Language, Identity, & the Stress of Learning Science Language

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Science language has been conceptualized as a hindrance to students’ learning. Research on the challenges of learning science language varied from examinations of the complexity of language to explorations of the identity implications of using science discourse. This study adds to the existing body of research by examining how science language may have a socio-affective impact on students. Through a quasi-experimental study of N=56 students we used two psychological measures, Stroop Tests and Flanker tests, to measure if using complex language has a socio-affective impact.
Students were randomly assigned to two conditions. Control group students watched an instructional video on the water cycle taught using complex science language. The Experimental group students watched the same video with simple language explanations. The results showed that there was no significant difference in students’ ability to answer the questions correctly. Conversely, statistically significant findings were found in the rate of students’ responses on complicated items. When students needed to answer questions with an increased cognitive load, students in the experimental group (everyday language condition) answered significantly faster. These results implicated the manner in which complex science language limits students’ cognitive capacity on complex cognitive tasks.

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Over the past thirty years, the science education community conducted a wealth of research on the ways language learning matters in science classrooms (Baker & Saul, 1994; Fang, 2005; Keys, 1999; Lee, 2001; Rincke, 2011).

The diversity of research on this topic ranges from studies about the patterns of language meanings (Arons, 1973; 1983), to studies of the volume of new word acquisition (Arons, 1973; 1983), to studies of the types of words learned (Wellington & Osborne, 2001), to the cultural conflicts associated with learning science language. Collectively, these studies paint a picture of classroom based science language learning as a complex and often under-estimated experience.

One of most thoroughly understood aspects of research on science language involves our collective understanding of the complexity of language. Lemke’s (1990) seminal research on the thematic patterns of science discourse introduced the research community to an understanding of the hidden curriculum that is science language learning. Halliday & Martin’s (1994) research continued the narrative about the intended rhetorical value of science discourse, by revealing the very complex and functional rhetorical structure of written discourse. Where these perspectives find common ground is in their ability to elucidate the good and bad of science language. In one way, science language has a complex structure that helps sustain an international science community. On the other hand, the complex nature of science discourse generates unique learning problems.
Common language problems

As research on science language expanded, our knowledge about the complex problems with learning science language improved. Baker’s research highlighted how learning science in a first year Biology course often included more new terminology than a new Spanish course (Baker, 1994). Wellington and Osborne (2001) highlighted how students often conflated the meanings of words that had alternative meanings in science contexts. Others added to this discourse by highlighting how the language of science represented a cultural conflict for many minority students’ engaged in science classes (add Brown). Together, each of these perspectives highlights how the language of science can limit students’ cognitive development if teachers are not aware of these very real language-learning dilemmas.

Where these studies can be further enhanced is through the development of a more detailed understanding of the socio-affective interactions that are produced by using complex science language. In the same way that raising one’s voice or using harsh language produces an affective response from the listener, science educators have little to no research evidence about the socio-affective impact of reading complex discourse or being lectured through complex science discourse. This white paper outlines a recently completed study that examines how students are impacted in both a cognitive and socio-affective sense by the use of complicated science discourse.

Theoretical Framework

Language Identity Dilemma

Our theoretical framework attempts to synthesize the cognitive and socio-affective implications of learning science into a single theoretical lens. Know as the Language Identity Dilemma, we contend that learning science language presents teachers and students with a challenge that is cognitive and socio-affective in nature. From a cognitive perspective, learning new ideas in a new language can confound the learning process. If a student is reading
Science text or hearing scientific explanations, understanding the content hinges on how well they can process the ideas being expressed. The results of an overtly complicated explanation are a failure to understand the concept being taught. From a socio-affective perspective, if students are involved in reading complex texts or hearing a scientific explanation in a complex language, we contend that they can feel a sense of conflict or feel like science is not a place for them. Together, this cognitive and socio-affective challenge is a critical hurdle for science learning.

The question remains, how is this operationalized in the classroom experience of students? Cognitive scientists have identified how human cognition is guided by a memory system that actively stores visual and verbal representations (Mayer, 2009). This working memory capacity, or W.M.C., is limited by physiological structures, which require the human brain to store only vital information. It is for this reason that small details are rarely retained in our memories, while important information (e.g. our phone number, emails, or addresses) is stored for future retrieval. Psychologists have identified how being exposed to stress can limit one's ability to retain information (Klein & Boals, 2001). Those who are experiencing psychosocial stresses are less capable of performing complex cognitive tasks. If an individual is under the stress of losing a loved one, it can be safely assumed that their capacity to engage in complex memory tasks would be reduced. A proportion of their WMC would be dedicated to addressing the stressor and thus, unavailable in pursuit of the cognitive task.

This work has found popular appeal in the context of exploring the impact of Racism. Steele (1991) provided the research community with a fascinating vision of the impact of this perspective as he used awareness of stereotypes as the primary form of a stressor. Steele’s Stereotype Threat research cued students to be aware of the existence of racial stereotypes and found that students performed worst on tests compared to those who were cued...
positively. Ambady (2001) added additional depth to this line of research as she manipulated stereotypes in both positive and negative directions to find that stressors could be highlighted and removed in ways that could either limit WMC or free it from stress producing influences.

This manuscript attempts to make the theoretical leap from stresses and limited WMC in psychological contexts to understanding how the use of complex science discourse may serve as a stressor and limit WMC. In adopting the years of research on WMC, we contend that science taught with complex science language can generate additional stress for minority students. If students are given complex cognitive task after being introduced to science discourse, we assume that those being taught with complex language would experience more stress and be less able to complete the complex tasks. Ultimately, this project seeks to examine the socio-affect aspect of the language identity dilemma by assessing whether being taught in complex language produces psychological stress for minority students.

**Design**

To explore this phenomenon, we used a two-group quasi-experimental design. Figure 1, provides a representation of the design. We randomly assigned students to either the control group (simple language) or the treatment group (complex language). All students were provided a pre-test to measure their content knowledge prior to instruction. After the watching a video explaining the water cycle, with either simple or complex language, students were given to three measures to determine the impact ($O_2$).

**Figure 1. Representation of the research design**

We used 3 types of measures to determine the differential effects of the complex language. First, we used posttest comprised
of free released NAEP items to measure any potential differences in student’s cognition.

Second, we used a Stroop test to determine the impact on students’ working memory capacity. The Stroop test is a psychological measure used to assess cognitive interference (Cohen, Swerdlik, & Sturman, 2012). Designed by John Stroop in 1935, the test allows researchers to assess cognitive interference by showing the name of colors written in a number of different colors. For example, the word Red could be written in Red, Blue, Yellow, or Green. When Red is written in RED, the student would press the “R” key, when written in Green, they would press the “G” key. An individual’s ability to perform this task is associated with cognitive processing, which can be hindered by stress.

“An individual who is under stress would be less likely to manage their cognitive resources and answer the questions correctly.”
Third, we also used a Flanker test to measure potential stress. The Flanker test is similar to the Stroop test on its basic premise. The flanker test, derived from Eriksen Flanker in 1974, measure an individual’s ability to suppress wrong answers in favor of appropriate ones. For example, students are asked to pick the direction of the arrow, “↖”, that is embedded in contradictory arrows, “↘”. Similar to the Stroop test, an individual who is under stress would be less likely to manage their cognitive resources and answer the questions correctly. Collectively, these measures allowed us to isolate the impact of language instruction on both content understanding and socio-affective stress.

This project was conducted with students age 15-18. These African-American and Latino students are participants in Level Playing Field Institute summer institute. These minority students attend a diversity of high schools of low SES throughout the San Francisco Bay Area. There were 29 males and 31 females. The racial background of the participants was diverse; there were 36 Hispanic students, 32 African-American students, 1 Pacific Islanders, and 3 multi-racial students.

As students arrived in our laboratory, we randomly assignment to computers pre-programmed with either the control or treatment software. All the images and questions in the software were identical with exception of the language used to explain the concept, the water cycle. After viewing the videos embedded in the software, students were given the Stroop and Flanker tests, while the content test were embedded in the software itself. The second that follows provides an overview of the results of the study.
Findings

The results of this study provide evidence that the complex language of science is not only difficult to understand, but can also serve as a stressor that limit students’ cognition. Although the students’ ability to answer the Stroop and Flanker questions correctly did not differ, significant differences were found in students’ ability to answer complex tasks quickly.
Both the Stroop Test and the Flanker test, embed contradictory items in the question process. For example, the word red will be written in blue ink, or for the Flanker test an arrow pointing left to right (←) will be embedded in a large number of arrows facing right to left (→). In both tests, these types of items reflect complex tasks that require cognitive focus to answer quickly and accurately. It is in these questions where the use of complex language was found to limit students’ ability to answer these questions quickly. These results would indicate that the use of complex science discourse could serve as an intellectual stressor.

**Stroop Test Results**

The overall results of the Stroop tests represent a mixed message about the impact of complex language on students. Although there were question types where students from the control condition (*complex language*) performed worse than their experimental group counterparts, there were instances where the control group performed better and none of the findings emerged as statistically significant.

Table 1 provides an overview of the results the initial analysis. As indicated in Cell (A-1), the control group’s mean percentage scores of 94.739 are nearly identical to the experimental group’s mean score of 94.155(Cell A2).

<table>
<thead>
<tr>
<th></th>
<th>Stroop (%Correct)</th>
<th>Stroop (Congruent)</th>
<th>Stroop (Incongruent)</th>
<th>Flanker Mean (% Correct)</th>
<th>Flanker Mean (Congruent)</th>
<th>Flanker Mean (Incongruent)</th>
</tr>
</thead>
<tbody>
<tr>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>94.739</td>
<td>1195.040926</td>
<td>1454.7115520</td>
<td>95.4688</td>
<td>724.55969</td>
<td>896.93241</td>
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<tr>
<td>2</td>
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<td>1103.212963</td>
<td>1449.1225926</td>
<td>96.6129</td>
<td>650.27290</td>
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</tr>
<tr>
<td><strong>Experimental Group</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

This is indicative of the fact that the language of instruction had no effect on students’ ability to accurately answer questions from either test. The data that emerges as most interesting is the impact of language on student’s reaction rate. The results of the Stroop Tests and the
Flanker test highlight that although the students’ answer at a similar rates the students in the experimental group demonstrated faster reaction rates on all measures. Such a finding indicates that students’ cognitive capacity was potentially limited by the independent variable; the nature of science language.

Figure 2 provides an overview of the data regarding the rate of response as measured in milliseconds. It highlights how on all the items, the students in the experimental group were able to answer the questions and recognize the patterns faster than their control group counterparts. This highlights an intriguing pattern that emerged. Our congruent items are unique because of the manner in which the cognitive task is less complex. Said differently, in congruent item the color written matches the color it is written in and the arrows are pointed the same direction as the other arrows. As indicated in Figure 2, the control group is slower to respond on these items. These differences are even more profound on incongruent items. These are items where the cognitive task is even more complicated. So the color of the letters in the word do not match the color the word states (i.e. “Red” written in blue). Similar, the incongruent Flanker items presented the greatest challenge as the arrows that students have to identify are embedded in a sea of arrows point a different direction. It requires additional focus to identify the direction.
The most intriguing results emerged in reviewing the t-test scores from Flanker test. Although, we conducted t-tests on all our assessment measures, we found that students’ cognition was dramatically limited on incongruent items.

Table 2. Flanker Test t-test results

<table>
<thead>
<tr>
<th>Descriptive Stat Type</th>
<th>Control Group</th>
<th>Experimental Group</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>A</td>
<td>B</td>
</tr>
<tr>
<td>1</td>
<td>Mean</td>
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<tr>
<td>2</td>
<td>SD</td>
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<tr>
<td>3</td>
<td>SEM</td>
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<tr>
<td></td>
<td>N</td>
<td>29</td>
</tr>
</tbody>
</table>
These are items where the direction of the arrow demonstrated a pattern contradictory to the arrow students were required to recognize. Simply said, when the cognitive complexity was increased students from the control group were consistently slower. More importantly, there was a large statistical significance on the incongruent Flanker items. We conducted a two-tailed t-test with a p value equaling p = 0.0050 Using a 95% confidence interval ranging from 77.37480 to 415.94422 this data is considered to be statistically significant by conventional criteria, this difference is considered to be statistically significant. The intermediate values used in the calculations were a t value of t=2.9166 with 58 degrees of freedom and a standard error distance of 84.570. Ultimately, this suggests the language of instruction to have a profound impact on students’ affective response rate.
Conclusion & Contribution to NARST

This research project documented how language has an impact on students that extends well beyond students’ learning alone. Cognition is an intellectual domain that has both schematic and affective aspects. Years of research on teaching and learning in science have indicated that learning language has limited students’ capacity to learn.

This manuscript contributes an additional aspect to this discourse by identifying the potential impact of language on students’ socio-affective capacity. Although this study is a new line of inquiry, it has the potential to highlight how using culturally specific language important for students learning and their capacity to reason.
Literature Cited


Journal of Science Education, 33, 229-258.

