Vocabulary for the AUSTRALIAN CURRICULUM SCIENCE

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Table of Contents

About the Authors v

Marzano Research Development Team vi

About Marzano Research vii

Introduction 1

PART I

Vocabulary Instruction for the Australian Curriculum: Science 3

1 The Importance of Vocabulary 5

- Vocabulary Knowledge and Learning to Read 5
- Vocabulary Knowledge and Reading Comprehension 6
- Vocabulary and Socioeconomic Status 7
- Vocabulary Growth Through Wide Reading 8
- The Need for Vocabulary Instruction 9
- Elements of Effective Vocabulary Instruction 11
- Chapter Summary 13

2 A Six-Step Process for Direct Vocabulary Instruction 15

- Step 1: Provide a Description, Explanation or Example of the New Term 16
- Step 2: Ask Students to Restate the Description, Explanation or Example in Their Own Words 20
- Step 3: Ask Students to Construct a Picture, Symbol or Graphic Representing the Term or Phrase 24
- Step 4: Engage Students Periodically in Activities That Help Them Add to Their Knowledge of the Terms in Their Vocabulary Notebooks 26
- Step 5: Periodically Ask Students to Discuss the Terms With One Another 37
- Step 6: Involve Students Periodically in Games That Allow Them to Play With Terms 42
- Chapter Summary 46

Introduction

In recent years, the Australian Federal Government has been working closely with state and territory educational offices in an effort to implement a national curriculum for all Australian schools. This Australian Curriculum sets consistent national standards in an effort to improve learning outcomes for all students, as well as laying the foundations for future learning, growth and active participation in the community (ACARA, 2015).

Effective science instruction is crucial to all students, as the skills they learn and cultivate in the science classroom are not only important tools for use in other subject areas, but also in everyday life. The Australian Curriculum: Science emphasises the need for students to apply their scientific thinking in all aspects of their studies, encouraging exploration, investigation, observation and problem solving. The curriculum also prompts students to look back at the influence science has had on their own lives, as well as on society as a whole. Ultimately, the Australian Curriculum: Science is designed to provide students with the knowledge, skills and reasoning abilities to make informed decisions not only about their own lives, but about global issues and concerns.

The Australian Curriculum: Science is designed to replace previous standards documents and to clearly describe progressions of learning in four dimensions of science understanding across the F–12 continuum:

- Biological Sciences/Biology
- Chemical Sciences/Chemistry
- Earth and Space Sciences/Earth and Environmental Science
- Physical Sciences/Physics

As with any set of standards, educators are faced with the significant challenge of designing instruction that allows students to meet the standards' requirements. We believe that an important element of effective science instruction involves a comprehensive program of direct vocabulary instruction.

As Marco Bravo and Gina Cervetti (2008) stated, "Content areas expose students to a large corpus of challenging and often abstract words, many of which require the use of other equally challenging words to define and exemplify them" (p. 130). Understanding science content in particular requires familiarity with precise and specialised language and vocabulary terms. Consider a term such as *tissue.* Many students might be familiar with a number of common meanings for it: a disposable handkerchief, a piece of thin paper used for wrapping presents and so on. But the scientific term *tissue* has a precise and specialised meaning: it refers to the material that composes living things and is made of different types of cells. This example highlights the significance of direct vocabulary instruction in science: terms are the labels for important concepts. Knowing the labels for concepts allows students to connect one understanding to another, forming networks of knowledge. As Bravo and Cervetti (2008) explained:

> In science, social studies, and mathematics, words index important concepts and those concepts are organized in thematically related networks. . . . This web of concepts affords students a rich context from which they can learn the new technical terminology offered by content areas. Yet, students must be challenged to consider the semantic relationship among the core set of words. Under this approach, a term like *organism* would be semantically introduced as referencing such living things as plants and animals. An example of such is an *isopod*, an animal characterized by its seven pairs of legs, flattened body, and existence in forest floor *habitats*, which is the place where it gets what it needs to *survive*, including *shelter*, *food*, *protection*, *moisture*, and so forth. These italicized words tied semantically together assemble a structure of knowledge within the life science domain. (p. 139)

In other words, vocabulary is the medium that allows students to learn new concepts, work with the ones they know and expand their understanding of foundational scientific ideas and theories.

Although some might question whether the time spent on vocabulary instruction is worthwhile, Judith Scott, Dianne Jamieson-Noel and Marlene Asselin (2003) explained that "when conceptual understanding is central, the time devoted to understanding the vocabulary is well worth the effort. . . . When students understand vocabulary and concepts more completely at the beginning, reading and comprehension of subsequent materials will improve" (p. 283). Additionally, understanding vocabulary (which leads to improved conceptual understanding) gives students the linguistic tools they need to produce higher-quality oral and written products, as noted by Olga Maia Amaral, Leslie Garrison and Michael Klentschy (2002).

This revised Australian edition of *Vocabulary for the New Science Standards* includes three parts. Part I contains chapters 1–4. In chapter 1 we explain the importance of vocabulary knowledge, give evidence for the efficacy of direct vocabulary instruction and highlight critical elements of effective vocabulary instruction. Chapter 2 outlines a six-step research-based process for vocabulary instruction. It also gives teachers explicit, concrete guidance about how to introduce and explain new terms, prompt students to create descriptions and graphic representations of new terms and facilitate activities, discussions and games to deepen their knowledge by using new terms in a wide variety of contexts. In chapter 3 we narrow our focus to the menu of science terms in parts II and III, explaining how the Australian Curriculum: Science and other standards documents were analysed to identify terms and then organised here to facilitate teaching and learning in the classroom. Finally, chapter 4 walks teachers and school leaders through the process of building a classroom, school-wide or region-wide vocabulary program.

Part II contains two lists of terms: (1) vocabulary pertaining to crosscutting practices and concepts in science and (2) cognitive verbs. These are terms from the Australian Curriculum and other documents that are not necessarily specific to science (for example, *investigate*, *measurement* and *complex*), but are essential for students to understand if they are to interact effectively with scientific content.

Part III contains the domain-specific terms from the Australian Curriculum: Science standards.

1

The Importance of Vocabulary

There is a clear and urgent need for vocabulary instruction in schools. Loren Marulis and Susan Neuman (2010) stated that "vocabulary is at the heart of oral language comprehension and sets the foundation for domain-specific knowledge and later reading comprehension" (p. 300). Teaching students new vocabulary terms expands their world by helping them access new concepts and the network of ideas connected to those concepts. A student who knows the terms *photosynthesis*, *carbon dioxide* and *oxygen* thinks about plant-related concepts differently than a child who only knows *leaves*, *soil* and *water*. Similarly, a student who understands *galaxy*, *comet*, *planet*, *light year* and *interstellar* has a significantly wider scope than a student who only grasps *sun*, *moon*, *sky* and *star*. As Katherine Stahl and Steven Stahl (2012) explained, "To expand a child's vocabulary is to teach that child to think about the world, and in a reciprocal fashion, more refined vocabulary indicates that child's degree of knowledge about his or her world" (p. 73). Words are the medium through which ideas are formulated and communicated; the more words a person comprehends, the more ideas they will be able to ponder and express.

Beyond conceptual learning, a person's vocabulary also communicates information about themselves to other individuals during social interactions. As Stahl (2005) pointed out:

> To a large extent, the words we know and use are who we are. Words can define, to the outside world (and maybe even to ourselves), how smart we are (or think we are), what kinds of jobs we do, and what our qualifications for jobs might be. . . . Words are not just tokens that one might memorize to impress others. Instead, the words that make up one's vocabulary are part of an integrated network of knowledge. (p. 95)

This integrated network of vocabulary terms allows a person to talk about the world, share information with others and expand their knowledge by connecting new concepts to existing ones. More words extend the network and enhance one's ability to expand it further. More words also facilitate greater precision (*crystalline* versus *sparkly*) and complexity (*cells* and *chromosomes* versus *looking like my mum*) of thought. In short, a person's vocabulary plays an enormously important role in their life and future possibilities (Beck & McKeown, 2007; Neuman & Dwyer, 2011). To begin, we explore several areas that are affected by, and which have an effect on, students' vocabulary knowledge.

Vocabulary Knowledge and Learning to Read

At a very basic level, vocabulary knowledge is a critical factor in the process of learning to read. Keith Stanovich (1986) explained that understanding how letters and sounds combine to form words is largely useful because "it allows children to recognize words that are in their vocabulary but have not been

taught or encountered before in print" (p. 375). As students learn the sounds for individual letters and gain an understanding of how to string those sounds together to read words (decoding), their oral vocabulary (the words they understand when heard or spoken) allows them to match the string of sounds to words they already know.

For example, imagine a student sounding out the word *material.* Beginning with the first chunk, /mat/, the student might also identify /er/ as a chunk, then /i/ and /al/ as the final part of the word. The critical moment occurs when the student says the sounds of each chunk, stringing them together either aloud or in their head. A student who is familiar with the term *material* will likely be able to match the string of sounds to the term they know, and therefore comprehend it. But a student who has never heard (or is otherwise unfamiliar with) the term *material* may not be able to match the sounds of /mat/, /er/, /i/ and /al/ to a meaning, even if the student is able to pronounce the word correctly. As the National Reading Panel (2000) stated, "Benefits in understanding text by applying letter-sound correspondences to printed material come about only if the target word is in the learner's oral vocabulary. When the word is not in the learner's oral vocabulary, it will not be understood when it occurs in print" (chapter 4, p. 3). In other words, vocabulary knowledge is the critical link between decoding and reading comprehension (Biemiller & Slonim, 2001).

Vocabulary Knowledge and Reading Comprehension

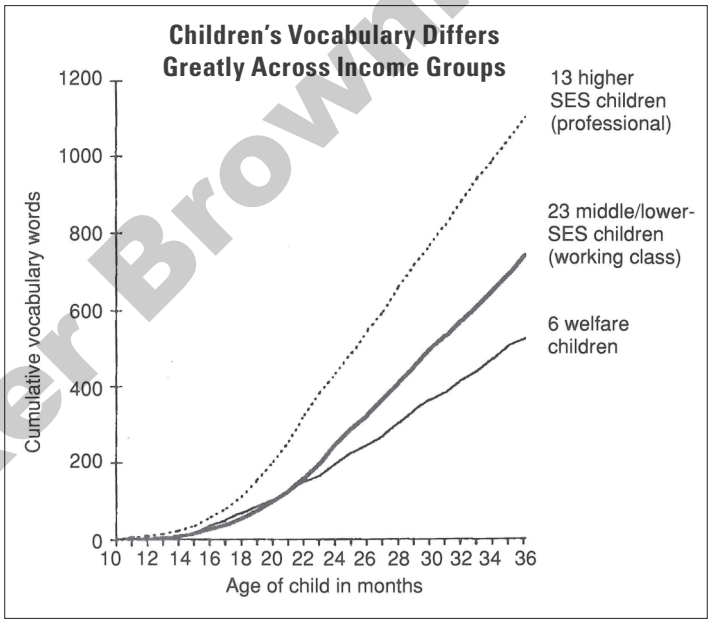
In support of this idea, many researchers have found a strong and persistent relationship between vocabulary knowledge and reading proficiency (Anderson & Freebody, 1979, 1985; Beck & McKeown, 2007; Beck, Perfetti & McKeown, 1982; Cain, Oakhill, Barnes & Bryant, 2001; Cunningham & Stanovich, 1997; Davis, 1942, 1944, 1968; Farkas & Beron, 2004; Just & Carpenter, 1987; McKeown, Beck, Omanson & Perfetti, 1983; McKeown, Beck, Omanson & Pople, 1985; Mezynski, 1983; National Reading Panel, 2000; Scarborough, 2002; Singer, 1965; Stahl, 1983; Stahl & Nagy, 2006; Stanovich, Cunningham & Feeman, 1984; Storch & Whitehurst, 2002; Thurstone, 1946; Whipple, 1925). Specifically, Andrew Biemiller (1999) found a correlation of 0.81 between vocabulary size and reading comprehension. A correlation of 1.00 indicates a perfect positive relationship between two variables; as one variable increases, so does the other. A correlation of zero indicates no relationship between two variables, and a correlation of -1.00 indicates a perfect negative relationship between two variables; as one variable increases, the other decreases. Therefore, a correlation of 0.81 indicates a strong positive relationship between vocabulary size and reading comprehension: the more vocabulary terms a student knows, the better they are able to understand what they read.

In many studies (Beck & McKeown, 2007; Biemiller & Boote, 2006; Cunningham & Stanovich, 1997; Davis, 1944, 1972; Pearson, Hiebert & Kamil, 2007; Scarborough, 1998, 2002), students' vocabulary knowledge actually predicted their reading proficiency later in life. For example, in a meta-analysis of 61 studies, Hollis Scarborough (1998) found a significant correlation of 0.46 between the complexity of kindergarten students' vocabularies and their reading achievement in Year 2. In other words, the more complex a student's vocabulary was in kindergarten, the more likely they were to be proficient in reading by Year 2. Anne Cunningham and Keith Stanovich (1997) reported that the size of Year 1 students' vocabularies strongly predicted their reading comprehension a decade later (in Year 11). Other studies have also found that vocabulary size consistently predicted later reading comprehension, with positive correlations between 0.60 and 0.80 (Pearson et al., 2007).

Even more interestingly, Biemiller (2005, 2012; Biemiller & Slonim, 2001) found that after Year 3, most students could decode (on average) 25–30 per cent more words than they could understand: "From third grade on, the main limiting factor for the majority of children is vocabulary, not reading mechanics (i.e. decoding print into words)" (Biemiller, 2012, p. 34). Therefore, students with smaller vocabularies in Year 3 experienced declining reading comprehension in subsequent years (Biemiller & Boote, 2006; Chall & Jacobs, 2003). The work of Biemiller and his colleagues highlights a critical issue in the discussion of vocabulary in schools – certain subgroups of students are particularly hindered by limited vocabulary knowledge.

Vocabulary and Socioeconomic Status

Extensive research (Becker, 1977; Coyne, Simmons & Kame'enui, 2004; Hart & Risley, 1995; Templin, 1957; White, Graves & Slater, 1990) has found that students from lower-income families typically begin school with smaller vocabularies than students from higher-income families. In one of the best-known studies, Betty Hart and Todd Risley (1995, 2003) followed young children from 42 families for two and a half years. Thirteen of the families were of a higher socioeconomic status (SES), 10 were middle SES, 13 were lower SES and six families were on welfare. Hart and Risley found that "the three year old children from families on welfare not only had smaller vocabularies than did children of the same age in professional families, but they were also adding words more slowly" (2003, p. 7). To illustrate, figure 1.1 shows the vocabulary growth of children from different SES families.



Source: Hart & Risley, 2003, p. 7. Used with permission.

Figure 1.1: Vocabulary growth for children from different SES families.

Perhaps most importantly, the trends shown in figure 1.1 are persistent. Hart and Risley found that children's rate of vocabulary growth at age three (36 months) was strongly associated with their scores on measures of vocabulary, language skill and reading comprehension at ages nine to 10. In sum, students with smaller vocabularies began school at a disadvantage that was still evident six to seven years later.