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About the Journal

Founded in 2013, the Journal of Teacher Action Research (ISSN: 2332-2233) is a peer-reviewed online journal indexed with EBSCO that seeks practical research that can be implemented in Pre-Kindergarten through Post-Secondary classrooms. The primary function of this journal is to provide classroom teachers and researchers a means for sharing classroom practices.

The journal accepts articles for peer-review that describe classroom practice which positively impacts student learning. We define teacher action research as teachers (at all levels) studying their practice and/or their students' learning in a methodical way in order to inform classroom practice. Articles submitted to the journal should demonstrate an action research focus with intent to improve the author's practice.

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EXAMINING THE EFFECT OF LANGUAGE-BASED INSTRUCTIONAL INTERVENTIONS ON ELL AND NON-ELL LANGUAGE PRODUCTION AND TASK-ORIENTED BEHAVIOR IN ELEMENTARY MATH, SCIENCE, AND SOCIAL STUDIES CLASSROOMS

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Abstract As the population of K–12 English language learners (ELLs) grows, teachers are challenged to employ strategies that efficiently promote content-learning and language-learning. This paper reports an action research project investigating the effects of three consecutive instructional interventions on student language production at a suburban elementary school. Teachers identified a problem of practice, consulted scholarship for intervention design, and conducted collaborative action research in science, mathematics, and social studies classes. Participants included grades 2–4 ELL and non-ELL students. Data was collected using a modified version of Soto's ELL Shadowing Protocol Form (2012), monitoring frequency of student-speaking, teacher-speaking, student-listening, and on- and off-task behavior. Quantitative analyses found that utilization of message abundancy, 'tasks that require talk,' and stretched language positively impacted student language production and on-task behavior. Statistically significant differences were found in mathematics language production for both ELL (Intervention 1 to 2 $p=0.0028$; Overall $p=0.0023$) and non-ELL students (Intervention 1 to 2 $p<0.0001$) and in task-oriented behavior in science and social studies for non-ELL students (Baseline to Intervention 1 and Overall $p<0.0001$). Differences between ELL and non-ELL students for both language production and on-task behavior narrowed with time, suggesting that the interventions employed equalized student behaviors.

Keywords: teacher action research, English Language Learners, language production, action research, message abundancy, complex tasks, elementary, mathematics, science, social studies

Introduction

The population of English language learners (ELLs) in public schools is increasing at a rapid rate (U.S. Department of Education, 2017). Statistics vary across the nation, but in Minnesota alone, the number of ELL students has increased 300%—making them the state's fastest growing student population (Minnesota Department of Education, 2016). As a result, educators are challenged to find strategies that promote learning in an increasingly diverse student body.

Integrated Science Education Outreach (InSciEd Out) is one program working within Minnesota to promote educational excellence for all students. It achieves this goal by fostering a culture of change that emphasizes student-driven scientific inquiry and health literacy (Pierret, Sonju, Leicester, Hoody, LaBounty, Frimannsdottir, & Ekker, 2012; Yang, LaBounty, Ekker, & Pierret, 2016). One arm of InSciEd Out, the Gold Master Collaborative, supports teams of teachers as they conduct action research in their classrooms to improve student learning around identified areas for growth. In the fall of 2015, InSciEd Out's teacher partners from City Elementary School (a pseudonym) in Minnesota entered into the Gold Master Collaborative to critically analyze their curricula for reaching all students. The teachers identified a "problem of practice" unique to their school's context to be examined via instructional rounds (City, Elmore, Friarman & Teitel, 2009, p. 102). The problem cited was a culture of low expectations for ELL students that appeared to contribute to a discrepancy in math and science achievement between ELL students and their English-speaking peers (non-ELLs). In particular, teachers noted that ELL students were often "given a pass" when it came to science and math education due to the complexity of academic language unique to these disciplines. Less was expected from ELLs in spoken and written form because the dual demands of learning the language *and* the content seemed too rigorous. Teachers recognized that this "pass" may impede students' proficiency in math and science and sought to interrupt the pattern in ways that could extend to other disciplines and would not be detrimental to non-ELL student learning.

The purpose of this study was to strengthen the instructional core for ELLs (and all students) by increasing student language production. The project addressed the following research questions:

1. How effective are the interventions of message abundancy, tasks that require talk, and stretched language at increasing ELL and Non-ELL language production in mathematics, science, and social studies classes?

2. How effective are these interventions at increasing task-oriented behavior?

Literature Review

Academic Language. Current trends in academic standards have recognized the essential role language plays within teaching and learning. The Common Core Standards for Math and English Language Arts (National Governors Association, 2010) and the Next Generation Science Standards (2013) explicitly address ways in which speaking, listening, reading, and writing impact content learning. Researchers have consequently begun to investigate what these new standards mean for ELLs and the teachers facilitating learning in their classrooms. Many have identified theoretical and practical recommendations (Santos, Darling-Hammond, & Cheuk, 2012; Quinn, Lee, & Valdés, 2012; Lee, Quinn, & Valdés, 2013). Even with the recommendations in place, an analysis of National Assessment of Education Progress data from 2003 to 2013 found the difference between ELL and non-ELL student achievement to be the largest disparity between subgroups of students studied, and one that has increased over time (Carnoy & Garcia, 2017; National Assessment of Educational Progress, 2018). While education policy specifies educators should address the relationship between content- and language-learning in their classrooms, bringing theory to practice remains a challenge. A gap between theory and practice is especially evident in the fields of mathematics and science (Moschkovich, 2012; Santos et al, 2012; Quinn et al, 2012). Careful selection of techniques to highlight the role of language in learning is needed to bridge this gap. Three areas of focus addressed in this study are: message abundancy, language production, and complex tasks. Each was selected because of its established potential for influencing ELLs' reception and production of academic language (Cohen & Latan, 2014; Gibbons, 2015; Hammond & Gibbons, 2005).

Message Abundancy. Message abundancy builds learners' understanding through the deliberate use of multiple modes of communication to convey the same information (Gibbons, 2015). Often, information presented via teacher-talk is delivered at a pace that students, particularly ELLs, find difficult to keep up with. Message abundancy allows a learner to receive comprehensible input multiple ways, thereby increasing the odds that the conceptual or procedural knowledge is, in fact, understood (Hammond & Gibbons, 2005; Krashen, 1982). Use of message abundancy supports students' understanding of language, content, and the symbiotic relationship between language and other forms of meaning that mediate teaching and learning (Hammond & Gibbons, 2005). Resultant meta-awareness equips students with strategies to decode language using other modes of meaning when faced with linguistic uncertainty (Hammond & Gibbons, 2005).

Language Production. In addition to understanding what is being taught, learners need opportunities to produce the language utilized within a teaching and learning session (Gibbons, 2015; Goldenberg, 2013). Swain (2000, 2005) refers to this as comprehensible output. Studies have found that speaking is the foundation of literacy for all learners, advising that ELLs be given opportunities to use extended stretches of language in order to become proficient in reading and writing (Soto, 2012). Historically, the ratio of teacher-talk to student-talk within teaching and learning sessions has been grossly disproportionate; teachers tend to out-talk students, which can have a direct impact on student learning. Flanders (1970) found that teachers of high-achieving students spend 55% of the time talking, compared with 80% in teachers of low-achieving students. More recent data suggest that there is still much room to increase language production in classrooms. One study found that fifth grade students spend 91.2% of their time in whole group or independent settings (Pianta, Belsky, Houts, & Morrison, 2007). Researchers have yet to develop systematically sound measures of student language production.

Complex Tasks. Embedding opportunities for language production requires thoughtful design of learning tasks. Research has established that well-designed group work affords students more opportunities to interact with speakers, practice language production, and refine meaning, when compared with whole-class discussions (Cohen & Lotan, 2014; Gibbons, 2015). Historically, ELLs have often been subjected to less-rigorous tasks that limit their ability to make content- and language-learning gains (Gibbons, 2015). Lower expectations leave ELLs unable to make the gains necessary to achieve academic equity from a language- and content-learning perspective. This can hold students in a static state of being ELLs (Olsen, 2010). Careful construction of complex tasks that require language production promotes both language- and content-learning (Gibbons, 2015; Hammond, 2008).

Methodology

Setting and Participants. This study utilized collaborative action research by a team of educational professionals and scientists. The action research team consisted of three elementary teachers, one ELL specialist, one Magnet School Coordinator, one educational researcher, and two scientists. The study was conducted in a suburban elementary school located within the Midwest region of the United States. At the time of the study, City Elementary School had approximately 394 students, with 31.3% of the student population identified as ELL. Participants included students from three classrooms: one second grade, one third grade, and one fourth grade ($N = 53$). Both ELLs and non-ELLs were included in the study. Consent was attained via parent-teacher conferences at the beginning of the school year. While *all* students participated in the lessons being studied, only students with signed consent forms were formally observed and included within data analysis.

Instructional Interventions. The project employed three interventional strategies: message abundancy, tasks that require talk, and stretched language. The strategies were selected in an effort to create high-challenge, high-support learning opportunities which previous research established as effective (Gibbons, 2008; Gibbons, 2015; Hammond, 2008; Thomas & Collier, 1999; Walqui, 2007). Additionally, these strategies were chosen because they made learning objectives clear, required students to produce language in vernacular discourse, and challenged students to produce language using discipline-specific academic discourse. The curriculum to which the instructional strategies were applied was the same as that which would have been taught if the project were not taking place. The delivery method, not the content, was the intervention being studied. Interventions were deployed on a monthly basis.

Message Abundancy. Message abundancy indicates that the concepts and procedures taught during math and science or social studies lessons were presented through at least three forms of modality. During the intervention, input portions of each lesson conveyed meaning through textual, pictorial, gestural, and/or spoken language. Lessons were video-recorded to ensure the strategy was utilized as intended. Math lessons occurred daily, while science and social studies alternated during a shared block. For analyses, science and social studies are grouped to represent equivalent time.

Tasks that Require Talk. Tasks that Require Talk provided opportunities for students to produce oral language during math, science, and social studies classes. The intervention made use of carefully constructed group tasks. The tasks utilized within the intervention were inquiry-oriented and included an information gap that required oral communication between group members. This followed recommendations that a group task should "*require*, not simply *encourage*, talk" and that tasks should be cognitively complex to engage students around the content of focus (Gibbons, 2015, p. 56).

Stretched Language. Stretched language is language beyond students' current linguistic capabilities; it can be specific vocabulary that is unique to subject-area disciplines, but can also refer to the way language is organized, utilized, and valued within a particular academic discipline (Gibbons, 2015; Swain, 2000). For example, scientific discourse values the role evidence plays in substantiating theories or explanations. Without explicit rehearsal of this concept, the value of evidence can be lost when students draw conclusions. Using a 'Give One, Get One' template (Give One Get One, 2018), students were challenged to complete the following sentence frame: "*Our conclusion is _____. The evidence that supports our conclusion is ____."* In this instance of language production, both the academic language and the implicit values of science are strategically scaffolded and rehearsed. Students are stretched beyond simply stating a conclusion to also substantiate that conclusion with a body of evidence.

Data Collection. To measure the interventions' effects on language production and task-oriented behavior, trained observers used a modified version of Soto's (2012) "ELL Shadowing Protocol Form" (p. 119).

Modified ELL Shadowing Protocol. Soto's protocol was designed to follow one ELL student across the arc of an entire school day, monitoring academic speaking, academic listening, and on- or off-task behavior. The modified tool utilized within this study (Appendix A) monitors similar data but allowed ten students to be observed during a single lesson by focusing two observers' attention on an assigned student's behavior at the top of each minute and rotating each observer through a set of five students every five minutes.

Observation Logistics. Students were observed in each classroom at baseline (no interventions) and at the end of each intervention period. A team of two observers was placed in each classroom to collect data during two separate 30-minute lessons for math and science or social studies classes. During a lesson, each observer monitored five students total. At the top of every minute, the observer recorded details regarding language production, listening, and on- or off-task behavior for the student assigned to him/her for that minute. Observation rosters were carefully constructed such that one ELL and one non-ELL student were observed at the top of each minute. The paired nature of this set-up worked to ensure that variability in response to instruction was not a product of differences in what was happening during the lesson, but rather a product of student response to the same opportunity to learn.

Student Sampling. It is worthwhile to note that there was substantial, but incomplete, overlap between the students observed from intervention to intervention. This is a product of the natural student flow within any classroom environment. Respective sample size numbers are thus provided in each supplementary table to give context to results presented (Appendix B).

Metrics. Each preceding intervention served as the new point of comparison for subsequent interventions (Baseline vs. Intervention 1; Intervention 1 vs. Intervention 2; Intervention 2 vs. Intervention 3), and overall change was also analyzed (Baseline vs. Intervention 3). Language production was analyzed as percent student speaking, which was calculated by dividing the summed observational counts of student speaking by total speaking (student plus teacher). In this manner, percent student speaking can be used as a rough estimate of time spent speaking. On-task behavior was calculated for each student by subtracting observational counts of off-task behavior from five (the total number of observations per student). Total on-task behavior divided by the total number of observations then calculated percent on-task.

Data Analysis. The observational analysis tool used counts of student and/or teacher actions rather than the number of students themselves as a benchmark for data. Unmatched analyses were conducted because total numerical values for student and/or teacher actions were not normalized to a singular possible number. For instance, neither "Student Speaking" nor "Teacher Speaking" could be occurring at the time of each observation (i.e. student is reading, writing, or listening to a video). Statistical tests for categorical data were employed to determine statistical significance of study results. Language production analyses utilized Pearson's Chi-squared, whereas on- or off-task behavior was analyzed by Fisher's Exact Test due to small expected cell counts. Pearson's Chi-squared was also used for initial analysis on the full spread of data to measure potential differences across all time periods (interventions) and ELL/non-ELL students simultaneously. Only one set of observations of each student was included for each intervention for consistency.

Data collected using the observation tool were analyzed in JMP Pro 13 (SAS; Cary, North Carolina). The threshold for significance was p=0.05 for the full spread and p=0.0042 (p=0.05/12) for pairwise comparisons after Bonferroni correction. Four comparisons on each data set looked for differences between ELL and non-ELL students at each intervention level (including baseline). Six additional comparisons probed for changes within both student cohorts from intervention to intervention. Finally, the two remaining comparisons analyzed changes in both groups from baseline. Any other possible pairwise comparisons were not statistically analyzed and are not reported in any tables or figures. Fisher's results presented are two-tailed *p*-values.

Results

Initial statistical analyses conducted on the full spread of data revealed statistically significant differences in math language production ($p<0.0001$), task-oriented behavior in math ($p=0.0325$), and task-oriented behavior in science and social studies ($p<0.0001$) when comparing pre- and post-interventions. Changes in science and social studies language production ($p=0.1659$) were not significant. Due to significant variation in three of these analyses, pairwise sub-analyses were warranted. Detailed results with exact counts, percentages, and *p*-values are provided in Figure 2.

Language Production. No statistically significant differences were observed in science and social studies language production over time (Figure 1). Non-ELL student speaking percentage remained fairly constant from baseline across all interventions. ELL students' speaking percentage dropped between baseline and the end of Intervention 1 (Baseline: 59.46%; Message Abundancy: 35.14%) but was rescued by the end of intervention 3 (Stretched Language: 54.29%).

In comparison, math language production was lower at baseline and showed more variation across interventions over time (Figure 2). The increase in student speaking percentage from intervention 1 (Message Abundancy) to intervention 2 ('Tasks that Require Talk') was particularly significant for both ELL ($p=0.0028$) and non-ELL ($p<0.0001$) students. In fact, this increase from baseline remained statistically significant for ELL students overall ($p=0.0023$). Gains in math language production elevated students to levels comparable to that observed in science and social studies language production by the end of the study.

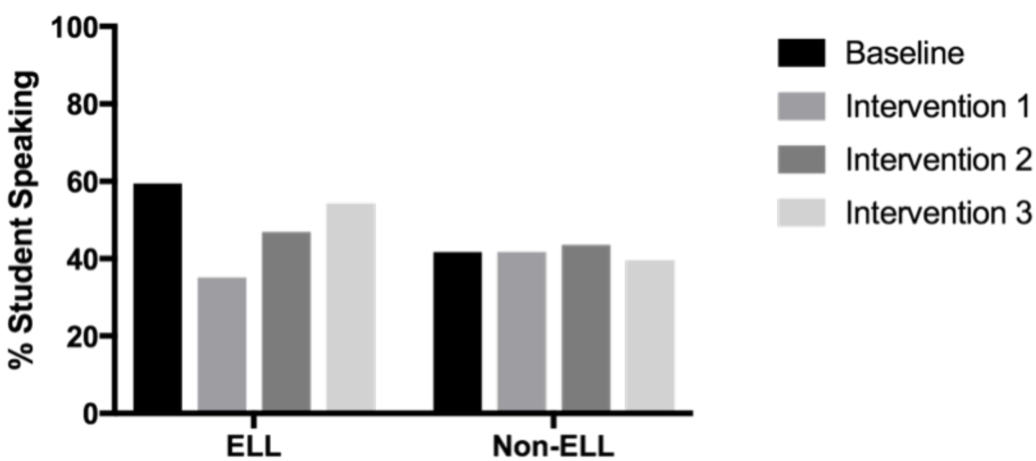

Figure 1: Science / Social Studies Language Production Analysis

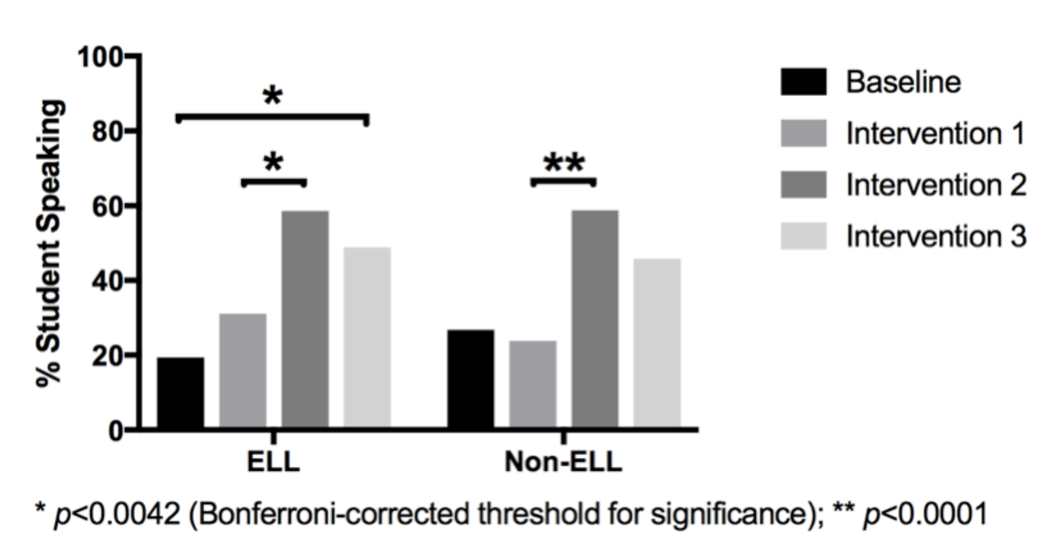

Figure 2: Math Language Production Analysis

Task-Oriented Behavior. On-task behavior in science showed a general upward trend over time (Figure 3). There were no statistically significant differences between ELL and non-ELL students at any given time point across the interventions. Non-ELL students' percent on-task behavior did increase significantly ($p<0.0001$) from baseline to the end of intervention 1 (Message Abundancy). The overall effect of all interventions upon non-ELL students' on-task behavior was also significant ($p<0.0001$).

There were no statistically significant differences in task-oriented behavior in mathematics (see Figure 4). Non-ELL student on-task behavior was much higher at baseline in math (92.86%) than in science and social studies (78.62%) and moderately higher than ELL students' math on-task percentage (84.21%). Percent on-task increased marginally across all interventions for ELL students. Non-ELL student on-task percentage followed a similar pattern for intervention 2 (Tasks that Require Talk) and intervention 3 (Stretched Language).

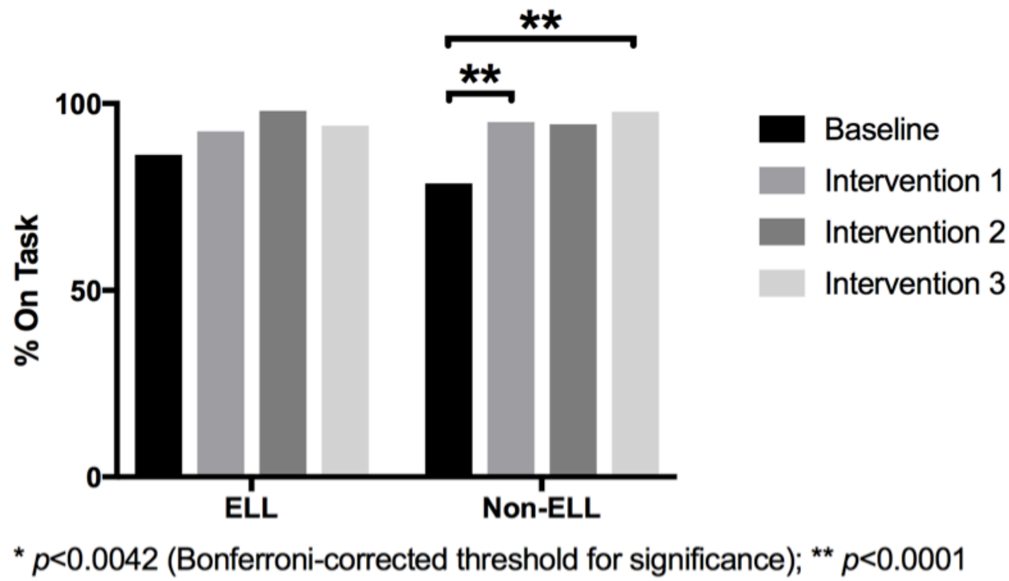

Figure 3: Science / Social Studies On-Task and Off-Task Analysis

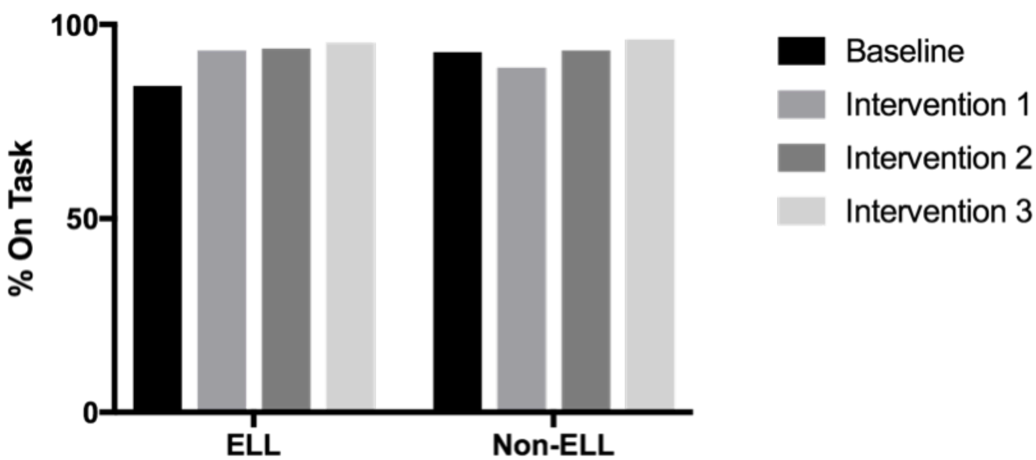

Figure 4: Math On-Task and Off-Task Analysis

Discussion

Language production strategies appear to have had a positive impact overall upon both language production and on-task behaviors for the students in the study. Language production effects are particularly noticeable in math for both ELL (overall $p=0.0023$) and non-ELL students, due in part to a comparably lower baseline in mathematics than in science and social studies. On-task behavior generally trended upward over time, especially for non-ELL students in science and social studies (overall $p<0.0001$), and was high at baseline across the board, particularly for non-ELL students in math (92.86%). Differences between ELL and non-ELL students for both language production and on-task behavior were most pronounced at baseline but narrowed with time, suggesting that the interventions employed equalized student behaviors.

Message Abundancy. Intervention 1 did not appear to be particularly effective for language production, as it greatly reduced ELL student percent speaking in science and social studies (-24.32%) and only had a minor positive effect for ELL students in mathematics. However, the intervention did generally increase on-task behaviors in science and social studies and for ELL students in math (non-ELL science and social studies % on task $p<0.0001$). Teacher perception following intervention 1 predicted these outcomes. All three teachers perceived that the instructional time given to message abundancy took away from time for students to talk. However, they also perceived that the clarity of instruction led to increased and sustained participation by students. As a result, the team worked to refine the manner in which message abundancy was facilitated to make time for more student-talk. Notably, when message abundancy was coupled with 'Tasks that Require Talk', student language production (both ELL and non-ELL) showed a statistically significant increase in math. This suggests that instructional efforts to ensure accessibility of conceptual and procedural knowledge increase the likelihood that students will engage and remain on-task. This has valuable insight to offer general elementary educators and ELL teachers.

Tasks that Require Talk. Intervention 2 made improvements to student language production across the board, partially reversing intervention 1's dip for ELL students in science and social studies and was statistically significantly improving both ELL ($p=0.0028$) and non-ELL ($p<0.0001$) students' percent speaking in math. The intervention also maintained similar levels of on-task student behavior across all groups. Results from this intervention are important because people learn language by using it (Gee, 2008; Halliday, 1993; Vygotsky, 1986). Using language requires both consumption (listening/reading) and production (speaking/writing) (Gibbons, 2015; Krashen, 1982). Tipping talk-time in favor of students necessitates careful attention to the kinds of tasks students are engaged in during teaching and learning sessions. As City et al. state, "The task predicts performance" (2009, p. 30). The tasks that students spend their time engaged in during an instructional session are the best predictor for what students will know and be able to do. Requiring students to listen will build only those skills, but requiring production of discipline-specific discourse will yield students capable of just that. Utilizing tasks that require students to produce language (vernacular and academic alike) throughout the lesson increases students' interaction with both content- and language-learning.

Stretched Language. Intervention 3 had mixed effects upon student language production but generally maintained on-task student behaviors. It continued the trend of reversing intervention 1's ELL science and social studies language production dip but resulted in decreased percent student speaking for other comparisons that were not statistically significant. A possible explanation for the measured decrease in student speaking is incongruity between the observation tool and the protocol of the stretched language task. 'Give One, Get One' prompts were designed to encourage student production of stretched language, both qualitatively and quantitatively. When a student was 'on,' s/he shared a response to each of the sentence frames that comprised the 'Give One, Get One' protocol while the remaining group members listened. The structured nature of the protocol reduced the frequency of dialogic exchange within each small group. The observation tool monitored individual students every fifth minute (i.e. A, B, C, D, E cycle). Given that observations occurred at the top of every minute and moved to a different student at the end of each minute, it is possible more student-talk took place than was captured by the observation tool.

Summary. While quiet classrooms were once considered ideal for the facilitation of learning, awareness that language production is correlated with high student achievement (Flanders, 1970) challenges educators to promote student-talk throughout teaching and learning sessions and especially within complex, interactive tasks. Relegating student-talk to whole group discussion at the beginning or end of a lesson unnecessarily limits the number of students who have the opportunity to practice language production. The largest gains in language production over the course of our study were found post-intervention 2, 'Tasks that Require Talk'. This particular intervention specifically challenged more students to produce language, as it required oral communication by design. From an equity perspective, it may be an effective tool for ensuring equal access to language production, which may be the most efficient opportunity to learn.

That said, evidence in the field suggests the kind of talk students engage in matters (Gibbons, 2015; Huang, Normandia & Greeg, 2005; Schleppegrell, 2004; Soto, 2012). Language production alone does not equate itself with the acquisition of academic discourse. There will always be a need to model the unique style of language that accompanies any academic discipline. Yet, modeling alone is not sufficient. Students need to "talk their way into habits of expressing higher-level knowledge structures" (Huang et al., 2005, p. 44). Tasks that require talk can theoretically benefit from being coupled with stretched language, though 'Give One, Get One' did not appear to be the most ideal protocol for the student population here, however.

Finally, using a tool to monitor student language production provides a more accurate read of exactly how much language students are producing within a typical lesson. Too often, quantification of student-talk is left to teacher perception. Using a modified version of Soto's (2012) ELL Shadowing Tool Form enabled us to have a more objective measure of the amount of student-talk relative to the amount of teacher-talk. This strategy could be utilized in classrooms on a routine basis, and the data could be utilized to inform (re)design of future instruction.

Implications and Conclusion

The goal of this research was to identify ways to strengthen the instructional core in a manner that promoted student language production. In particular, the action research team worked to narrow a perceived expectation gap between ELL and non-ELL students with regard to language production. Interestingly, baseline data did not support the perceived expectation gap.

The study found that systematic use of interventional strategies had a generally positive impact on ELL and non-ELL students' language production and task-oriented behavior. This is significant because stakeholders in school communities sometimes worry that use of strategies to promote learning for ELL students will diminish the learning of non-ELL students. We found the opposite effect. Systematic use of strategies recommended for ELL students had a largely positive impact on language production for both ELL and non-ELL students. Additionally, the study found that systematic use of the strategies of focus resulted in increased or maintained on-task behavior during mathematics, science, and social studies classes.

Limitations. The study was limited by the variability that accompanies all elementary education settings. Teachers, students, and para-professionals differ from classroom to classroom. This inconsistency constrains the goal of having the independent variable be the only difference between the experimental group and the control group. Other school- and/or district-based initiatives also ran concurrent to the interventions being studied. The findings must therefore be read through a lens that recognizes other modulating factors.

Secondly, this study used a proxy for measuring student-talk time and on-task behavior, as it did not continuously monitor students and instead observed each student at five specific time points during one selected class period. This was the result of the observational tool utilized, as well as practicality in a classroom setting. More exact measures of time spent talking or time spent on-task could be obtained by using a stopwatch. More class periods could also have been observed to ensure that the data taken was not as heavily influenced by the lesson being delivered on any particular day.

Finally, this study did not work to establish a direct correlation between student language production and academic achievement, which previous studies have done (Flanders, 1970). The study conducted cut across three grade levels: second, third and fourth. Assessment policy within the district placed limits on the amount of standardized testing each student could complete. The requirements resulted in different testing schedules across grade levels. As such, a statistical analysis of student achievement as measured by a single, growth-based assessment could not be completed for this particular population.

Recommendations. Recommendations that evolve out the study fall into two categories: future research and curriculum development.

Research:

- *Quality of student-talk:* If a student-based recording device is used, researchers could analyze student-talk to measure qualitative shifts from vernacular language to academic discourse.
- *Quantity of student-talk:* If a student-based recording device is used, researchers could analyze student-talk to determine exact amount (vs. frequency) of student language production during each lesson.
- *Correlation to student-achievement:* This study did not establish a correlation between language production and student achievement. A similar study could be conducted that focuses on students at a single grade level such that a common

assessment could be utilized to investigate the impact of language production on student achievement.

Curriculum Development:

- *Mathematical Tasks that Require Talk:* Well-designed math tasks that utilize group-work and require talk increased student language production in this study but are rarely found in teaching and learning resources. Establishing a library of "tasks that require talk" for students at each grade level would be useful to teachers.

- *Code-Switching:* A step this study did not take was to systematically invite students to explain new concepts in their own language first. Research has shown this to be an effective approach (Brown & Ryoo, 2008).

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References

Brown, B., & Ryoo, K. (2008). Teaching science as a language: A "content-first" approach to science teaching. *Journal of Research in Science Teaching. 45(5):* 529-553. Retrieved from: https://eric.ed.gov/?id=EJ793041

City, E., Elmore, R., Friarman, S., & Teitel, L. (2009). *Instructional rounds in education: A network approach to improving teaching and learning.* Cambridge, MA: Harvard Education Press.

Cohen, E., & Latan, R. (2014). Designing groupwork: Strategies for the heterogeneous classroom. NY: Teachers College Press.

Conroy, M., & Garcia, E. (2017). *Five key trends in U.S. student performance: Progress by blacks and Hispanics, the takeoff of Asians, the stall of non-English speakers, the persistence of socioeconomic gaps, and the damaging effects of highly segregated schools*. Washington, DC: Economic Policy Institute.

Flanders, N. (1970). *Analyzing teacher behavior.* Reading, MA: Addison-Wesley.

Gee, J. (2008). *Social linguistics and literacies: Ideology in discourses* (3rd ed). NY: Routledge.

Gibbons, P. (2008). 'It was taught good and I learned a lot': Intellectual Practices and ESL Learners in the Middle Years. *TESOL Quarterly 32*(2): 247 – 73. Retrieved from http://www.collaborativelearning.org/gibbons2008.pdf

Gibbons, P. (2015). *Scaffolding language, scaffolding learning: Teaching English language learners in the mainstream classroom.* Portsmouth, NH: Heinemann.

Give One, Get One (2018). Retrieved from https://www.facinghistory.org/resource-library/teaching-strategies/give-one-get-one.

Goldenberg, C. (2013). Unlocking the research on English learners: What we know – and don't yet know – about effective instruction. *American Educator*, *37*(2), 4-11.

Halliday, M. (1993). Towards a language-based theory of learning. *Linguistics and Education, 5*, 93–116.

Hammond, J., & Gibbons, P. (2005). Putting scaffolding to work: The contribution of scaffolding in articulating ESL education. *Prospect*, *20*(1), 6-30.

Hammond, J. (2008). Intellectual challenge and ESL students: Implications for quality teaching initiatives. *Australian Journal of Language and Literacy, 31*(2), 128-154.

Huang, J., Normandia, B., & Greeg, S. (2005). Communicating mathematically: Comparison of knowledge structures in teacher and student discourse in a secondary math classroom. *Communication Education, 54*(1), 34–51.

Krashen, S. (1982). *Principles and practices in second language acquisition.* Oxford, UK: Oxford University Press.

Lee, O., Quinn, H., & Valdés, G. (2013). Science and language for English language learners in relation to the Next Generation Science Standards and with implications for Common Core state standards for English language arts and mathematics. *Educational Researcher, 42*(4), 223 – 233.

Minnesota Department of Education. (2016). Data report and analytics. Retrieved from http://w20.education.state.mn.us/MDEAnalytics/Data.jsp

Moschkovich. J. (2012, January). *Mathematics, the Common Core, and language*. Paper presented at the Understanding Language Conference, Stanford, CA. Retrieved from http://ell.stanford.edu/sites/default/files/pdf/academic-papers/02-JMoschkovich%20Math%20FINAL_bound%20with%20appendix.pdf

National Center for Education Statistics. (2018). Washington, D.C.: National Center for Education Statistics, Institute of Education Sciences, U.S. Dept. of Education.

National Governors Association Center for Best Practices, & Council of Chief State School Officers. (2010). Common Core State Standards for English language arts. Retrieved from http://www.corestandards.org/ELA-Literacy/

National Governors Association Center for Best Practices, & Council of Chief State School Officers. (2010). Common Core State Standards for mathematics. Retrieved from http://www.corestandards.org/Math/

NGSS Lead States. 2013. *Next Generation Science Standards: For States, By State*s. Washington, DC: The National Academies Press.

Olsen, L. (2006). Ensuring academic success for English learners. *University of California Linguistic Minority Research Institute Newsletter, 15*(4), 1–7.

Pianta, R., Belsky, J., Houts, R., & Morrison, F. (2007). Opportunities to learn in America's elementary classrooms. *Science 315*: 1795-96.

Pierret C., Sonju J., Leicester J., Hoody M., LaBounty T., Frimannsdottir K.R., Ekker S.C. (2012). Improvement in Student Science Proficiency Through InSciEd Out. *Zebrafish*, *9*(4), 155-68. doi: 10.1089/zeb.2012.0818. PMID: 23244687

Quinn, H., Lee, O., & Valdes, G. (2012, January). *Language demands and opportunities in relation to Next Generation Science Standards for English language learners: What teachers need to know.* Paper presented at the Understanding Language Conference, Stanford University. Retrieved from http://ell.stanford.edu/sites/default/files/pdf/academic-papers/03-Quinn%20Lee%20Valdes%20Language%20and%20Opportunities%20in%20Science%20FINAL.pdf

Santos, M., Darling-Hammond, L., & Cheuk, T. (2012, January). *Teacher development to support English language learners in the context of Common Core State Standards.* Paper presented at the Understanding Language Conference, Stanford University. Retrieved from http://edfs200ell.pbworks.com/w/file/fetch/54675861/Teacher%20Development.pdf

Schleppegrell, M. (2004). *The language of schooling: A functional linguistics perspective.* Mahwah, NJ: Lawrence Erlbaum Associates.

Schleppegrell, M. (2007). The linguistic challenges of mathematics teaching and learning: A research review. *Reading & Writing Quarterly*: *Overcoming Learning Difficulties, 23*(2), 139-159.

Soto, I. (2012). *ELL shadowing as a catalyst for change.* Thousand Oakes, CA: Corwin Press.

Swain, M. (2000). The output hypothesis and beyond: Mediating acquisition through collaborative dialogue. In J. Lantolf (Ed), *Sociocultural Theory and Second Language Learning.* Oxford, UK: Oxford University Press.

Swain, M. (2001). Integrating language and content teaching through collaborative tasks. *Canadian Modern Language Review* 58(1), 44 – 63.

Swain, M. (2005). The output hypothesis: Theory and research. In E. Heinkel (Ed), *Handbook of Research in Second Language Teaching and Learning*, (pp.471-83). Mahwah, NJ: Lawrence Erlbaum Associates.

Thomas, W., & Collier, V. (1999). *School effectiveness for language minority students.* Washington, DC: National Clearinghouse for Bilingual Education.

U.S. Department of Education. Institute of Education Sciences, National Center for Education Statistics.

Vygotsky, L. (1986). *Thought and language.* Cambridge, MA: MIT Press.

Walqui, A. (2007). Scaffolding Instruction for English Language Learners: A Conceptual Framework. In O. Garcia & C. Baker (Eds.), *Bilingual Education: An Introductory Reader*. Clevedon, UK: Multilingual Matters.

Yang, J., LaBounty, T.J., Ekker, S.C., Pierret, C. (2016), Students being and becoming scientists: measured success in a novel science education partnership Palgrave Communications 2, Article number: 16005 (2016) doi:10.1057/palcomms.2016.5.

Appendix A: Data Collection Tool

Modified from ELL Shadowing Protocol Form (Soto, 2012, p. 119)

Time	Student	Specific Activity or Location	Academic Speaking	Academic Listening	If student is *not* listening	Comments
0	A		○ S to S ○ S to T ○ S to small group ○ S to whole class ○ T to S ○ T to small group ○ T to whole class	One or two way, mostly to… ○ student ○ teacher ○ small group ○ whole class ○ video ○ ipad	○ Reading or writing silently ○ Student is off-task	
1	B		○ S to S ○ S to T ○ S to small group ○ S to whole class ○ T to S ○ T to small group ○ T to whole class	One or two way, mostly to… ○ student ○ teacher ○ small group ○ whole class ○ video ○ ipad	○ Reading or writing silently ○ Student is off-task	
2	C		○ S to S ○ S to T ○ S to small group ○ S to whole class ○ T to S ○ T to small group ○ T to whole class	One or two way, mostly to… ○ student ○ teacher ○ small group ○ whole class ○ video ○ ipad	○ Reading or writing silently ○ Student is off-task	
3	D		○ S to S ○ S to T ○ S to small group ○ S to whole class ○ T to S ○ T to small group ○ T to whole class	One or two way, mostly to… ○ student ○ teacher ○ small group ○ whole class ○ video ○ ipad	○ Reading or writing silently ○ Student is off-task	
4	E		○ S to S ○ S to T ○ S to small group ○ S to whole class ○ T to S ○ T to small group ○ T to whole class	One or two way, mostly to… ○ student ○ teacher ○ small group ○ whole class ○ video ○ ipad	○ Reading or writing silently ○ Student is off-task	

Teacher: __________________________ Date: __________________________ Time: ______________ Subject: ___________________________ Observer: ______________________

Appendix B: Supplementary Tables

This appendix contextualizes figures presented in the main text. The tables include sample sizes, exact counts, and percentages for data graphed in Figures 1 through 4. Full *p*-values are also provided with bars connecting each pairwise comparison run. Significant *p*-values (after Bonferroni correction) are asterisked in all tables.

Supplementary Table 1: Science / Social Studies Language Production

	N	SS	TS	% SS
ELL 0	19	44	30	59.46%
Non-ELL 0	29	40	56	41.67%
ELL 1	16	13	24	35.14%
Non-ELL 1	28	30	42	41.67%
ELL 2	10	15	17	46.88%
Non-ELL 2	18	27	35	43.55%
ELL 3	10	19	16	54.29%
Non-ELL 3	18	23	35	39.66%

X^2 p-value

0.0214
0.5088
0.7585
0.1696
0.0156
1.0000
0.5445
0.6655
0.3220
0.8261
0.6096
0.8057

Supplementary Table 2: Math Language Production

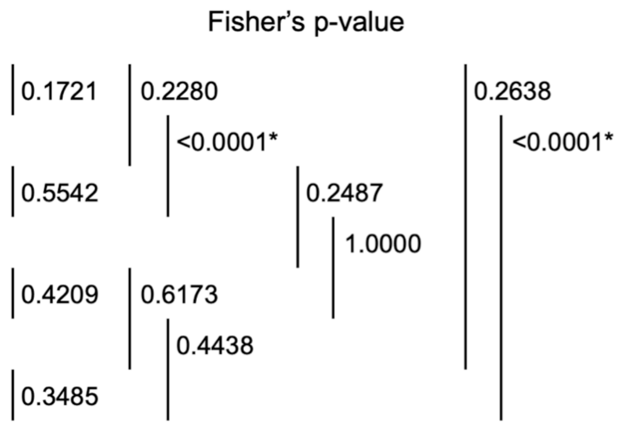
	N	SS	TS	% SS
ELL 0	19	12	50	19.35%
Non-ELL 0	28	24	66	26.67%
ELL 1	18	18	40	31.03%
Non-ELL 1	27	20	64	23.81%
ELL 2	16	34	24	58.62%
Non-ELL 2	27	60	42	58.82%
ELL 3	17	20	21	48.78%
Non-ELL 3	26	33	39	45.83%

X^2 p-value

0.3362
0.3436
1.0000
0.8453
0.1478
0.7285
0.4133
0.1226
0.0028*
<0.0001*
0.0023*
0.0133

Supplementary Table 3: Science / Social Studies Task-Oriented Behavior

	N	Off	On	% On
ELL 0	19	13	82	86.32%
Non-ELL 0	29	31	114	78.62%
ELL 1	16	6	74	92.50%
Non-ELL 1	28	7	133	95.00%
ELL 2	10	1	49	98.00%
Non-ELL 2	18	5	85	94.44%
ELL 3	10	3	47	94.00%
Non-ELL 3	18	2	88	97.78%



Supplementary Table 4: Math Task-Oriented Behavior

	N	Off	On	% On
ELL 0	19	15	80	84.21%
Non-ELL 0	28	10	130	92.86%
ELL 1	18	6	84	93.33%
Non-ELL 1	27	15	120	88.89%
ELL 2	16	5	75	93.75%
Non-ELL 2	27	9	126	93.33%
ELL 3	17	4	81	95.29%
Non-ELL 3	26	5	125	96.15%