The Development of Science Proficiency Through Argument Focused Lab Instruction in High School Biology

PURPOSE

This study explored the extent to which high school students enrolled in Biology developed several aspects of science proficiency as a result of a year of argument focused laboratory instruction. The ADI instructional model shifts classroom laboratory investigations towards more productive interactions among students that engage several aspects of science proficiency. In order to focus more on scientific proficiency, classroom instruction needs to shift from traditional, prescriptive activities to those that afford students the opportunity to engage in the practices and discourse of science (Duschl, Schweingruber, & Shouse, 2007; National Research Council, 2005, 2008).

The Argument-Driven Inquiry (ADI) instructional model (Author, 2011) is one strategy that is designed to foster the development of the four key aspects of scientific proficiency. Classroom activities structured according to the ADI model engage students in designing data collection and analysis, argument generation, group argumentation, scientific writing, and double blind peer review processes. Figure 1 describes the stages involved in the ADI model. The ADI instructional model is well aligned with various aspects of the scientific proficiency framework and provides a way for students to develop the knowledge and skills they need to be proficient in science while in school.

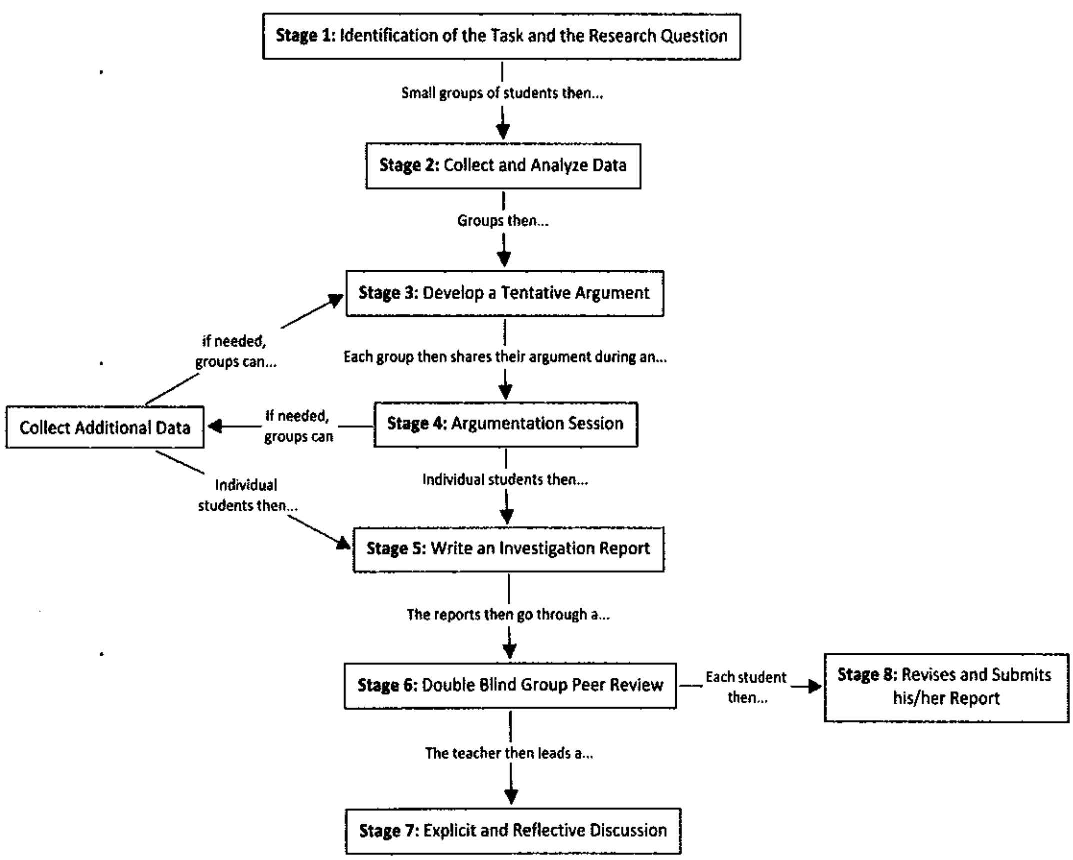

Figure 1: Stages of the Argument Driven Inquiry (ADI) instructional model

METHOD

The study described here occurred during year one of a larger, three-year project aimed at refining the ADI instructional model and assessing students' improvements in science proficiency as a result of experiencing ADI-based instruction. The project is using an iterative outcome-focused approach that is consistent with the major tenets of design-based research (Brown, 1992; Brown & Campione, 1996; The Design-Based Research Collective, 2003) to develop and refine the ADI instructional model through several iterative cycles of design, enactment, analysis, and redesign. This research setting involved the high school biology course at a university research K12 school. Each class engaged in at least 14 unique ADI investigations over the course of the 2010-2011 school year. These investigations, which were designed by the researchers and project teachers, focused on several major themes in biology, including cell theory, evolution, genetics and several others. Several assessments were given to the student subjects to complete. The assessments used in this study focus on the key aspects of scientific proficiency. Table 1 identifies the aspects of science proficiency and the accompanying assessment that will be addressed in this proposal.

Table 1: Aspects of Science Proficiency and Associated Assessment

Aspect of Science Proficiency	Description	Assessment Instrument
Aspect 1	Students know, use, and can interpret scientific explanations of the natural world	Biology Content Knowledge Assessment
Aspect 2	Students can generate and evaluate scientific explanations and arguments	Biology Performance Task - Argument Generation Section
Aspect 3	Students understand the nature and development of scientific knowledge	SUSSI
Aspect 4	Students productively participate in the practices and discourse of the scientific community	Biology Performance Task - Investigation Design Section Scientific Writing Assessment

<u>*Data Sources*</u>

Biology Content Knowledge Assessment: This assessment measures how well a student knows and can use scientific explanations of the natural world. The assessment is comprised of eight free response questions, each related to one of several "Big Topics" in Biology, as determined by the teachers and researchers. Each question includes an opening paragraph that provides a relevant scenario or context, followed by two questions. One question asks the student to *describe* the fundamental science concept (*Know*) and the other asks the student to *apply* that concept to the scenario provided (*Use*). The rubric for this assessment was developed from answers provided for the questions by a practicing biologist. A students' score was developed from the rubric based on correct description of several content elements identified in the expert's answer to the question. The rubrics were then scaled so that individual questions could be compared. The scoring team for this assessment achieved an ICC of 0.897.

Scientific Writing Assessment: The scientific writing assessment was developed to assess students' ability to communicate in science. This assessment provides a student with a small amount of background information and a related data table followed by a prompt. The prompt presents an argument by a scientist who provides an inaccurate explanation for the data. The students are directed to respond to the scientist's claim by generating an argument in support of a countering claim, which includes evidence and a rationale based on the data and information provided in the question, being mindful of writing style and grammar. The rubric, with an overall possible score of 28 points, was divided into three subscales: *Argument Structure* focusing on the inclusion of fundamental argument components including claims, evidence, and rationale (6); *Argument Content* concerning the quality and relevance of the argument components with respect to scientific discourse (10); and *Mechanics* regarding the punctuation, grammar, and technical quality of the writing (12). The ICC for this scoring team was 0.709.

Biology Performance Task Assessment: The performance task assessment was developed to understand and measure the progress in students' abilities to design an investigation that will allow them to generate an argument in response to a research question. The students must develop an original investigation and make decisions about the appropriate data to collect and evidence to use to generate their argument. These assessments are done in groups of 3-4 students, and the group submits a final product for scoring. The final product includes areas for students to describe the investigation they designed, the data they collected, and the argument they created, along with justification for each of these sections. Initial group composition was maintained as much as possible during separate administrations, and if it was not, the resulting scores were not included in the analysis. The rubric for this assessment followed the structure of the assessment packet and focused on technical and theoretical elements present in each section that related to the nature of scientific inquiry. The scoring team for this assessment achieved an ICC of 0.792.

SUSSI: The Student Understanding of Science and Scientific Inquiry (SUSSI) instrument (Liang, Chen, Chen, Kaya, Adams, Macklin, & Ebenezer, 2006) was adapted to measure students' understanding of the development and nature of scientific information. The assessment was comprised of 44 statements about science with Likert-scale agreement responses offered. Analysis of these answers assigned raw points to each response in relation to the nature of the item. Statements representing accurate ideas about science and scientific inquiry were scored on a scale from 0 (strongly disagree) to 4 (strongly agree). Statements representing inaccurate ideas about science were scored in a reverse manner. The authors of this instrument originally separated the assessment into several subscales representing major NOS concepts; however, the researchers condensed these subscales into two groups to better align them with Aspect 2 of the science proficiency framework.

Data Collection and Analysis

All of the assessments were administered at the beginning and the end of the year. All assessments were scored using rubrics developed by the research team. A pair of research team members scored at least 25% of the full set of each assessment, which had been blinded concerning student identity and pre/post timing. The intra-class correlation coefficient (ICC), a measure of reliability similar to Cohen's Kappa and interpreted using the same scale, was determined for each team (two-way random effects, absolute agreement). An ICC above 0.6 is considered substantial agreement (Landis & Koch, 1977), and once this level of agreement was determined, the team members scored the remainder of their assessment sets individually. The initial subject sample included 249 students from 9 different sections of the course, which were taught by two teachers. However, due to consent form considerations and attendance on the assessment administration days, the analyzed samples vary for each assessment. By using a pre/post administration schedule for these measures, a Paired Samples t Test was employed in analyzing the results for each assessment using the PASW (was SPSS) statistical software package.

RESULTS

Figure 2 provides a graphical representation of the mean (for the matching sample) Pre and Post percentages of correct/desired responses for each aspect of science proficiency. This alignment used collections of scores from the assessments as described in Table 1. Increases are noted in every aspect of science proficiency although there were not equal amounts of growth on each aspect.

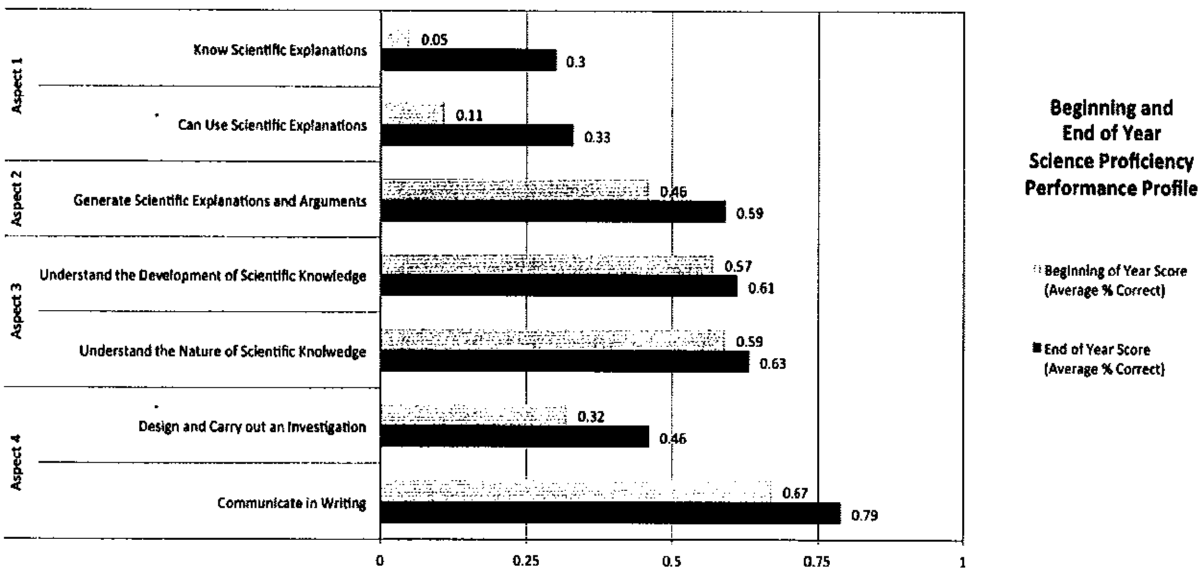

Figure 2. Percentage of Correct or Desired Responses on the Assessments for each Aspect of Science Proficiency

Table 2 presents the Paired Samples t Test results for each assessment. The overall score and the scores from the various subscales were compared on each assessment pre and post intervention. The results of these tests indicate that all the observed gains were statically significant.

Figure 3 provides a graphical representation of the effect size of the intervention on each aspect of science proficiency. Large effect sizes were observed for aspects 1, 3 and 4. This type of instruction, however, only resulted in a moderate effect for aspect 3 (understand the development and the nature of scientific knowledge).

Table 2: Results for Paired Samples t Tests of Overall and Subscale Assessment Data

Assessment	Pre M	Pre SD	Post. M	Post. SD	t	df	p
Biology Content Knowledge							
Overall	4.45	3.74	17.89	6.51	21.78	110	<.001
Know	1.57	1.64	8.93	3.83	20.77	110	<.001
Use	2.90	2.54	8.96	3.24	20.81	110	<.001
Scientific Writing Assessment							
Overall	18.80	3.90	22.20	4.07	8.74	127	<.001
Structure	3.16	1.28	4.13	1.43	7.42	127	<.001
Content	4.86	2.23	6.95	2.17	8.67	127	<.001
Mechanics	10.68	1.36	11.12	1.23	3.23	127	.002
Biology Performance Task							
Overall	14.11	5.23	19.64	4.79	5.5	27	<.001
Argument Development	4.57	2.04	5.93	1.92	3.08	27	.004
Investigation Design	9.54	3.91	13.71	3.98	5.0	27	<.001
SUSSI (Pre-Post)							
Overall	85.77	10.91	91.33	12.00	4.47	118	<.001
Development of Science Knowledge	52.79	8.82	56.15	9.19	3.64	118	<.001
Nature of Science Knowledge	32.98	4.53	35.04	4.35	3.78	118	<.001

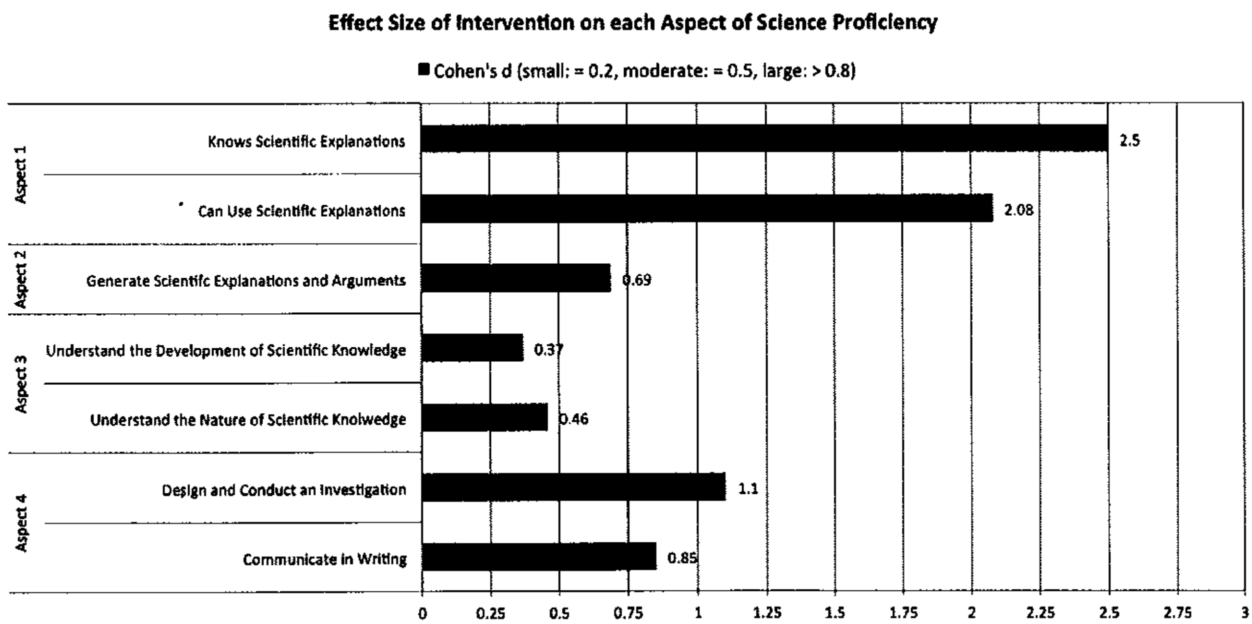

Figure 3: Effect Size of the Intervention for each aspect of Science Proficiency

CONCLUSIONS AND POTENTIAL IMPLICATIONS

The results provide evidence for the positive impact of ADI-based instruction on the development of science proficiency in the context of high school biology. Significant changes from the beginning to end of the year were noted on all assessments with moderate to large effect sizes. Aligning the scores from the assessments to related aspects of science proficiency, the findings demonstrate that

ADI instruction enhanced the development of some elements of high school biology students' science proficiency more than others. Further discussion of specific trends and potential explanations for them will be provided as part of the presentation. The broad performance profile generated from this analysis also demonstrates the importance of using multiple assessments for gaining insight into complex science learning, as opposed to relying on a single measure.

SIGNIFICANCE

The study described in this proposal provides further evidence of the benefits of argument focused science instruction in general. The findings further the research base on the impact of specific argument focused curricula and potential targets for improvement. As K12 science education shifts focus to developing students' science proficiency, this study contributes to the research base on ways of assessing aspects of a very broad and complex construct that serves as one approach to understanding the learning of critical thinking skills.

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