeper the course delves into the material, the less time is left to cover the broad areas that are generally expected to be completed in an high school honors course in physics. Third, how can the difficulty of a course be objectively judged? Finally, what is the best curriculum design to use in putting all of the pieces together?

One of the objections to inquiry instruction is that there is a lack of quantitative data supporting its efficacy in the classroom. Of course, two points that might be raised in favor of inquiry are 1) that considering the failure of more traditional techniques to teach all students, it cannot hurt to give inquiry a chance, and 2) inquiry is the natural state of the human mind. However, more and more research is now being done on the question. In the article by Travis and Lord (2004), two college general biology classes were taught, one using a traditional lecture/lab approach and the other using inquiry techniques. The results were that the inquiry students scored higher on weekly quizzes and the same as the traditional students on the test of concept understandings. On other measures, the emotional reaction of the inquiry students was better and student attendance was higher.

Inquiry is usually identified as being in a group of instructional strategies described as “teaching for understanding”. As Wallace and Louden (2003) ask, what teacher doesn’t teach for understanding? As a preface to analyzing conversations with teachers who are converting to inquiry, they cite three core principles of teaching for understanding:

(1) a conception of knowledge as constructed by the learner and, therefore, situated in the context of prior knowledge, skills, values and beliefs;

(2) a conception of teacher as guide, as co-constructor of students’ knowledge; and

(3) a conception of the classroom as a community of learners, in which shared goals and standards, an atmosphere of mutual trust, and norms for behavior support students in taking the risks and making the sustained efforts needed in serious learning.

Note that the qualities listed above may be regarded as a necessary condition for the inquiry process to proceed, but is not sufficient. There are, in fact, a numbers of effective learning strategies that allow students to construct knowledge as part of the curriculum. Gable (2003) compiled a list of some of these:

* Learning Cycle Approach – involving three phases: exploration, invention, and application.
* Science/Technology/Society – developing an appreciation of the interactive natures of science, technology, and society.
* Real-Life Situations – using real-life situations that do not necessarily include technological or societal problems.
* Discrepant Events – presenting anomalous data to students, usually by a demonstration.
* Analogies – comparing the scientific principle under scrutiny with one that is familiar, to gain a better understanding of the principle.
* Collaborative Learning – students working in groups to solve problems, perform laboratory exercises, or participate in projects.
* Wait-Time – the time that an instructor waits to call on a student for a response after posing a question or withholding whether the answer given is correct before calling on another student to respond.

* Concept Mapping – creating schematic diagrams that use words to show the relation of one concept to another.
* Inquiry – asking questions as hypotheses and then use certain processes (such as making observations, inferences, or predictions; classifying; controlling variables; measuring; and making charts and graphs) to draw conclusions.
* Mathematical Problem Solving – creating mathematical models, and in making calculations based on these models.

Inquiry is only one of the items on the list above. What are the characteristics that make inquiry such an important factor in teaching for understanding? Chiappetta and Adams (2004) cite five ways that using inquiry benefits students, building their:

1. understanding of fundamental facts, concepts, principles, laws and theories
2. development of skills that enhance the acquisition of knowledge and understanding of natural phenomena
3. cultivation of the disposition to find answers to questions and to question the truthfulness of statements about the natural world
4. formation of positive attitudes toward science and
5. acquisition of understanding about the nature of science.

So, ultimately, what is inquiry? In an article focusing on reworking "cookbook" labs into inquiry experiences, Volkmann and Abell (2003) stated that students involved in inquiry:

1. are engaged with scientifically oriented questions
2. give priority to evidence
3. formulate evidence based explanations
4. compare and evaluate the merits of explanations
5. communicate and justify explanations.

In choosing an inquiry approach to instruction, a teacher has implicitly decided to limit the number of topics to be covered in the course because of the amount of time required for developing the understandings required for inquiry. Additionally, the inquiry approach excludes the choices of frequent lectures and extreme reliance on textbooks in favor of more experimental activities and discussions of the data. The types of analysis that students will be doing are less likely to be a problem set and more likely to be related to the actual inquiry or research questions that the class is focusing on. Some activities that are common in most physics classes have become incompatible with the instructional model the teacher is using. In order to assure that the material is being satisfactorily taught, the teacher must choose the included topics carefully. One technique to organize this process is called curriculum mapping, which charts standards and benchmarks and allocates time to specific topics.

Another controversy involving traditional physics instruction versus inquiry physics is concerned with the difficulty of the course. One way to look at difficulty is to ask whether students are successful or not. If students are more successful, some teachers say, the course must be too easy. This reasoning, in fact, accounts for much of the adverse opinion against inquiry. The counter argument can be advanced that students are less successful because traditional instruction is not as effective, but that is still a subjective statement. State testing of science standards is beginning to give us objective data on the efficacy of different ways of teaching science. By studying the way the state defines complexity, teachers can learn how to judge the depth of knowledge required to do well in their course. The Florida Department of Education recently moved from a two stage model based on Bloom's Taxonomy to a three level model based on Webb's four level depth of knowledge model. The first level 1 is recall and reproduction, which would include recall of information such as a fact, definition, term, or a simple procedure, as well as performing a simple science process or procedure. Level 2 is labeled skills and concepts and would include the engagement of some mental processing beyond recalling or reproducing a response, requiring students to make some decisions as to how to approach the question or problem. Level 3 (strategic thinking) requires reasoning, planning, using evidence, and a higher level of thinking than the previous two levels. Tasks at Level 4 have high cognitive demands and are very complex. Students are required to make several connections—relate ideas *within* the content area or *among* content areas—and have to select or devise one approach among many alternatives on how the situation can be solved. Most on-demand assessments do not include tasks at this level.

Finally, there is the choice of a curriculum design model. In Duval County, many teachers use the default model, which consists of teaching in a sequence derived from a textbook, a county curriculum guide or some other outside source with a test given at the end of a chapter, the end of the week or at other points and other assignments sprinkled throughout. Another popular model is called "America's Choice" (NCEE). This design is based on the examination of student work to match a set of performance and content standards. The classroom is tightly configured and is structured to encourage cooperative learning and the creation of work products. Time is allocated for a mini-lesson, a cooperative work period, a closing and a reflection time. The specifics of what to do during these time periods are in the hands of design coaches who (along with subject area coaches) guide teachers in constructing their lessons and satisfying the requirements of the model. Duval County has also adopted the Understanding by Design planning model. UbD combines "backward planning" (starting with the end in mind), essential questions to set the stage for the inquiry process through student generated research questions and performance assessments in which students transform knowledge and skills by applying them in unfamiliar situations, Understanding by Design is the best planning tool to use to fill the workshop model of America's Choice with appropriate experiences for physics students.

Variables

The variables I will be studying include:

- the extent to which each course concentrates on Sunshine State Standards
- the extent to which each course concentrates on annually assessed standards for science FCAT
- the number of topics each course concentrates on
- the complexity of each topic in each course
- the nature of the instruction for each course in terms of the number of hours spent in various types of activities (inquiry investigations, drill and practice, lecture, traditional lab, reading activities, etc.)

My effect size will be determined by:

- performance assessments given to both classes
- student performance on teacher made assessments
- student performance on the District end of course final

Intervention

The traditional Physics class is math intensive and concentrates on completing as many of the topics in the book as possible. The labs are from the textbook and are primarily "structured inquiry" in which students work toward a pre-determined result. Evaluation is primarily through testing, written class work and homework, lab reports and chapter projects.

The inquiry-based Physics class uses activities that are based on guided inquiry. Evaluation is based primarily on completion of the inquiry-based activities and a performance assessment based on real world situations. The knowledge and skills sections of the student book and the performance assessment are laid out in a format that parallels the Stage 2 of Understanding by Design.

The District has two approved Physics curricula, one using the Merrill book *Physics: Principles and Problems* and the other using the Active Physics books. Both will be instructed using the same standards and District Performance Standards. Both will use activities from the Active Physics books. The Active Physics class will use every lab, while the Merrill class will use about half the labs. Both will use the same supplemental readings. The Merrill class will spend more time solving problems and will cover topics that are not included in the Active Physics books.

Student population

11 students in the inquiry class – 5 black, 6 white.

14 students in the traditional class – 6 black, 7 white, 1 asian (LEP)

Comparable average GPA, FCAT scores and SES.

Planning steps and other people involved

- Create project team including standards coach and other Physics teacher
- Create plan for using Active Physics performance assessment for Merrill course
- Create plan for evaluating the success of the modified Merrill course
- Present plans to principal and APC.

Timeline

January 2005	Started using traditional curriculum with fourth period class after deciding the full inquiry curriculum might be a mismatch for these students.
February 2005	Integrated selected Active Physics activities into traditional course.
March – May 2005	Continued intervention for fourth period modified traditional course.
April – May 2005	Preliminary Analysis of Data – Preparation of preliminary results.
June 2005	Preparation of final report.

Resources

Active Physics books and materials provided by USI/DCPS

Results

I measured the coursework in four ways.

1. Both courses Sunshine State Standards for physics.
2. Students in the traditional physics course completed 73 physics topics through reading, mathematical analysis and experimentation while the inquiry physics students completed only 35, mostly through experimentation and analysis of data.
3. The traditional physics students were given problems of greater mathematical complexity (using Webb's Depth of Knowledge criteria) than the inquiry students. Both classes had inquiry problems of equal difficulty, although the traditional physics class did not have as many.
4. The traditional class spent approximately 50 percent of their time in experimental activities, 30 percent of their time in reading inquiry activities and 20 percent of their time in mathematical analysis. The inquiry class spent approximately 75 percent of their time in experimental activities and 25 percent of their time in reading activities that were not part of the inquiry curriculum. No time was spent in mathematical analysis except for what was part of the Active Physics curriculum.

I measured the student results in three ways. Use of the single tail t-test showed no significant difference in the performance of the students on the Duval County end of course test or the final exam I gave which was made up of academic prompts similar to the two point FCAT questions. The explanations by the students in the traditional class on the performance assessment for electricity and magnetism were significantly better, however. One result, on looking at individual questions, was that only two of the inquiry physics students correctly solved the electrical problem, while seven of the traditional students were successful.

Analysis

I originally expected that my Active Physics class would do better on the performance and that my traditional class would do better on the problem solving portion of the final exam. Looking at specific pluses and minuses on the performance assessment rubric, inquiry students had very good instructions on using the appliances, but fell short on knowledge of the relationships that justified the instructions or on their abilities to communicate the ideas behind the relationships. The traditional class was far more successful in performing more complicated mathematical analysis as I had expected.

Carrying On

I was careful in this investigation not to separate the work in each class by too much, since both classes were standard level. As a result, the treatment was perhaps too small to show a full effect. My goal for next year would be to teach a Physics I Honors class in a completely traditional fashion. My question would be whether or not students who had not done any of the specific activities in the Active Physics curriculum could successfully complete the performance assessments as a culminating activity.

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