Relationships among prior learning, anxiety, self-efficacy, and science vocabulary learning of middle school students with varied English language proficiency

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ABSTRACT

Vocabulary is essential for comprehension and achievement across disciplines. Understanding factors that contribute to vocabulary learning is important, especially for English learners (ELs) studying science, a linguistically and cognitively demanding topic. Our study examined structural relationships among background characteristics, science anxiety and self-efficacy, and science vocabulary learning of 252 Grade 8 students (31% current ELs; 69% former/non-ELs). Path analysis results indicated strong model fit and accounted for 47% of the variance in science vocabulary learning. Results identified academic vocabulary knowledge, initial science vocabulary knowledge, and science anxiety—variables under control of educational systems—as strong contributors to or mediators of learning and highlighted the importance of initial vocabulary knowledge in mitigating the negative relationships between anxiety and both learning and self-efficacy. Lower percentages of the variance explained in science anxiety (14%) and science and genetics self-efficacy (12% and 9%, respectively) suggest a need to include other predictors in future.

1. Introduction

Research identified vocabulary teaching as essential for effective instruction for young students, including English learners (ELs), the population at the heart of this study. Yet, efforts to extend such work to secondary schools, especially in linguistically and cognitively demanding subjects such as science, remain limited (Ford-Connors & Paratore, 2015; Wright & Cervetti, 2017). When conducted in the content-areas, however, vocabulary studies rarely take into consideration individual difference variables related to disciplinary attitudes (e.g., anxiety) and disciplinary self-concepts (e.g., self-efficacy).

This is problematic for EL science education for at least two reasons. First, similar to vocabulary (Taboada, 2012; Townsend, Carter, Taboada Barber, & Kiernan, 2016), disciplinary attitudes and self-concepts have been linked to science achievement (Baroody, Merritt, & Rimm-Kaufman, 2014; Britner & Pajares, 2006). This is especially important for ELs whose achievement gap across science outcomes remains a reality (Taboada, 2012; Torres & Zeidler, 2002). Though, it is also important to note emergent evidence suggesting that former ELs, students who reached an English language proficiency benchmark, tend to close achievement gaps associated with current EL status (see

Ardasheva, Tretter, & Kinny, 2012), including in science (Ardasheva, Firestone, Lamb, & Newcomer, 2016; Kim & Herman, 2009).

Second, content-based instruction models for EL science education are growing in popularity worldwide (e.g., content and language integrated instruction in the United Stated and Europe, English as medium of instruction in Asia; Ardasheva, Norton-Meier, & Hand, 2015; Lo & Macaro, 2015). Thus, there is an increasing need to better understand the interrelationships between language and content learning, while taking disciplinary attitudes and self-concepts into consideration. Further, understanding what student characteristics contribute to disciplinary attitudes and self-concepts—both linked to subsequent career choices—is a worthwhile endeavor in and of its own right, especially at the secondary level when such attitudes tend to form (Maltese & Tai, 2010, 2011).

The purposes of this study, then, were two. First, using statistical modeling techniques, we examined the structural (direct and mediated) relationships among background characteristics, disciplinary self-concepts and attitudes (science self-efficacy, anxiety), and science vocabulary learning of middle school students of varied English proficiency. To advance our knowledge regarding the still under-researched population of ELs, we were particularly interested in examining whether or

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not anxiety and self-efficacy mediated the relationship between EL status and learning, in the presence of other relationships suggested by the literature. Second, we examined relative contributions of student background characteristics to science self-efficacy and anxiety.

2. Study background

2.1. Science vocabulary demands

Scholars typically identify two vocabulary types contributing to the substantial language demands of science, namely, *academic vocabulary* and *science-specific, technical vocabulary*. Academic words in science texts include non-concept loaded words commonly encountered across disciplines such as 'analyze' and words connecting concept-loaded words such as 'be the result of' (Harmon, Hedrick, & Wood, 2005). The main functions of academic vocabulary in science include conveying specific information about a topic and illustrating relationships among scientific phenomena.

Science-specific vocabulary—further referred to simply as science vocabulary—refers to concept-loaded words such as 'chromosome' (Harmon et al., 2005). The main purpose of science vocabulary is to name new knowledge with greater usefulness and precision than common words do (Arya, Hiebert, & Pearson, 2011). As Cervetti, Hiebert, Pearson, and McClung (2015) argued, it is precisely the greater precision that makes science vocabulary difficult to know and to learn for all students. In their reviews of the topic, Cervetti et al. (2015) and Arya et al. (2011) identified a number of characteristics of science vocabulary—including conceptual complexity, abstractness, low frequency outside of science contexts, and linguistic complexity—that may contribute to such knowing and learning difficulties.

Conceptual complexity (or vocabulary familiarity; Arya et al., 2011) refers to a learner's knowledge about a given topic. Greater topic familiarity, Arya et al. argued, contributes to the development of schemata, "an organized network of knowledge" (p. 111), which allows learners to integrate new learning with prior knowledge more readily and with greater ease. Such topic-related background knowledge may have a great impact on vocabulary learning as becoming more experienced with a given topic would necessarily lead to the development of word meanings that are contextualized and integrated within systems of related concepts (Arya et al., 2011; Nagy & Townsend, 2012). In turn, abstractness refers to a learner's ability to "conjure up a 'picture,' a mental image of the concept to which the word refers" (Cervetti et al., 2015, p. 161). In science, as Cervetti et al. observed, word abstractness is often complicated by the nonobservable nature of the corresponding phenomenon. Indeed, a larger body of educational literature has linked higher levels of word abstractness with higher vocabulary learning difficulties (De Groot & Keijzer, 2000) and slower word processing speeds (Altarriba, Bauer, & Benvenuto, 1999; Basnight-Brown & Altarriba, 2015).

Among factors contributing to science words' linguistic complexity, scholars noted morphological complexity (e.g., length, Latin and Greek origins), the words' functioning as different parts of speech (e.g., 'force'), and polysemy (words' having multiple meanings; Cervetti et al., 2015). All of which have been documented, with some inconsistencies across studies, to impact science vocabulary knowledge and learning (e.g., Johnstone, 1991; Dockrell, Braisby, & Best, 2007; see Cervetti et al., 2015). Finally, when discussing frequency of science words, Arya et al. (2011) noted that although science texts may have "more than twice the number of rare [low-frequency] words as texts from any other discipline" (p. 111), these words rarely occur outside of science readings. Such low frequency of science words translates into a "low chance of environmental learning" from exposure (Ardasheva & Tretter, 2017, p. 263). Indeed, word frequency is strongly associated with both word learning and word knowledge (Cervetti et al., 2015; see National Institute of Child Health and Human Development, 2000).

Although still very limited, the results estimating relative contributions of science and academic vocabulary to science reading comprehension are mixed. Whereas Taboada (2012) found that academic vocabulary was the strongest contributor to science reading comprehension among Grade 5 students, Ardasheva et al. (2016) reported a reverse pattern among Grade 7 students. In fact, science vocabulary knowledge was the only statistically significant predictor of science reading comprehension among current ELs. Notably, both studies used grade-appropriate (grade-level) reading materials, suggesting that discrepancies in research results may be attributed to higher linguistic demands of science texts in upper grades (see Fazio & Gallagher, 2014). Such higher language demands at the secondary level may contribute to increasing anxiety and diminishing self-efficacy among middle school students, especially among ELs, the non-native speakers of the language of schooling and testing.

2.2. Science self-efficacy

Self-efficacy refers to "people's beliefs about their capabilities to exercise control over their own level or functioning and over events that affect their lives" (Bandura, 1993, p. 118). According to Bandura (1977, 1993), self-efficacy is believed to impact how people think, behave, and motivate themselves. Academic self-efficacy, broadly, reflects a learner's perceived competence regarding tasks in a given academic domain (Komarraju & Nadler, 2013). In discussing science self-efficacy, in particular, Britner and Pajares (2006) argued:

> [Students] who have a strong belief that they can succeed in science tasks and activities will be more likely to select such tasks and activities, work hard to complete them successfully, persevere in the face of difficulty, and be guided by physiological indexes that promote confidence as they meet obstacles. (p. 486)

Indeed, previous research, conducted primarily with native speakers of the language of schooling, has established a strong association between science self-efficacy and a host of science learning outcomes.

In a sample of 319 upper elementary and middle school students, Britner and Pajares (2006), for example, found that students' science self-worth and grade self-efficacy scores significantly correlated with students' science GPA. Student scores on both self-efficacy measures also significantly correlated with those on self-regulation, engagement, and mastery performance orientation measures. Further, the two science self-efficacy measures' scores combined, explained 39% of the variance in students' GPA. Strong intercorrelations between self-efficacy scores and science GPA were also reported in Pajares, Britner, and Valiante's (2000) study of middle school students. Similar results were reported for elementary (Baroody et al., 2014) and high school (Britner, 2008; Kupermintz, 2002) students. In examining these relationships, however, it is essential to also consider student characteristics (discussed next), which empirical literature suggests may serve as antecedents, correlates, or mediators of science self-efficacy and science outcomes.

2.3. Antecedents, correlates, and mediators of science self-efficacy and achievement

Among student characteristics implicated in contributing, directly or indirectly, to science self-efficacy and achievement, researchers and educators have identified EL status, gender, and science anxiety (Baroody et al., 2014; Griggs, Rimm-Kaufman, Merritt, & Patton, 2013; see Usher & Pajares, 2008).

2.3.1. EL status

Both second language acquisition theory (Krashen, 1985) and emergent empirical evidence in science education suggest that EL status may be an important student-level characteristic to consider when examining student achievement (Ardasheva et al., 2016; Ardasheva, Newcomer, Firestone, & Lamb, 2017; Taboada, 2012; Tong, Irby, Lara-