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Integrating Argument-Based Science Inquiry with Modal Representations: Impact on Science Achievement, Argumentation, and Writing Skills*

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Abstract

This study aims to investigate the effect of integrating the Argument-Based Science Inquiry (ABSI) approach with multi-modal representations on students' achievement, and their argumentation and writing skills. The study was conducted with 62 female and 57 male college students at the Central Anatolian Turkish University. All participants were in their third year of the science education program. The study was carried out within four identical sections of a "Laboratory Applications in Science" course with an instructor and two lab assistants in the 2010-11 academic year. While the ABSI approach was implemented in all sections, additional multi-modal awareness and integration instruction was carried out in two of the randomly assigned sections . The collected data included midterm and final exam scores, as well as science activity writing reports. Qualitative and quantitative data was analyzed to explore differences between ABSI only (comparison) and ABSI and Multi-Modal (treatment) groups on science academic achievement, argumentation and writing skills. Analyses yielded that the students in the treatment group not only outscored the students in the comparison group on the science achievement tests, but also demonstrated significantly higher performances in writing and argumentation scores.

Key Words

Argument Based Science Inquiry, Argument Generation Skills, Modal Representations, Science Literacy, Writing Skills.

With the fast development of cumulative knowledge through science and technology, nations began emphasizing science education and science literacy. Within this framework, science and science literacy ideas have large intersections with language not only for doing science, but also for understanding and teaching science. Thus, current literature overwhelmingly emphasizes science literacy as a backbone of science education where language plays an important role as a medium (Collins, 1998; DeBoer, 2000; Millar & Osborne, 1998). While science literacy encompasses skills to understand and communicate science ideas, as well as the ability to conduct informed decisions, such skills can only be developed through meaningful reading, communicative writing, and argumentation in teaching science (Keys, 1999;

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Norris & Phillips, 2003; Prain & Hand, 1996). The fundamental role of language in science teaching and science literacy has recently become a point of focus in Turkish educational settings with the current reform movements and calls for further research attention (Milli Eğitim Bakanlığı [MEB], 2005).

Argumentation and Science Inquiry

At an international level, inquiry and argument-based science teaching approaches are pursued as effective learning environments to cultivate and stimulate components of language (European Commission, 2007; Duban, 2008). Approaches integrating science inquiry, argumentation, and language practices are the subject of wide interest across the globe, and vary in both methodology and practices (Bybee, Trowbridge, & Powell, 2004; Carin, Bass, & Contant, 2005; Cavagnetto, 2010; Clark & Sampson, 2007; Eisenkraft, 2003; Erduran, Simon, & Osborne, 2004; Kingir, Geban, & Gunel, 2012; Marek & Cavallo, 1997; Sampson & Gleim, 2009; Sampson, Grooms, & Walker, 2009; Simon, Erduran, & Osborne, 2006; Simonneaux, 2001; Walker & Zeidler, 2007). For example, the Science Writing Heuristic approach adopted as Argument-Based Science Inquiry (ABSI), containing features of hands-on inquiry and a language-enriched student-centered learning environment, aims to provide a scaffolding structure to promote science literacy in the learning environment (Akkus, Gunel, & Hand, 2007; Kabataş Memiş, 2011; Keys, Hand, Prain, & Collins, 1999; Kıngır, 2011). Researchers argue that the ABSI approach encompasses critical student and teacher frameworks to enhance critical thinking, reasoning, argumentation, writing, and higher order cognitive skills, as well as tools to develop a robust understanding of the nature of science (Burke, Greenbowe, & Hand, 2005; Hand, Wallace, & Prain, 2003; Keys, 2000; Yore, 2000).

Research carried out in international and national settings showed science learning enhancement, as well as the development of positive attitude and argumentation skills for students in various settings, and of different socioeconomic status and achievement levels (Günel, Kabataş-Memiş, & Büyükkasap, 2010; Hand & Choi, 2010; Hasancebi-Yesildag & Gunel, 2013). Yet, by and large, such studies did not focus on the function of modal representations (e.g. text, mathematical formulas, graphs, and tables) which are fundamental elements of doing and learning science. Such gaps in the research agenda are closely linked with a disciplinary way of knowing science that encompasses science literacy (Ford, 2008; Klein, 2001).

Modal Representations

Multi-modal representations are widely perceived as forms to demonstrate concepts or convey an understanding in the form of a picture, text, diagram, or mathematical expression (Günel, Hand, & Gündüz, 2006; Owens & Clements, 1997; Pineda & Garza; 2002). In the fields of linguistics, mathematics, technology, and science, modal representations become a focus not only for research studies but also for learning theories such as Generative Learning Theory, Dual Coding Learning Theory, and Generative Theory of Multimedia Learning (Clark & Paivio, 1991; Kozma, 2003; Mayer, 1996, 1997; Meij & Jong, 2006; Witrock, 1990). Influenced by the above-mentioned learning theories, researchers have argued that modal representations are the essential elements for learning meaningful science and for building necessary science literacy skills (Alvermann, 2004; Airey & Linder, 2009; Lemke, 1998). The above-mentioned connection between modal representations and learning science has become a subject in science education research in national and international settings (Günel, Atila, & Büyükkasap, 2009; Günel, Kabataş & Büyükkasap, 2010; Kozma, 2003; Mayer, 2003; McDermott, 2009; Seeger, Voigt, & Waschescio; 1998; Yeşildağ, 2009). The findings of research studies have clearly dealt with the theme of science learning improvement with either instruction by multi-modal representations or emphasis on modal representations in writing activities. However, the development of students' argumentation skills with multi-modal representations within different instructional settings, for example, Argument-Based Science Inquiry, calls for further consideration (Choi, 2008). Guided by the current literature and emerging reform movements, this study aims to investigate the following research questions:

Research Questions

1. Are there differences between the treatment and comparison groups on science achievement tests?
2. Are there differences between the treatment and comparison groups on writing scores at the end of the implementation?
3. Are there differences between the treatment and comparison groups on the multi-modal scores?
4. Are there differences between the treatment and comparison groups on holistic argument scores?

5. Is there a relationship between multimodal scores and holistic argument scores?

Method

Research Design

The study adopted a quasi-experimental research design with both qualitative and quantitative data collected (Büyüköztürk, Çakmak, Akgün, Karadeniz, & Demirel, 2009).

Variables

The independent variable of the study was the group, being the comparison (ABSI only) or the treatment (ABSI with Multi-Modal Instruction). On the other hand, the dependent variables were students' science achievements, multi-modal writing, and argument scores.

Participants

The participants of the study included a total of 119 students (62 females and 67 males) studying the third year of the science education program at the Central Anatolian University in Turkey. There were four identical sections in which participating students were enrolled. While two of the randomly selected sections were assigned to the treatment group, the other two sections were designated the comparison group.

Groups and Implementation Procedure

The ABSI was a uniform approach adopted in all sections. Within this approach, students were asked to generate research questions, design an observation procedure or experiment to investigate the research questions, collect data, generate evidence, form a claim in relation to the research questions and evidence, and reflect on the investigation procedure as well as changes in their ideas during the activity. Throughout the investigation activities, students were required to share their arguments within small or large group discussions. At the end of each activity, students filled out activity reports where they were asked to display the research question, design, claim, evidence, and reflections. The role of the instructor(s) was to regulate students' research questions within the curriculum, encourage students to share their ideas, findings, claims, and reflections, and create oral and written negotiation environments. In all sections, at the end of the implementation procedure, students prepared a writing-to-learn activity and a poster, to communicate their understanding about the topics studied to middle school students.

By adopting the same curriculum, time-on-task, and pedagogical approaches, two of the randomly assigned sections (treatment) were exposed to multi-modal instruction. The remaining two sections where ABSI was the only instruction medium were labeled the comparison group.

The treatment group experienced multi-staged multi-modal instructions in order to understand the roles and functions of modes, integration of modes into written communication, and evaluation of written materials with modal representations.

Data Collected

In order to compare groups' prior science achievements, students' previous year chemistry and physics grades were collected. Furthermore, during the implementation, students were administrated science achievement tests as for midterm and final exams. Each of those testing instruments included five open-ended conceptual questions covering the topics studied. Items were adapted to Turkish from Hewitt's (2006) Conceptual Physics book. Upon the completion of the implementation, the reliability of the test instruments (Crombah's Alpha) were found to be .51 and .54 respectively. Sheskin (2004) argued that for open-ended testing instruments including multiple topics, alpha value .5 and above can be considered reliable.

The activity reports (gravity, heat and temperature, cohesion of liquids, electricity, and buoyancy) composed for each investigation were the data source for evaluating argument quality, writing skills, and modal representation coherence. The collected reports from all groups were scored according to the rubric proposed by Choi (2008). A faculty member and seven graduate students scored the activity reports. The type of inter-rater agreement adopted for this study was percentage of absolute agreement calculated by the number of times raters agree on a rating, then divided by the total number of ratings. Thus, this measure can vary between 0 to 100%. In this study, percentage of absolute agreement between any pairs of scores for each report ranged from 90% to 95%.

Findings

Results for Prior Science Understandings

A One-way ANOVA was conducted to compare groups' previous years' physics and chemistry scores as advised by Gravetter & Vallnau (2013). ANOVA results yielded no statistical performance difference between the groups on modern physics midterm scores ($F(1,104)=3.36$, $p>0.05$), final scores ($F(1,104)=0.35$, $p>0.05$) as well as general chemistry midterm scores ($F(1,104) = 0.26$, $p>0.05$) and final scores ($F(1,104)=0.27$, $p>0.05$).

Results for the First Research Question

A One-way ANOVA was conducted to compare groups' performance on midterm and final exams in order to investigate the effect of the treatment. ANOVA results yielded that there were statistical performance differences between the groups on midterm scores ($F(1,115)=5.73$, $p<0.05$) and final exam scores ($F(1,115)=5.34$ $p<0.05$). In both measurements, the treatment group outscored the comparison group.

Results for the Second Research Question

A One-way ANOVA was conducted to compare groups' performance on ABSI activity reports. ANOVA results yielded that there were statistical performance differences between the groups on activity reports scores ($F(1,116)=19.16$ $p<0.05$) where the treatment group outscored the comparison group.

Results for the Third and Fourth Research Questions

Two separate One-way ANOVAs were conducted to compare groups' multi-modal representation coherence and argument quality scores based on the ABSI activity reports. ANOVA results yielded that there were statistical performance differences between the groups on multi-modal representation coherence scores ($F(1,114) = 8.71$, $p= 0.004$, $p<0.05$) and on the argument quality scores ($F(1,114) = 4.60$, $p= 0.034$, $p<0.05$), where the treatment group outscored the comparison group in both measures.

Results for the Fifth Research Question

The relationship between the multi-modal representation coherence scores and argument quality scores was investigated through Pearson's Correlation analysis. The Pearson's Correlation Coefficient was found to be .646. According to Cohen (1992), such a coefficient value can be interpreted as an indicator of a strong relationship between multi-modal representation coherence and argument quality.

Discussion

This study was conducted with two essential motivations from the literature. The first idea was the need for disciplinary ways of knowing experiences, where students acted, thought, and communicated like scientists. The second driving concept was the role of meaningful interactions of language components including text, mathematical formulas, graphs, tables, and pictures in building science understanding and science literacy. While ABSI or other argument-related science teaching approaches provide enriched learning environments to scaffold disciplinary ways of knowing science and enhanced learning outcomes (Cavagnetto, 2010; Erduran et al., 2004; Grimberg & Hand, 2003; Norton-Meier, Hand, Hockenberry, & Wise, 2008; Osborne, Erduran, & Simon, 2004; Simon et al., 2006; von Aufschnaiter, Erduran, Osborne, & Simon, 2008), the current literature calls for research on the outcomes of implementation where the essential components of science literacy, an understanding of modal representation, and argumentation are blended.

Findings of the current study show evidence about the value of implementing multi-modal instruction within an argument-based inquiry-learning environment for college students.. Not only were students' science understandings scaffolded by multi-modal instruction, but also their ability to understand and use multi-modal representations, and to generate better quality arguments. Such findings have vital importance since being able to generate accurate, consistent, and persuasive argument and reasoning is an essential element of science literacy (National Research Council, 1996). In practice, science instructors teaching science at different levels can adopt multi-modal representation instruction to enhance science learning, writing, and argumentation skills. Meanwhile, there is need for further research on the concurrent areas of multi-modal representation and pedagogical content knowledge, science process skills, cognitive load theory, and international exams such as TIMSS and PISA.

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