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EXAMINING THE TRANSFER OF LANGUAGE FROM SCIENCE TO MATH WRITING: AS AN EPISTEMIC TOOL

Ali Cikmaz

Yejun Bae

Brian Hand

Kyong Mi Choi

University of Iowa

ABSTRACT: The purpose of this study to examine how students transfer their language practices from science classrooms to math classroom in terms of writing activities. For this aim, 64 5th grade students, who were familiar with the SWH approach that supports multimodal writing from their science classrooms, participated in the study. The students were provided questions to complete a writing activity in their math classrooms in each semester. Multimodal writing samples from two consecutive semesters, and scores of Cornell Critical Thinking (CCT) Test, conducted at the beginning and the end of year, were collected. The findings suggest that students were able to use the writing and representational work from science classrooms to math classrooms, and across time from the first semester to second semester, they improved their math writings in terms of multimodality, and also, writing scores are also significantly predictor of final CCT scores. In conclusion, when students have a rich learning environment, in this context it was the SWH approach, they learn not only content knowledge but also how language can serve as an epistemic tool. It is this use of language that, we believe, is being transferred into new context and is improved by the time.

Key Words: Science writing, language, transfer of knowledge, critical thinking

INTRODUCTION

Transferring of Multimodal Writing from Science to Math learning

There is a significant amount of research on the use of writing to learn approaches in science during last few decades (Gunel, Hand, & McDermott, 2009). The aim of the writing to learn activities is to provide a learning milieu which promotes students critical thinking (Kieft, Rijlaarsdam, & Van den Bergh, 2008; Klein, Piacente-Cimini, &Williams, 2007; Zohar & Peled, 2008) and conceptual understanding (Holliday, Yore, & Alvermann, 1994). Findings of previous research show that including writing to learn activities in science classrooms can have beneficial outcomes on students learning regardless of grade level (Jaubert & Rebierre, 2005; Boscolo & Mason, 2001; Hand, Wallace, & Yang, 2004, 2004; Bangert-Drowns, Hurley, & Wilkinson, 2004). The focus of writing to learn approaches has begun to shift from a process where students need to not only produce text, to incorporate an emphasis on integrating text with various modes. When scientists and engineers communicate through writing, they employ diagrams, charts, symbols, equations by integrating with the text (NRC, 2012). The goal of core science practices is to construct understandings of the knowledge to represent and communicate science concepts. To achieve these goals, students need to do engage in these practices in a manner similar to what the scientist do in real settings. Therefore, students should be able to use charts, mathematics, drawings, and diagrams with integrating text (NRC, 2012). Multimodal representations need to be supported in science classrooms to promote science learning and communication of ideas.

The Science Writing Heuristic (SWH) approach, which combines inquiry and argumentation with an attention on language, employs writing-to-learn approaches by promoting multimodal representation during the writing

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*Corresponding author: Ali Cikmaz -icemstoffice@gmail.com

process. Previous research shows that SWH has a significant impact on students' achievement and Cornell Critical Thinking Test (CCTT) scores. When students engage with argumentation and writing practices in a language rich environment, they can have better results in reasoning and achievement rather than non-SWH classrooms (Chanlen, 2013). Chanlen's (2013) study highlighted that not only were benefits gained initially when implementing the SWH approach, with significant gains made each year of continual use. Further to these results, a recently completed RCT grant using the SWH approach at grade 3-5 showed that benefits are gained in the disciplines of mathematics and reading. Importantly, significant gains were also made in the rate of growth of critical thinking skills. Adey and Shayer (2015) have also emphasized the transferability of learning from one context into another context and situation. After they offered PD for intervention only in science classrooms, they examined results on not only science but also math and English test results. The findings shows that there is significant students' gains on all three area based on test results. Although the intervention was restricted to the science content, substantial gains were obtained in math and English.

These two studies described above examined and compared the transfer of learning across disciplines based on standardized tests. In this study, we would like to examine how students transfer writing gains from science classrooms to math classrooms. The questions guiding this study were;

1. Is there any transfer from science classrooms to math classrooms in terms of writing gains and multi-modality, although the intervention of SWH approach is restricted with science classrooms?

a. Does students' math writing improve across time? Is there any improvement in their math writing? If there is, which components of students' writing has improvement?

b. Is there any improvement in students' writing in terms of multi-modal representation?

2. Is there any correlation between CCTT scores and students' writings?

3. Does students' writing predict students' reasoning skills (Critical thinking)?

METHODS

Participants and Design

Participants are 64 5th grade students at a mid-west rural school. They were taught with SWH approach in their science classrooms, however the teachers were responsible for teaching them both science and mathematics. As part of their science experiences the students were required to engage in writing and using multimodal representation. To examine the transfer of use of these language opportunities the students were given a writing task as part of their mathematics classwork in each semester (fall'14 & spring'15). Besides writing, students had taken CCTT beginning and the end of the year.

The teachers involved in this study were previously rated as high implementers of the SWH approach. They agreed to continue to use the approach in science and to undertake to set the writing assignments in mathematics. They had not previously asked the students to do this type of writing exercise in mathematics and wanted to examine if the students were able to transfer the work in science in terms of writing and multimodal use into mathematics.

Table 1. Design of study

1st CCTT	1st Writing	2nd Writing	2nd CCTT

Coding

The rubric which was developed by McDermott (2009) was used as a base to analyze students' writings. The rubric was originally developed for science writings; therefore, it was modified for the requirement of math writings. The final form of rubric includes four categories: (1) text assessment, (2) overall cohesiveness, (3) general non-text mode analysis, and (4) individual mode analysis. Each category has subcategories that are presented in table 2 in detail.

Table 2. Coding Rubric

Text assessment	Assignment expectations	-Grammatically correct -Covered required topic -Accuracy of math concepts
	Audience considerations	-Appropriate language -Identified Key term
Overall cohesiveness	Text tied to alternative modes Alternative modes linked to each other Main conceptual idea continually addressed	

General non-text mode analysis	Non-Text Mode Type Total # of different types of Mode Frequency of use of modes Modes linked to Main Concepts	
Individual non-text mode analysis	Embeddedness strategy	-Type of Mode -Original -Caption -Relation with text
	Characteristic of mode	-Accurate -Conceptual Connection to Text -Mode is Self-Explanatory

The graduate students who scored the writing samples had previously used the rubric on scoring science writings. To analysis the math writings a series of steps were adopted to ensure inter-reliability. First, each scorer analyzed the same 10 samples with discussion following to discuss about the how to modified this rubric and to ensure inter-rater agreement was reached. Second, after agreement on modification, in each round, each student scored 20 samples independently and randomly selected 5 of the scorings to compare the results in terms of reliability. The coding and scoring was a dynamic and continuously in consensus throughout the process with an overall, inter-rater reliability 88% (Miles & Hubermann, 1994)

Analytic Approach

Descriptive analysis including means, standard deviations and participant numbers were calculated for each category of the writing samples. The group differences were examined by computing t-test for each code. By examining the difference we were able to determine whether there was a development on students' math writing across the time, and the transfer is occurred from science classroom to math writings.

Correlations between scores of writing samples and Cornell Critical thinking test (CCTT) scores were calculated. For the regression analysis, the CCTT scores were matched with students writing scores. The regression analysis provided a prediction for the second CCTT (end of year) and show if there was an impact of the first CCTT, first semester writing samples and second semester writing samples on the final CCTT score.

RESULTS

Research Question 1:

Independent t-tests for each category in rubric were computed to compare students writing samples from consecutive semesters. The results are presented in the table 3. Although there were no significant changes in text quality and characteristic of modes, overall cohesiveness, and number of modes have a statistically significant increase. However, the embeddedness of modes had a statistically significant decrease.

Table 3. Comparison of consecutive semester writings

		N	Mean	Std. dev.	P value
Text assessment	fall	64	6.08	1.45	.830
	spring	64	6.13	0.97	
Overall cohesiveness	fall	64	2.61	1.48	.000
	spring	64	4.06	1.74	
Number of modes	fall	64	1.27	0.45	.000
	spring	64	1.64	0.48	
Embeddedness	fall	64	2.19	0.69	.004
	spring	64	1.81	0.75	
Characteristic of modes	fall	64	2.77	0.82	.254
	spring	64	2.60	0.86	

Research Question 2:

The correlation between overall statistically significant categories and CCTT scores was calculated (Table 4). There is a significant growth in CCTT scores and writing scores ($p<0.001$). The correlation between first and second CCTT is high (.680). The correlation is getting higher from first semester to second semester writing scores. Second semester writing correlation with final CCTT is getting higher rather than beginning CCTT.

Table 4. Descriptive statistic for CCTT and Writing scores, and Correlations

	N	Mean	Std. Dev	Correlations		
Final CCTT	64	42.234	6.883	Final CCTT	Beginning CCTT	Fall Writing
Beginning CCTT	64	36.250	7.113	.680		
Fall Writing	64	6.063	2.088	.220	.043	
Spring Writing	64	7.516	2.558	.460	.297	.117

Research Question 3:

A multiple linear regression was calculated to predict students' CCTT scores based on their beginning CCTT, fall and spring writing scores. A significant regression equation was found ($F (3, 60) = 25.668$, $p < .000$), with an R2 of .562. Students' predicted CCTT score is equal to 12.757 + .575 (beginning CCTT) + .539 (fall writing) + .712 (spring writing). Both beginning CCTT ($p<.000$) and spring writing ($p=.005$) were significant predictors of final CCTT. Fall writing ($p=.062$) trended toward significant.

DISCUSSION

This study examined the transfer of learning that promotes multimodal science writing into math courses. The students were familiar with having to use writing and multimodal representations as part of science but not as part of the normal mathematics instructional approach. The results would appear to indicate that students were able to using the writing and representational work from science classrooms to math classrooms. Across time from the first semester to second semester, they improved their math writings in terms of overall cohesiveness of writing, and number of modes, although their embeddedness of modes slightly decreased. A possible explanation for this decrease in embeddedness may be nature of the mode they added to use in second semester writing samples. In the first semester, the common mode the students used was equations. We believe that mathematical equations require more connection to the text in order to explain the function they are describing. However, in the second writing task the students added drawings to explain the topic. Drawings, as their nature, can be self-explanatory; thus, this can be a reason for decreasing in the embeddedness.

There are similar increases between growth in students writing and CCTT scores. These parallel results may be explained by previous work that indicates that students' reasoning skills can improved by improving writing skills (Norton-Meier, Hand, Hockenberry, & Wise, 2008). We believe that learning is a negotiation process and writing is also negotiation because it is a learning tool. During the writing process, an individual negotiates with him/herself between his/her prior knowledge and encountered knowledge. This process requires the use of reasoning skills. Multimodal writing is not only simple writing, it requires more negotiation to integrate mode to text, so it requires a higher level of self-negotiation. Thus, we would suggest that growth in multimodal writing skills can support growth in CCTT scores. Besides t-test analysis, Regression analysis also support this idea by showing both of the writing tasks are significant predictor of final CCTT scores.

As a conclusion, if the students learn with understanding, which is the main goal of the SWH approach, they can transfer their learning into new context when appropriate tasks are provided. In this study, the students were taught by teachers who are high implementers of the SWH approach in science classrooms, we believe that students learned with understanding, and were more aware of the critical role of language in the learning process. The students were transferring their development of language as an epistemic tool into a new context: math courses. This resulted in them developing more sophistication on multimodal writing in newer contexts.

Limitations and Implications

This study was conducted in only one school district and all the students were familiar with SWH; therefore, there is no control group to compare the CCTT scores. Because the maturation can be an important factor for increasing in the CCTT scores, firm causal claims are difficult to make in this conditions. Moreover, the size of data should be larger than the number that is used in this study. The planned number was larger than 150 students, but in nature of data collection procedure, the number was decreased.

One important implication of this research is that when students have a rich learning environment, in this context it was the SWH approach, they learn not only content knowledge but how language can serve as an epistemic tool. It is this use of language that we believe is being transferred into new context and is improved by the time.

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