The Influence of Training in Argumentation on Students' Individual Learning Outcomes

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Abstract: We conducted an in vivo experiment (Aleven & Koedinger, 2002) to investigate the impact of *Adventures in Argument*, a week-long online unit in argumentation, on subsequent science learning from an online course in which individual and collaborative argumentation were the primary forms of pedagogy. The context of the study was HAL Online, an undergraduate course in The Learning Sciences that enrolled 44 students. Using a nested design (students within groups within treatment), the treatment condition, Trained Argumentation with Modest Scaffolding (TAMS) was compared with an ecological control group: Emergent Argumentation with Modest Scaffolding (EAMS). Results of quantitative analyses indicated that TAMS was an effective intervention that positively influenced students' individual learning as measured by a test of scientific literacy and scores from coding of individual reflective blogs. Direct training in argumentation offers a viable, pragmatic supplement or alternative to immersive collaborative pedagogies that require guidance and scaffolding of students' online argumentation processes by faculty (Cavagnetto, 2010).

Introduction

We have embraced collaborative and individual argumentation as the primary pedagogical strategies for Human Abilities and Learning Online (HAL Online), an undergraduate course in The Learning Sciences designed for educators. The benefit of argumentation as pedagogy has been recognized for its potential to improve science knowledge and promote scientific literacy (e.g. Cavagnetto, 2010; Driver, Newtown & Osborne, 2000). A belief common among science educators is that immersing students in the collaborative process of science, where argumentation is implicitly embedded in this process, is the optimal way to promote scientific literacy (Cavagnetto, 2010). One drawback to this approach, however, is that it is extremely time-consuming, requiring students to be immersed for long periods in the scientific process. Moreover, as research indicates (e.g. Glassner & Schwarz, 2005; Kuhn, 2005), argument quality is generally poor among students across levels. Therefore, teachers and curriculum designers have significant responsibility for scaffolding and guiding argumentative discourse. This may be impossible to accomplish effectively through an immersive approach in large classrooms where teachers are overloaded, restricted by time, and may in some cases have weak argumentation skills themselves. In our university setting, where there is constant pressure to increase enrollments despite lower instructional budgets, scaffolding and guidance may be provided online to many students by a single faculty member unassisted, or with the help of relatively inexperienced teaching assistants. We therefore needed to investigate viable, pragmatic alternatives to guided argumentation during immersion. One option is designing instruction that formally trains students in argument structure *prior* to introducing domain content through pedagogies that engage learners in activities requiring evaluation and use of science concepts as evidence for claims and that hold them responsible for well-reasoned thinking.

The purpose of this study was to investigate the effectiveness of a week-long argumentation lesson on subsequent student learning of science and the development of scientific literacy. The performance of a group receiving the treatment lesson, designated the *Trained Argumentation with Modest Scaffolding* (TAMS) group, was compared with an ecological control group that did not receive the training: *Emergent Argumentation with Modest Scaffolding* (EAMS). Following the treatment manipulation, both groups participated in an identical four-week unit which focused on cognitive and neuroscience concepts. Analysis of student performance data from this unit addressed a range of research questions related to outcomes and discourse processes. Here, we will focus primarily on results related to the following questions: Q1. Based on a post-unit measure of scientific literacy, does TAMS, compared to EAMS, promote better science learning from instruction that engages students in scientific discourse? Q2. Relative to EAMS, does TAMS increase the spontaneous tendency to use and make connections among scientific course concepts during subsequent course-related tasks and discussions, likely indicating more sophisticated processing of the material?

Theoretical Basis for TAMS

Toulmin's model (1958), the Toulmin Argument Pattern (TAP) has served as the basis for many educational approaches using argumentation (e.g. Kuhn, 1991; Leitao 2000; Stegmann, Weinberger & Fischer, 2007). The

TAP focuses on six core elements of arguments. Toulmin's model is the basis of Halpern's (2003) *Analyzing Arguments*, a chapter in her award-winning text *Thought and Knowledge*. This chapter was used as the basis of argument training in this study. After introducing the TAP, Toulmin (1972) introduced the idea of argumentation fields, the idea (briefly stated) that argument components and qualities are not universally generalizable but must be reflectively adapted to contexts. Thus Toulmin's perspective denotes a 'sweet spot' between absolutism and relativism that is useful in framing instructional approaches in which a general argument model can be adapted to different problem contexts. Kuhn (2005) also recognized the importance of meaningful context with emphasis on teaching general argument skills in a way that can be transferred to new situations. Our TAMS treatment, a lesson entitled *Adventures in Argument*, was inspired by these views.

Data Source and Design

This study used an *in vivo* experimental design (e.g. Aleven & Koedinger 2002). The context of the study was the spring, 2011 online section of Human Abilities and Learning (HAL Online) at a large Midwestern university, an undergraduate course that enrolled 44 future educators from various fields. Undergraduates in this course read about sophisticated science concepts from cognitive and neuroscience research, and were expected to gain understanding of and practice with integrating these ideas to support decision making in individual and group problem-based learning activities. The course was divided into four units comprised of four or five week-long lessons each. During a lesson, students read and accessed multimedia resources while completing weekly activities that involved problem solving and higher-order thinking with the learning-science material, and that incorporated embedded assessments. Every other week the assessment activity required students to write an individual reflective blog. In alternate weeks, the assessed activity involved small group discussions online. The treatment manipulation was the last lesson in the first course unit. The course was offered in the Moodle course management system. A separate Moodle course environment was created for each condition. These were identical except for the treatment-related manipulations, described next.

Treatment: Training in Argumentation with Modest Scaffolding (TAMS)

The TAMS treatment involved students in a course of formal training in argumentation based on the hypothesis that the training would improve thinking and lead to more meaningful learning. During the lesson students read "Analyzing Arguments," a substantial chapter on argumentation from the text *Thought and Knowledge* (Halpern, 2003). After reading, students completed an individual quiz and participated in collaborative forum discussion that involved evaluating an argument. The quiz assessed student understanding of key concepts in the text, including the ability to analyze a written argument. To complete the discussion task, students watched a TED video of Patrick Awuah (2007) describing a program of liberal arts education offered at Ashesi University and arguing that this program was developing African leadership. Small groups then collaborated to evaluate the observed speaker's argument.

Ecological control: Emergent Argumentation with Modest Scaffolding (EAMS)

In the EAMS control group students received an alternative week-long lesson that did not focus on argument training, but rather on a scientific model of hypothesis testing. During this lesson students read an alternate chapter of comparable length and complexity from *Thought and Knowledge*, "Thinking as Hypothesis Testing." This topic was selected for the control condition because it represents a widely accepted alternative scientific model for good thinking that is widely taught but does not emphasize argument structure or process. During EAMS students also completed a quiz and participated in a collaborative forum discussion. In the forum discussion, students watched the same TED video of Patrick Awuah (2007) seen by students in TAMS and collaborated to design a study that would evaluate the speaker's causal hypothesis.

Participants

Using a within classroom design (Salden & Koedinger, 2009), students who enrolled in HAL Online were assigned to small groups based on common interests as determined by self-report surveys. Small groups were randomly assigned to the two conditions. Groups comprised three or four students and, to avoid confounding the group dynamic, students worked in the same groups throughout the course.

Method of Analysis

We used a mixed quantitative and qualitative approach (e.g. Barron, 2003). Statistical analysis followed procedures for nested designs recommended by Kirk (2012), where individual students were nested in small groups, which were compared across conditions. Qualitative analysis followed procedures for quantifying qualitative data recommended by Chi (1997).

The analysis related to the first research question was based on scores from a scientific literacy post-test, a written essay requiring students to respond to (supporting or challenging) a statement about the role of the study of brain research in college curricula for future educators. Post-tests were scored by a panel of three paid experts in scientific literacy who were blind to condition and were trained to use a scoring rubric. The rubric was developed using the definition of scientific literacy given by the National Science Education Standards, which is based on historically agreed-upon principles of what it means to be scientifically literate. Rubric criteria subjects were scored on included: demonstrates understanding of science constructs in the article; accurately uses science to support claims; takes credibility of sources into account; and recognizes multiple positions on the issue. The scoring reliability based on Fleiss' kappa was .89 on a sample of 10 post-tests. Scores for TAMS and EAMS were compared using a nested ANOVA design. An identically scored baseline measure of scientific literacy and concept use, collected from embedded assessments for a course lesson prior to the experimental/control lessons, provided a covariate.

We addressed the second research question using Chi's verbal analysis method (Chi, 1997) to score an individual reflective blog assignment in which students spontaneously used any course concepts they chose to explain what they learned from a lesson. In this analysis we asked how many concepts students used from course readings and how they integrated these concepts in their blog posts. The specific adaptation of Chi's method included searching the data, coding the data for seven pre-defined target concepts about Lifelong Learning & Expertise (synaptogenesis; brain region growth with use; regional compensation; expert cognitive structures; genetics and environment interaction; emotion/motivation; and practice ["use it or lose it"]), representing the data as simplified semantic webs, and seeking and interpreting patterns. Based on semantic webs, the number of concepts and a score representing the interconnection rate among concepts ($n(n-1)/2$, where n = number of concepts used) were tabulated. Reliability of 95% (Cohen's kappa .91) was reached between coders after a single round of coding based on a sample of 10 blogs. Remaining data were coded by the first author of this paper. A semantic web was created from each student's blog, with reliability of 89% reached between coders after one round of discussion. Based on these scores, a nested ANOVA was conducted for number of concepts and connection rate.

Results and Discussion

The results of this study indicate that TAMS was an effective intervention that enhanced students' subsequent learning of science content as measured by a test of scientific literacy and assessments of students' understanding of target science concepts revealed in individual reflective blogs.

Q1: Scientific Literacy

A between subjects analysis of variance (condition (TAMS, EAMS); group (1-12); covariate: baseline) indicated the effect of treatment on a test of scientific literacy was significant. There was a main effect for condition: $F(1, 10.478) = 13.125$, $p = .002$. This means students in the treatment, TAMS ($M = 9.898$, $SE = .531$, 95% CI [8.709, 11.088]), had a significantly higher mean scientific literacy score than students in EAMS ($M = 7.111$, $SE = .556$, 95% CI [5.891, 8.331]), as measured using the rubric criteria described above. The interaction of condition and pre-score was non-significant, which indicates the treatment effect did not depend on the baseline score.

This finding suggests that, for advanced undergraduate learners in a learning sciences course, a week-long formal training lesson in argument structure and quality prior to engaging with science learning was an effective approach that promoted scientifically literate written essay responses from students. This finding extends the work of Veerman, Andriessen & Kanselaar (2002) showing that argument prompts at the beginning of a lesson promote more sophisticated understanding during content-based arguments. Moreover, this finding adds to the limited body of existing research of how training in argumentation prior to participating in science-based activities can promote scientific literacy (e.g. Osborne, Erduran, & Simon, 2004).

Q2: Understanding of Science Concepts

A between subjects analysis of variance based on individual student blog data (treatment (TAMS, EAMS); group (1-12); covariate: pre-treatment score) indicated a statistically significant main effect of treatment on connection rate $F(1, 9.764) = 3.239$, $p= .04$. The main effect of the condition for the number of concepts used by subjects, however, was not significant $F(1, 10.302) = 1.596$, $p= .107$. This means that students in the treatment, TAMS ($M = .862$, $SE = .062$, 95% CI [.722, 1.001]) demonstrated a significantly higher connection rate than students in EAMS ($M = .701$, $SE = .064$, 95% CI [.560, .843]). However, TAMS students did not use significantly more concepts ($M= 4.062$, $SE = .220$, 95% CI [3.617, 4.506]) than students in EAMS ($M = 3.667$, $SE = .229$, 95% CI [3.203, 4.130]). For both analyses, the interaction of condition and pre-score were non-significant, which indicates the treatment effect does not depend on the baseline score.

The relatively high connection levels for TAMS suggests that treatment students integrated ideas in their explanations rather than talking about them in a disconnected way. We speculated that higher rates of connection among concepts may indicate that TAMS students engaged in more evidence gathering, synthesis, and transformation – all processes of higher-order thinking required to participate in online discourse around complex educational problems that are better understood through conceptual lenses from the learning sciences.

This speculation has been partially confirmed by further qualitative analyses of group interactions that are not reported here due to space limitations.

Scholarly Significance and Conclusion

Results indicate that TAMS was an effective intervention that influenced online student learning in positive ways. This suggests that direct argumentation training designed to fall within Toulmin's (1972) 'sweet spot' between generalizability and context can promote scientific literacy and deeper understanding in online course environments. This study thus contributes to our "cognitive roadmap" of the types of skills that should be developed to improve argument-based science pedagogy online (Kuhn, 2005, p. 116). Moreover, this study sheds light on an issue raised in a recent review of argumentation interventions in science classroom activities (Cavagnetto, 2010). Cavagnetto asserts that argumentation skills are best developed through immersive engagement with science. He recognizes, however, the need for systematically investigating efficient alternative approaches. The current study demonstrates that, at least for undergraduate learners in online discussion environments, a skill-based training approach has strong potential to improve subsequent meaningful learning of psychological science, promoting scientific literacy while addressing practical concerns of efficiency. Online argument training might be especially useful in relatively unsupervised massive open online courses (**MOOCs**), a recent development in distance education aimed at large-scale participation and open access via the web.

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