

Implementation of Physics and Everyday Thinking in a High School Classroom: Concepts and Argumentation

Shelly N. Belleau, Mike J. Ross, and Valerie K. Otero

University of Colorado, Boulder, Colorado, 80309

Abstract. The Physics and Everyday Thinking (PET) curriculum is based on educational research and consists of carefully sequenced sets of activities intended to help students develop physics ideas through guided experimentation and questioning with extensive small group and whole class discussion. A high school physics teacher has adapted and implemented the PET curriculum in a low-income urban high school with the aim of removing barriers that typically limit access to traditional physics curriculum. Though PET was not designed for secondary physics students, this teacher has worked closely with physics education research faculty and graduate students to simultaneously modify, implement, and investigate the impact of PET on urban high school students' physics learning. Preliminary results indicate that the PET curriculum has great potential to provide students with opportunities for success in understanding physics concepts, as well as helping to develop scientific argumentation strategies.

Keywords: High School Physics Curriculum, Argumentation, Inquiry Learning

PACS: 01.40.G-, 01.40.-d, 01.55.+b, 01.40.Ha

INTRODUCTION

One of the primary goals of science instruction is for students to develop scientific reasoning skills while learning the required content. When educators promote argumentation and discourse, they foster scientific thinking by providing authentic experiences for students to develop and modify their ideas [1]. In this learning environment, students are able to justify their claims with evidence and reasoning, [1] and criticize ideas as a means of critically thinking about science concepts [2]. As a result, argumentation may impact cognitive and metacognitive reasoning, development of critical thinking skills, scientific literacy, scientific culture, and evaluation of knowledge and reasoning strategies [3].

One way students develop argumentation strategies is when they learn using an inquiry approach, by collecting and using laboratory evidence to make and defend claims during small-group and whole-class discussions. Inquiry-based curricula are designed to help students learn to think like scientists while developing conceptual understandings [4] by focusing on concepts and scientific processes [5]. Inquiry involves students evaluating their prior knowledge and intuitions and then building new or modified understandings [4]. Studies on inquiry instruction indicate a positive relationship between inquiry instruction and high-school student content learning [5]. Specifically, hands on manipulation and learning without direct instruction have been shown to result in greater student conceptual understanding than did readings, lectures, and worksheets [5].

Physics and Everyday Thinking Curriculum

The Physics and Everyday Thinking (PET) curriculum was designed to help students gain positive attitudes toward science and develop scientific thinking strategies. PET consists of carefully sequenced sets of activities intended to help students develop physics ideas through guided experimentation, questioning, and extensive small group and whole class discussion.

When implemented in semester-long undergraduate university classrooms, students have been shown to demonstrate learning gains on the PET conceptual test, indicating that the PET curriculum helped students gain a conceptual understanding of physics ideas including Newton's laws, energy transfer and change, electric circuits, and light [6]. Additionally, when learning with the PET curriculum, undergraduate students demonstrated positive shifts in their understanding and attitudes toward science [7]. The PET curriculum was initially designed for use with post-secondary non-science major populations; however we hypothesized that because the curriculum is highly-interactive, evidence-based, and dependent on students owning and defending their ideas, it would be very effective in the high school setting.

As a part of the NSF-Funded Streamline to Mastery professional development program, we implemented PET in an urban high school with a large enrollment of students from backgrounds traditionally underrepresented in science. This study examines high school student shifts in argumentation strategies and

student content knowledge within an inquiry environment. We sought to answer two research questions regarding the implementation of the PET curriculum in the high school context. First, what is the impact of PET on high school students' conceptual understanding of physics? Second, how do student argumentation strategies change within the context of whole-class discussions?

RESEARCH CONTEXT

Twenty-two 12th grade students participated in this study. These students were enrolled at a small urban public high school where 37% of students were identified as English language learners and 60% of students qualified for free and reduced lunch programs. The ethnic diversity at the school was 38% white, 54% Latino, and 3% African American. Two students from the course were removed from the study due to truancy (missing greater than 40% of the instructional days).

The physics teacher's goal was to adapt and implement the PET curriculum based on the curriculum authors' goals: to help students develop ideas to explain physical phenomena and to develop an understanding of how science knowledge is developed within a science community [6]. Adaptation of the curriculum involved modifying the text to an appropriate reading level and occasionally modifying laboratory questions to help scaffold students in their efforts to interpret and analyze laboratory findings.

The PET inquiry investigations consist of four sections: Purpose, Initial Ideas, Collecting and Interpreting Evidence, and Summarizing Questions. In this course, students participated in a summarizing discussion after completing their summarizing questions. Summarizing discussions are whole-class discussions immediately following inquiry investigations; these discussions took place approximately once each week.

Summarizing discussions consist of the following sequence of activities: (1) individually complete the summarizing questions (typically a homework assignment); (2) compare and discuss responses in a small-group setting (the class consisted of 6 small groups of 3-4 students); (3) groups prepare a small white board about one of the summarizing questions; (4) students participate in a whole-class discussion. The discussion follows the sequence of summarizing questions, and each question is facilitated by the group of students who prepared that white board as a small group.

METHODOLOGY

Data Collection

Our goals were to adapt and implement the PET curriculum in the high school context and to study the success of the implementation. To evaluate these goals, we examined student conceptual understanding and student participation in scientific discourse and argumentation during summarizing discussions.

To collect evidence of student conceptual understanding, students completed a linguistically modified version of the PET post-test in April. This conceptual test consisted of eight questions focusing on the topics examined throughout the year: energy and interactions, forces, circuits, and light. This modified test assessed the same concepts as the original PET post-test (associated with the PET curriculum), but included language modifications to allow accessibility to the content for struggling readers and English language learning students. For example, instead of stating: *Briefly explain the reasoning behind your choice(s)*; the modified post-test states: *Explain your answer*. Additionally, one of the questions on the original PET post-test was not implemented (question 6), as the course did not cover the content of this question.

To examine how student participation in classroom discourse changed throughout the year, we videotaped summarizing discussions. For this study we watched and made content logs of two of the summarizing discussions, the first from September and the second from April. We then coded segments of discourse by classifying each cohesive statement made by the students based upon the codes presented in Table 1. Cohesiveness was determined by the researchers as a complete train of thought that appeared to follow an identifiable line of reasoning. The discussion coded from September was the sixth summarizing discussion conducted during the school year and covered conservation of energy. The discussion coded from April was the 19th and final summarizing discussion of the year and covered topics of light and refraction. According to the teacher's reflection, the two summarizing discussions adequately represent typical discourse from the beginning of the year and from the end of the year.

Data Analysis

Our analysis focused on student conceptual understanding and how students participated in the summarizing discussions throughout the course of the year. To analyze conceptual understanding, we scored student responses on the PET post-test using the scoring rubrics and sample responses provided with

the PET curriculum. Although no pretest was given, we are able to compare post-test scores to normative PET post-test data from twenty-seven (27) semester-long university classes in which the PET post-test was administered to 719 students (typically non-science majors).

To analyze student argumentation strategies and discussion contributions, we coded two video tapes of the summarizing discussions. Coding schemes were adopted from Sampson, Grooms, and Walker's work on student participation in scientific argumentation [8]. This framework breaks argumentation into four categories: Expository, Information Seeking, Oppositional, and Supportive, as shown in Table 1.

These codes examine the function and nature of student contributions during discourse as fitting into the following categories: (1) Expository: providing and supporting information; (2) Information Seeking: asking questions; (3) Oppositional: challenging ideas; (4) Supportive: supporting the direction and culture of the discussion. By evaluating student involvement in these summarizing discussions, we may better understand how students engage in argumentation, and how the nature of their participation changes.

TABLE 1. Codes for student contributions to discussions

Code	Definition	Examples
Expository	articulate, clarify, expand, support an idea	"I think..." "Our evidence showed..."
Information Seeking	request more information; request clarification; ask others to share; state confusion; ask if others agree; ask for summary	"What did you mean?" "Why?" "I'm confused" "What did you say?" "Agree or disagree?"
Oppositional	disagree; offer an alternative; provide a critique; require idea support	"That can't be right!" "How do you know...?"
Supportive	agree with or justify; restate; change an idea due to someone's claim; combine ideas; organize the discussion; support discussion culture and climate	"Right" "That is just what I was thinking" "That is just like..." "Will you share?" "How do we feel with that?"

RESULTS

We sought to determine whether students reached adequate conceptual understanding by the end of this one-year physics course and to explore how student argumentation strategies changed. We evaluated conceptual understanding by comparing post-test

scores with data from PET implementation in undergraduate university courses. In this study, the mean post test score was 60% with a standard deviation of 0.24 (n=22). When implemented in 27 university courses, the mean post-test score was 54.2% with a standard deviation of 0.13.

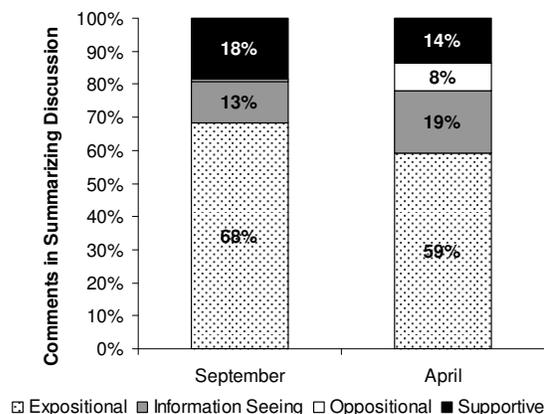
Students demonstrated the highest conceptual understanding on the two questions regarding light. The concepts of light and color are introduced in PET Chapter 6, which was implemented in April, just prior to the post-test. Student mean performance and standard deviation for each of the post-test questions are presented in Table 2.

TABLE 2. Post-test score and concept per question

Question Topic	Mean	Standard Deviation
1. Force & Motion	53%	0.49
2. Force & Motion	55%	0.51
3. Net Force	65%	0.39
4. Light	88%	0.18
5. Light		
6. Light & Color	Not Implemented	
7. Circuits	41%	0.40
8. Circuits	50%	0.49
9. Energy	53%	0.39
Overall Score	60.0%	0.24

To evaluate shifts in student argumentation strategies, we studied the proportion of comments in the summarizing discussions according to coding schemes presented in Table 1. Students demonstrated shifts in their argumentation strategies between the September and April summarizing discussions; the percentage of student comments that were oppositional grew from 1% to 8%, and information seeking comments grew from 13% to 19% (Figure 1).

FIGURE 1. Student Argumentation Strategies



CONCLUSIONS AND IMPLICATIONS

High school student conceptual understanding, as measured by the PET post-test, was shown to be comparable to that measured for university undergraduate students in PET courses. Student scores on the post-test suggest that high school students who are traditionally underrepresented in science demonstrate similar conceptual understanding following completion of the PET curriculum as undergraduate university students. Therefore, we may infer that the PET curriculum can be an effective curriculum for high school students, as it meets the curriculum content goal of helping students develop ideas to explain physical phenomena [6]. PET post-test results also suggest that the instructor's efforts to adapt and modify the curriculum to effectively meet the needs of struggling readers and English language learners did not interfere with the content goals of the curriculum. Of course, the population of students in the PET high school classroom includes students who might become majors in physics (in contrast to the university population consisting of non-majors), so the populations are not perfectly comparable. Future studies can compare PET high school courses to other traditional high school physics courses.

The findings from this study also indicate that implementation of the PET curriculum and a structured environment for promoting scientific discourse in the form of summarizing discussions have a positive effect on student discourse. While we only analyzed one summarizing discussion from the beginning of the course and one summarizing discussion from the end of the course, the preliminary findings indicate growth in student argumentation strategies.

More specifically, student willingness and ability to pose questions and challenge one another's thinking increased over time, which suggests that they became increasingly comfortable engaging in the scientific practice of argumentation. Osborne, Erduran, and Simon suggest that oppositional statements indicate more advanced discussions and opportunities for students to observe discrepant ideas and critically think about rationale for concepts [9]. We hypothesize that the increase in oppositional statements is directly related to skepticism and ultimately to enhanced conceptual understanding, but this is yet to be tested. The process of shifting the focus in science classrooms from traditional emphasis of skills and knowledge to how and why scientists make claims requires a focus on inquiry and literacy [3]. Based on the preliminary findings from this study, we argue that the PET curriculum provides an appropriate framework for this to occur.

One of the goals of the PET curriculum is for students to take accountability and leadership for their own science learning. We suggest that this increasingly occurred in the classroom largely due to the students facilitating their own class discussions. This is evidenced by greater than 40% of the students' participation (in the April summarizing discussion) being comprised of supportive, oppositional, and information seeking comments.

In the future, we will code transcripts from additional fall and spring summarizing discussions to ensure that the positive shift in oppositional comments was not an anomaly. Additionally, we will introduce a coding scheme to examine if and how students support their claims within discussions, and to further classify expository comments including the use of examples, evidence, and reasoning. Evaluating student discourse based upon these forms of contributions will add to a body of evidence about how students engage in discussions and interact with ideas in a manner that reflects science discourse and thinking [8]. Future work will also investigate how students defend their oppositional statements and provide rebuttals, as opposition statements that include rebuttals increase the quality of the argument and provide the opportunity for students to modify their ideas [9].

ACKNOWLEDGEMENTS

The University of Colorado Streamline to Mastery program was instrumental in making this research possible. This work was partially funded by NSF Grant DUE 937941.

REFERENCES

1. K.L. McNeil and D.S. Pimentel, *Science Education*, **94**(2), 203-229 (2010).
2. L.K. Bekland and K.L. McNeil, *Science Education*, **94**(5), 765-793 (2010).
3. R. Duschl, *Review of Research in Education*, **32**, 268-291 (2008).
4. D. Llewellyn. *Teaching High School Science Through Inquiry*, Corwin Press, Thousand Oaks, CA, (2005).
5. D.D. Minner, A.J. Levy, J. Century, *Journal of Research in Science Teaching*, **47**(4), 474-496 (2010).
6. F. Goldberg, V. Otero, and S. Robinson, *Am. J. Phys.*, **78**(12), 1265-1277 (2010).
7. V.K. Otero, and K.E. Gray, *Learning to Think Like Scientists with the PET Curriculum*, PERC Proceedings, Greensboro, NC, (2007).
8. V. Sampson, J. Grooms, and J.P. Walker, *Science Education*, **95**(2), 217-257 (2011).
9. J. Osborne, S. Erduran, and S. Simon, *Journal of Research in Science Teaching*, **41**(10), 994-1020 (2004).