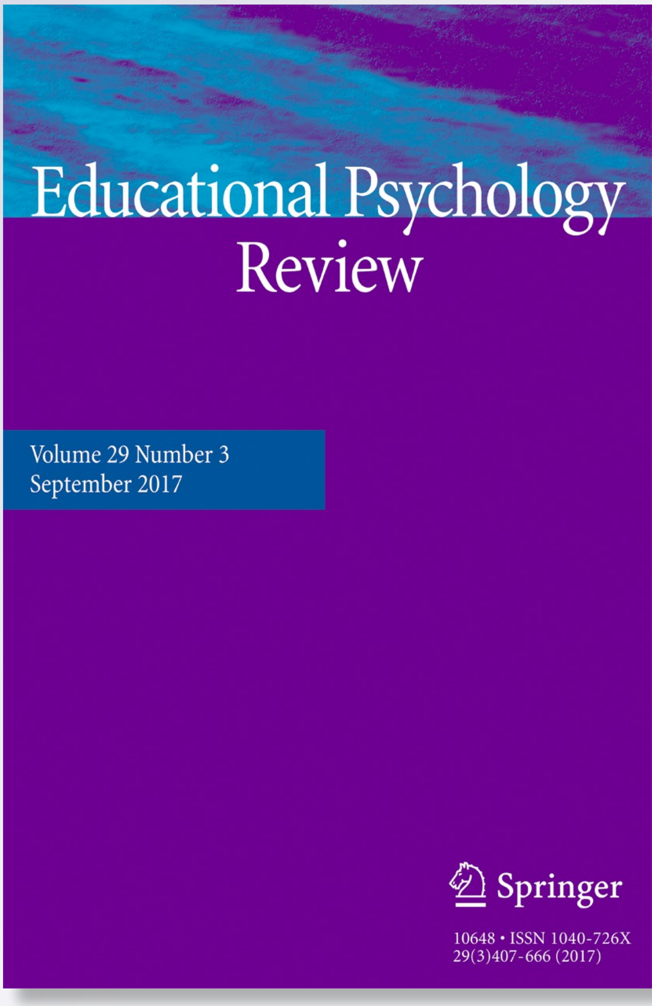
From Exploratory Talk to Abstract Reasoning: a Case for Far Transfer?

Paul Webb, J. W. Whitlow & Danie Venter

Educational Psychology Review

ISSN 1040-726X
Volume 29
Number 3

Educ Psychol Rev (2017) 29:565-581
DOI 10.1007/s10648-016-9369-z



Educ Psychol Rev (2017) 29:565–581
DOI 10.1007/s10648-016-9369-z

REVIEW ARTICLE

From Exploratory Talk to Abstract Reasoning: a Case for Far Transfer?

Paul Webb[1] **· J. W. Whitlow Jr**[2] **· Danie Venter**[3]

Published online: 28 April 2016

Abstract Research has shown improvements in science, mathematics, and language scores when classroom discussion is employed in school-level science and mathematics classes. Studies have also shown statistically and practically significant gains in children's reasoning abilities as measured by the Raven's Standard Progressive Matrices test when employing the practice of "exploratory talk". While these studies suggest that transfer of learning had taken place, a number of dialog-intensive designs have failed to find positive results, only reported delayed transfer, or have been criticized in terms of methodological rigor, small sample sizes, or because they have only shown small effect sizes. In this study, the claim is made that a particular set of studies which focused on exploratory talk and reasoning abilities, and which used designs that are better positioned to meet the standards mentioned above when presenting data in support of far transfer, provides robust evidence of far transfer within the framework of Barnett and Ceci's taxonomy of transfer. Possible relationships between exploratory talk, argumentation, and key domains in the science of learning are considered in an attempt to explain the apparent far transfer effects when children engage in exploratory talk.

Keywords Exploratory talk · Far transfer · Reasoning · Raven's standard progressive matrices · Argumentation

Over the past three decades there has been a shift in emphasis in science education from a Piagetian view of an individual struggling to make sense of the world to the Vygotskian notion of the social construction of knowledge (Hodson 2009). This shift largely reflects the accumulation of evidence for the efficacy of interventions that engage children in interactive

✉ Paul Webb
paul.webb@nmmu.ac.za

1 Faculty of Education, Nelson Mandela Metropolitan University, Port Elizabeth, South Africa

2 Psychology Department, Rutgers University, Camden, NJ, USA

3 Unit for Statistical Consultation, Nelson Mandela Metropolitan University, Port Elizabeth, South Africa

discussion. For example, a review of ten studies on discussion from the Philosophy for Children primary and secondary schools' project by Trickey and Topping (2004) revealed positive results for all participating children in terms of norm-referenced tests of reading, reasoning, and cognitive ability. These findings support Locke, Ginsberg, and Peers' (2002) claim that the development of spoken language should be a priority for all young children and that this emphasis is particularly beneficial for children from disadvantaged socio-economic backgrounds. Adey (2001) and Shayer and Adey (2002), who speak of "cognitive acceleration" and "learning thinking," argue that the Science Education (CASE) project, which employed group work and plenary discussions with the teacher asking questions that revealed the children's thinking processes and meta-cognition, was particularly effective in a number of ways (Adey and Shayer 1994). After a 3-year intervention, the experimental group of CASE learners not only scored approximately one grade better in their GCSE science achievement than their peers, but their mathematics and English GCSE grades were improved by about the same amount. Nevertheless, Trickey and Topping (2004) noted that most of the studies reviewed at that time lacked methodological rigor. Among those that did, Lipman's 1975 Philosophy for Children study, which used the Iowa Test of Basic Skills test, revealed the strongest effect on students' comprehension after 3 years of instruction, with an effect size of 0.55. However, the effect sizes for the other studies using multiple-group designs and standardized measures only averaged approximately 0.20 (Wilkinson et al. 2015).

Nevertheless, a recent call for the sharing of findings on the effects of orchestrated discussion in school learning resulted in responses that were considered to be "startling" (Resnick et al. 2015, p. 2). The startling aspect was that there were so many responses that revealed evidence that students who had engaged in dialogic teaching situations performed better on tests than students who had not experienced similar opportunities for discussion. These instances included better retention of knowledge by students (up to 2 to 3 years) and of transfer to a different domain (for example, from science to English literature). Similar results in terms of improvements in science, mathematics, and language scores have been shown in projects that incorporated classroom discussion in the USA (Webb 2010b). However, only a small number of studies showing positive results have involved measures that were standardized and independent of the texts discussed or designs with multiple groups (Wilkinson et al. 2015). Further, a number of studies of dialog-intensive frameworks have failed to find positive results (Reznitskaya et al. 2012) or only reported delayed transfer (Kuhn and Crowell 2011; Morehouse and Williams 1998).

In response to the challenges mentioned above, this paper focuses on studies in a particular context that used designs better positioned to meet the aforementioned standards when presenting data in support of the occurrence of far transfer. These studies, which were framed in the context of science and mathematics second-language students, used a shared quasi-experimental design. The design included experimental and control groups, pre-post testing, and large enough numbers for statistical analyses. The quasi-experimental aspect of the design was that participants were selected from existing classes in schools and were therefore not randomly assigned to conditions, i.e., purposive/convenience sampling was used. The design also included a shared method for introducing and assessing authentic discussion (exploratory talk) in science and mathematics classrooms. All bar one used the same assessment for pre- and post-testing that was standardized and was not related to the material discussed in the classroom (namely, Raven's Standard Progressive Matrices). The pre-post-test was administrated immediately prior to and after the discussion intervention. The duration of each intervention was similar (between 6 and 9 months) and the ages of the participants ranged between 11 and 14 years except for one study which worked with young adults. All of the studies which enabled teachers to facilitate exploratory talk among their students' produced large effect sizes, bar one which was moderate.

In considering these studies, we argue that the benefits on reasoning and understanding of a particular type of intervention known as exploratory talk constitute a case for *far transfer* of the effects of education. Specifically, we place the practice and effects of exploratory talk in a framework of "transfer of training," seeking to connect the sociological orientation of its origins with the cognitive and learning sciences orientation of much contemporary educational research. Thus, we explore possible cognitive processes that might produce such effects, particularly in terms of what is learned in exploratory talk interventions and the cognitive processes involved in solving Raven's test tasks (see Nussbaum and Asterhan in press for a similar approach to this issue).

Transfer of Training as a Measure of Reaching Educational Goals

Educational interventions almost always yield performance improvement on the tasks used in the intervention, but this fact is seldom of much interest. Instead, a common goal of most interventions is to prepare students to perform well in new situations, adapting what they have been explicitly taught so they can solve problems and produce outcomes that are new or different from their specific training. Consider, for example, the following statement from the US Common Core Standards for English Language Arts: "The skills and knowledge captured in the ELA/literacy standards are designed to prepare students for life outside the classroom..... Students will learn to use cogent reasoning and evidence collection skills that are essential for success in college, career, and life." Clearly, this goal extends well beyond any specific language arts instruction. Evaluating this broad goal is complex and quite difficult, but Barnett and Ceci (2002) have provided an illuminating approach that makes evaluation more manageable by framing the goals of education in terms of "transfer of training."

Commenting on transfer, Barnett and Ceci (2002, p. 612) note that there is "little agreement on the nature of transfer, the extent to which it occurs, and understanding of its underlying mechanisms." These authors believe that a major reason for the conflicting characterizations of transfer is the failure to specify the dimensions for a general taxonomic framework in which transfer studies can be situated. Consequently, they proposed a taxonomy designed to provide a principled basis for distinguishing between studies that involve *near transfer* and studies that involve *far transfer*, that is, the application of what was learned to tasks that are "new or different from their specific training." The taxonomy uses two major dimensions, termed *content* and *context*. Content encompasses whether transfer involves specific information or procedures or instead involves a general strategy or rule; whether the performance measures are the same as or different from those used in training; and what sorts of memory demands the transfer task places on the participants. Context encompasses whether the transfer context involves the same or a different knowledge domain, the same physical context, the same temporal context, the same social context, the same functional context, and the same modality of presentation. For each of these sub-dimensions, studies can be placed on a near versus far continuum, with the result that a given study might involve far transfer on one sub-dimension but near transfer on another dimension. Barnett and Ceci point out that it is important to distinguish between "near transfer tests" in which the assessment is close in time and similar in content and form of testing to training, and "far transfer tests" in which the assessment is remote in time and different in content and form of testing from the initial learning experience (Barnett and Ceci 2002). Importantly, they also state that "Despite a century's worth of research, arguments surrounding the question of whether far transfer occurs have made little progress towards resolution" (p. 612).

Exploratory Talk

There is a considerable agreement among scholars as to the nature of the discourse that characterizes productive discussion (Resnick, Asterhan, and Clarke 2015). Typically, productive discussion is structured and focused, but not dominated by the teacher. It is framed in a series of open-ended questions, individual and collective reasoning, and a high degree of agency and control in the co-construction of knowledge within a group. Students have opportunities to engage in individual and collective reasoning about issues, and to provide explanations for their claims by drawing on their experience and prior discussions. They are able to listen and react to each other's ideas, reason together and co-construct understanding (Wilkinson, et al. 2015).

Exploratory talk, a form of productive discussion, can be clearly distinguished from other types of classroom talk such as "disputational talk" with its trademark defensive stances, bickering, and personal diatribes and "cumulative talk" where there is sharing of ideas but no constructive challenges or conflict (Mercer 1996). It is not far removed from "collaborative reasoning" (Chinn and Anderson 1998; Reznitskaya et al. 2009), "critical discussion" (Keefer et al. 2000), "accountable talk" (Michaels and O'Connor 2002), and argumentation approaches to learning science (Osborne 2010). Exploratory talk is an approach which has been described as "thinking aloud with others" and which foregrounds student reasoning (Monaghan 2005). Exploratory talk uses the open sharing of ideas, receptiveness to the ideas of others, constructive conflict, and well-argued counter proposals in order to reach consensus in groups (Mercer and Littleton 2007). Research has also shown that in order for exploratory talk to be effective and take root in classrooms, it has to be taught explicitly and practiced continually (Mercer and Littleton 2007).

Studies by Rojas-Drummond and Mercer (2004) and Mercer et al. (2004) with school aged children (9–12 years old) all showed the value of explicit explanations to learners in terms of how to generate classroom discussion. Ground rules have to be set for talking and listening. These rules, formulated collectively by the teacher and students to promote ownership and compliance, usually involve issues of mutual respect for persons and ideas, the sharing of all relevant information, acceptance of challenges and rebuttals, and striving towards agreement on claims made.

The occurrence of exploratory talk in the classroom has been assessed in a number of ways. Mercer et al. (1999) used the frequency of certain linguistic features, for example, the use of words such as "because," "agree," and "I think" in the context of the discussions that they observed (and recorded) to generate qualitative and quantitative data. They also associated the relative incidence of "longer utterances" in context as an indicator of exploratory talk taking place. Similar forms of assessment using predetermined levels of word use and utterances made have been employed in other studies in the UK (cf. Rojas-Drummond and Mercer 2004; Mercer et al. 2004).

Mercer, Wegerif, and Dawes' seminal 1999 study, in which they worked with 60 children aged 9 to 11, provided the first link between exploratory talk and achievements on the Raven's test. This study revealed that improvements can be made over time in terms of children's ability to use exploratory talk meaningfully in class (measured as described earlier) with statistically significant gains being made in Raven's Standard Progressive Matrices (RSPM) scores. However, as the focus of the exploratory talk in this study was on how to solve the RSPM test any transfer effects would be classified as "near transfer." The Mercer et al. (2004) study also revealed a significant improvement in SATS science question scores in classes where exploratory talk was employed (SATS are sets of assessments provided to schools by the Qualifications and Curriculum Authority in England and Wales). In terms of Barnett and Ceci's taxonomy, while there was distance in terms of social context and modality (group discussion to individual written text), these findings still do not suggest full far transfer in that the knowledge domains are related and the physical and functional contexts were similar (science school-level tests). In the studies that we emphasize in this paper, the RPSM was used as a measure of transfer effects after lessons that focused on science education, not on solving the RPSM; hence, these studies fit the definition of far transfer in Barnett and Ceci's taxonomy.

Measuring Reasoning

Spearman proposed that there is a common or general factor in mental ability, commonly known as Spearman's *g*. The RSPM test has been described as the best assessment of abstract or non-verbal reasoning and is widely regarded as measuring the essence of the educative aspects of Spearman's *g* (Jensen 1998; Kaplan and Saccuzzo 1997; Lynn et al. 2004). The two main components of Spearman's *g* are educative ability and reproductive ability. *Educative ability* refers to the ability to educe relationships or further meaning from that what is known, while *reproductive ability* is the ability to reproduce a culture's store of verbal concepts. Reproductive ability is what enables one to achieve in examinations which requires memory, while educative ability enables one to solve abstract non-verbal problems (Raven et al. 2003). While the latter has been considered to be the more "heritable" component, Kan et al. (2013) have recently challenged this assumption and claim that societal demands influence the development and interaction of multiple cognitive abilities and knowledge. These interactions are believed to provide positive correlations among each other and give rise to the general intelligence factor, a consideration which may have implications when attempting to provide explanatory mechanisms for the effects of exploratory talk on Raven's scores.

The RSPM test is a widely used, well-established, reliable standardized psychological test of non-verbal abstract reasoning and problem solving (Kunda et al. 2009). The problems presented are language-free and can be used across a range of ages (Raven, Raven, and Court 2003). The test is made up of a series of diagrams or designs with a part missing. The use of abstract representations is a valued cognitive ability in terms of many of the concepts and processes used in sciences. Those taking the tests are expected to select the correct insert to complete the designs from a number of options printed beneath. There are 60 different questions in five sections (A–E) which are ordered from the easiest to the most difficult.

Raven's tests, which are based on Spearman's investigation of intelligence, appear particularly appropriate for exploring links between language practices and the non-culturally biased tradition of research in cognitive development as they correlate well with similar tests of reasoning and with measures of academic achievement (Raven, Court and Raven 1995, Richardson, 1991). The RSPM provide a means to assess, measure, and compare a person's capacity for observation and clear thinking relative to other people, irrespective of past experience or present ability for verbal communication, the ability of a person to deal with apparently meaningless figures, the ability to perceive the relationship between these figures, and the capacity for systematic reasoning. In general, the scales can be considered as tests of observation and clear thinking. Each problem in a scale is a source of a system of thought, while the order in which they are presented provides training in the method of working, i.e. they are progressive. In each set, the first problem is as self-evident as possible, after which the problems become progressively more difficult.

It is worth noting at this point that standardized non-verbal reasoning tests like Raven's have been commonly taken to be paradigmatic measures of individual reasoning ability, independent of social or cultural factors (Richardson 1991). However, more recent findings challenge this position and support Raven et al.'s (1995) position that non-verbal reasoning (like that involved in solving the Raven's problems) may be mediated by language and developed by adult guidance and social interaction among peers without the provision of any specific training in solving these problems. This position supports the claims of sociocultural theorists such as Bruner (1990), Rogoff (1990), Vygotsky (1981), and Wertsch (1991) that the development of human mental abilities depends on a link between the "intramental" and the "intermental" mediated by language.

Method

As noted in the introduction, a set of studies with similar designs using exploratory talk in the classroom and similar measures of reasoning abilities are reviewed in terms of possible far transfer effects within Barnett and Ceci's (2002) taxonomy of transfer (cf. Webb 2003, 2010a, b; Webb and Treagust 2006; Villanueva 2010; Sepeng 2011; Boschmans 2013). These studies represent all of the research projects undertaken over a decade by a special interest group at the University of Port Elizabeth (now NMMU) in South Africa. They all focused on the development of scientific literacy in learners through exploratory talk and included measures of changes in learners reasoning skills. Other studies on promoting scientific literacy undertaken by this group through writing and argumentation, but which did not focus on exploratory talk or measuring changes in reasoning skills, are not included (see Webb 2010b). All of the studies were done over a period of one calendar year with a 6-month period of implementation of the strategy with the students from March to September in each case. Two studies were replicated as first and second studies over two calendar years (Webb and Treagust 2006; Villanueva 2010).

The teachers in the experimental groups were introduced to, and trained in, the use of exploratory talk while the teachers in the control groups were not. Participating teachers in the experimental groups were introduced to the notion of "discussion" and the implementation of classroom discussion stimulation techniques via workshops which focused on notions of discussion, the effective use of the triggers to be used to initiate classroom discussion, and the rationale, theoretical position, methods, and processes of each study. The basis for discussion in each case was given in written form so that teachers could refer back to the written materials and their own notes during the course of the intervention. These workshops, which were run after the settings and teachers had been identified and the students had written the RSPM pre-test, took place over 12 to 14 h in each study spread over 2 or 3 days depending on teacher availability. A variety of triggers were used to initiate exploratory talk, viz. conversational readings, prompt-posters, practical work (Webb and Treagust 2006; Villanueva 2010), concept cartoons (Webb 2010a, b), word problems in mathematics (Sepeng 2011), and work covered in class (Boschmans 2013), but in each case, the processes of the implementation and assessment of exploratory talk were the same and a shared method for assessing authentic discussion (exploratory talk) in science and mathematics classrooms was used.

The classroom observation tool developed in the first study (Webb and Treagust 2006) was used with minor modifications in each subsequent study. Classroom observations were either video (Webb and Treagust 2006; Webb 2010a, b and Sepeng 2011) or audio-taped (Villanueva 2010; Boschmans 2013). A four-point scale classroom observation instrument was used to record the classroom activities that took place during classroom observation sessions. Each teacher was visited a minimum of three times during the duration of each project to establish whether exploratory talk was taking place. On-site discussions with teachers and pupils were also used as an indicator of whether exploratory talk had taken place and analyses of classroom observation records provided deeper insights into the types of discourse and interactions that took place. The criteria used to determine whether classroom discussion had taken place were the ability of learners to engage in the lexicon (use the words appropriately), use scientific explanations (apply connectives) and engage in discourses that included descriptions, predictions, explanations, and arguments.

A four-point scale classroom observation instrument was developed in order to record the classroom activities that took place during classroom observation sessions. Each teacher was visited a minimum of three times during the duration of the project as this number, based on previous experience in similar projects and schools, was deemed sufficient to establish if changes in teacher practice had occurred and whether newly introduced classroom discussion practices were ongoing or not. A minimum criterion was used as a cut-off point for judging whether classroom discussion had taken place or not, namely that each of the above interactions had been exhibited at least once, and that two of the three were exhibited three or more times per classroom observation over a period of 6 to 9 months with an average of three- or more on a four-point classroom observation scale. These data were used to provide a minimum criterion for a cut-off point for judging whether classroom discussion had taken place or not over the duration of the intervention This distinction, i.e., whether exploratory talk has taken place in a classroom or not, allows for stronger notions of falsification and verification of claims of association between exploratory talk and enhanced performance on the RSPM test.

The Webb (2003), Villanueva (2010), Webb (2010a, b), and Boschmans (2013) studies all used the Raven's test (RSPM) for pre-post testing. The RSPM test data revealed a high level of reliability ($\alpha \geq 0.8$) in all cases. The Raven's test is considered to be particularly useful as the non-verbal, abstract reasoning nature of the test makes performance on RPSM a good measure of far transfer effects when employing exploratory talk as, unless the participants were specifically trained on non-verbal reasoning, they would not be expected to show benefits of an intervention like exploratory talk on RPSM scores. Our first goal in this paper is to examine the results of these studies using exploratory talk, which is an example of an intervention that engages children in interactive discussion, in the light of possible far transfer as framed in Barnett and Ceci's taxonomy. The second is to highlight possible cognitive processes that might produce such effects, particularly in terms of what is learned in exploratory talk interventions and the cognitive processes involved in solving Raven tasks.

Results

The findings of the studies are firstly presented in Table 1 with narrative elaboration below.

Webb and Treagust (2006) reported on a study in South Africa where three triggers were used to initiate exploratory talk among 11 to 12 year-old Xhosa first-language speakers in

Table 1 Results of the studies under review focusing on exploratory talk and problem solving in terms of both statistical and practical (Cohen's *d*) significance

Study	Focus	Age	Students engage in exploratory talk	Significance on Raven's SPM
Webb 2003 (first study; $n = 146$)	Exploratory talk in science classes	11–12	Yes when using readings and practical work to stimulate discussion.	$p \leq 0.05$; $d = 0.50$ (moderate effect size)
			No when using the "prompt-poster" approach to stimulate discussion)	$p \geq 0.05$
Webb 2003 (second study; $n = 1192$)	Exploratory talk in science classes	11–12	Yes	$p \leq 0.05$; $d = 0.50$ (moderate effect size)
Villanueva 2010 (first study; $n = 168$)	Exploratory talk in science classes	11–12	No	$p \geq 0.05$
Villanueva 2010 (second study; $n = 675$)	Exploratory talk in science classes	11–12	Yes	$p \leq 0.05$; $d = 0.83$ (large effect size)
Webb 2010a ($n = 403$)	Exploratory talk in mathematics classes	11–12	Yes	$p \leq 0.01$; $d = 1.41$ (large effect size)
Sepeng 2011 ($n = 176$)	Exploratory talk in mathematics classes	13–14	Yes	$p \leq 0.05$; $d = 0.86$ (large effect size)
Boschmans 2013 ($n = 215$)	Discussion in supplemental instruction classes for Pharmacy students	Young adults	No	$p \geq 0.05$

schools where English is the language of teaching and learning. These triggers were conversational readings, prompt-posters, and practical work. Although the language of teaching and learning was English, the learners were encouraged to engage in exploratory talk in the language in which they were most comfortable. Small group discussions were monitored and the principles used for the assessment of whether exploratory talk had taken place or not were based on the criteria used by Mercer et al. (1999), as described earlier. In a first study with 146 children (36 in the comparison group), significant gains in Raven's scores were recorded in experimental groups where reading and practical work were used to successfully initiate exploratory talk. When using prompt posters, exploratory talk was not evident in the experimental groups and no significant differences were found between the experimental and comparison groups' pre- and post-intervention Raven's scores. As such, the approach to using the prompt-posters was redesigned to better facilitate exploratory talk. Thereafter, a second study the following year was undertaken among 1192 children (298 in the comparison group) over 6 months. Significant improvements between the Raven's pre- and post-test scores were recorded in all cases for the experimental groups but not for the comparison groups.

Villanueva (2010) also conducted repeat studies. In the first study ($n = 168$), where teachers of the experimental groups, who had been trained in exploratory talk, were not able to implement it successfully with their classes, no statistically significant differences were observed in terms of Raven's scores between learners ($n = 168$) in experimental ($n = 122$) and comparison ($n = 46$) groups. In the second study ($n = 675$), in different schools where the teachers were able to successfully implement exploratory talk, significant differences were found in the change between the pre-post-test scores of the experimental group ($n = 479$) but not for the comparison group ($n = 196$). Similarly, significant differences with a large effect size in favor of the experimental group ($n = 403$) were recorded in a study using exploratory talk based on concept cartoons in mathematics (Webb 2010a).

Boschmans' (2013) study, where pharmacology students discussed the content of their lectures in supplemental instruction sessions (and which did not result in exploratory talk), revealed no statistically significant differences between Raven's pre- and post-test scores. This particular finding, as well as instances in Webb and Treagust (2006) and Villanueva's (2010) studies where teachers were unable to promote successful exploratory talk in their classrooms (as documented through recordings of the classroom sessions), underscores the association between exploratory talk in classrooms and significant improvement in RSPM scores. The Sepeng (2011) study with 176 grade 9 learners, which was similar in all aspects to the other studies except that he used the ability to solve word problems in mathematics as a measure of reasoning, showed statistically significant improvements in reasoning with a large effect size.

Discussion

The South African studies that we have summarized here constitute additional evidence for the potential benefits of educational practices that embody what Nussbaum and Asterhan (in press) term *argumentive discussion*. Exploratory talk fits comfortably among the approaches described by Resnick et al. (2015) and shares conceptual and procedural features with a *dialogic argumentation* (e.g., Kuhn and Crowell 2011) and *dialogic discussion* (e.g., Reznitskaya et al. 2012), among others. Consistent with this literature, the studies we have summarized show that exploratory talk, as realized in these South African studies, improves student performance. More importantly, however, we believe these studies provide particularly strong evidence for improvements that can be characterized in the Barnett and Ceci taxonomy as far transfer effects. As such, in this section, we first discuss the significance of these findings with respect to the issue of near versus far transfer effects; we then take up the issue of how to explain such effects in terms of cognitive theories. Our analysis has some parallels with a recent examination of the issue by Nussbaum and Asterhan (in press) and it is encouraging to see many points of agreement between these separate efforts to connect the phenomena of improved learning through dialogical teaching practices with the concepts and constructs of cognitive theories.

The Nature of Transfer

As noted earlier, Barnett and Ceci (2002) developed their taxonomy in order to provide a principled basis for characterizing transfer studies with respect to whether they involve near transfer or far transfer. Using their taxonomy, the studies by Adey (2001), Shayer and Adey (2002), Wegerif et al. (1999), and Wegerif et al. (2005), all of which show positive transfer effects from exploratory talk, would be categorized as showing near transfer effects. The assessments of transfer involved the same knowledge domains, physical context, social context, functional context, and modality of presentation. In Shayer and Adey's CASE project, for example, the talk and the assessment were both based in science content and concepts, while in Mercer, Wegerif, and Dawes' studies the talk was about the test (namely solving the RSPM test). By way of contrast, the studies by Webb and Treagust (2006), Villanueva (2010), and Webb (2010a) would all be characterized in Barnett and Ceci's taxonomy as involving far transfer effects. In each case there was considerable distance in terms of knowledge domain (from exploratory talk around science and mathematics topics to solving test items in the RSPM) and in terms of temporal context (pre-post testing over 6 months to a year). Although the physical context was similar (both activities occurred in a classroom at a school), there was considerable distance in terms of social context and modality (from group discussion in science or mathematics to individual completion of the Raven's tests). Such gains suggest positive far transfer of learning characterized by the ability to reason better on a problem that was unrelated to the topic of previous learning (Barnett and Ceci 2002).

The Paradox of Far Transfer for a Science of Learning

Far transfer is easy to explain for a faculty-based psychology. If reasoning is a faculty, then any task that strengthens the faculty of reasoning will provide benefits for other tasks that involve reasoning. This line of argument leads to the doctrine of formal discipline, which was used to justify the teaching of Latin in nineteenth century schools (Hewins 1914). However, as noted by Taatgen (2013), for example, contemporary psychological theorizing has generally assumed that transfer occurs to the degree there is overlap in the knowledge or procedures used in one task and those used in another. The paradox of far transfer is that the conditions needed to demonstrate far transfer most convincingly are those that involve minimal similarity between one task and another, yet the occurrence of far transfer is the most convincing evidence that learning has produced some general benefit.

Thus, two challenges confront efforts to demonstrate far transfer. The first is to show reliable and robust evidence of transfer effects under conditions that involve little overlap in the dimensions identified by Barnett and Ceci (2002). Our discussion of the South African studies has been designed to show that this challenge has been met. Accepting this claim leads to the second challenge, which is to identify and test the various cognitive mechanisms and educational principles that might explain the success and effectiveness of approaches that yield far transfer. With this second challenge comes an additional task, however, which is to seek common ground with the sociocultural approaches that have guided many of the efforts in science education that we have cited. Although these approaches are paralleled by an emphasis on constructivism and social learning in applications of cognitive psychology to education (e.g., Bransford et al. 2000), the latter applications fall under a general umbrella of "learning sciences" and reflect a view that adopting a scientific approach to learning will improve the quality and efficiency of education (Roediger 2013). The promise of exploratory talk as a technique for enhancing reasoning is matched by its promise as a way to investigate the cognitive mechanisms and educational principles that underlie its documented success in educational contexts in general. That is, exploratory talk can be used as a "test-bed" for models of learning and performance (Singley and Anderson 1989) in which to investigate the cognitive mechanisms and educational principles that might explain the success and effectiveness of dialogic instructional approaches. However, the fact that exploratory talk emerged from a sociocultural approach rather than a social learning approach means that we have little in the way of initial guidance for structuring the investigation, a point that has also been noted by Nussbaum and Asterhan (in press). Consequently, we will frame our discussion of ways to further study the benefits of exploratory talk in terms of Moulton's (2014) summary of key findings in the science of learning.

In his summary, Moulton (2014) attempted to identify the most robust and well-documented findings from the cognitive research literature that seems to have significance for education. He organized his review of key findings with respect to three domains—effective learning techniques, mental architecture, and motivation and persistence. The following paragraphs briefly examine exploratory talk in relation to each of these domains in an effort to identify the most promising avenues for future research on how exploratory talk might support improved reasoning on a far transfer test. At the outset, however, it is important to recognize the distinction between *explicit* and *implicit* influences. That is, exploratory talk might be effective because it explicitly incorporates some aspects of a particular key finding. As we will discuss below, this is most likely to be the case in relation to mental architecture. Alternatively, exploratory talk might be effective because it provides a scaffold in which a particular feature of effective education is naturally contained or expressed. This seems most likely to be the case in relation to effective learning techniques and to motivation and persistence.

Effective Learning Techniques

Evidence-based assessments of effective learning techniques have shown that certain ways of presenting information are robustly more effective than other ways. In particular, giving students opportunities to practice retrieval of what they have learned (usually by means of testing) rather than by giving them additional study, giving them practice that is spaced over time rather than occurring all at once, and giving them practice with multiple topics intermixed rather than with one topic at a time, are all more effective in promoting learning than the alternatives (Roediger 2013). Exploratory talk might be effective because implementing it also embodies *retrieval practice*. That is, in order to make an argument, one has to remember the facts and concepts that one has studied to construct the argument. Exploratory talk might also implicitly provide *distributed practice* in that the process of developing and presenting argument is likely to involve coming back to the same material at different times. Similarly, developing an argument often requires a combination of reviewing past history, analyzing data from current findings and constructing a coherent narrative, a process that interleaves different tasks to complete a project. These tasks underpin the "educative ability" noted by Raven et al. (2003), namely problem identification, re-conceptualization of the field and monitoring proposed solutions for consistency within all available information.

Evidence-based research on practice has also shown that continued improvement in a given task depends on deliberate practice, in which feedback is used to strive toward achievement of a practice-related goal (Ericsson 2014). This is true whether the task is the sensory-based expertise of master perfumers, the motor skill performance of elite athletes, the sensory-motor skill of elite musicians, or the cognitive skills of experienced programmers. By providing a general structure for argument, and by explicitly encouraging students to challenge each other to make a good argument, exploratory talk may support, both explicitly and implicitly, deliberate practice in learning material, which can be examined by studies that look for practice effects in exploratory talk protocols.

These speculations about how exploratory talk might provide implicit support for effective learning techniques seem reasonable, but it seems to us unlikely that exploratory talk enables far transfer effects primarily through this route. One reason is these techniques are primarily useful for learning material that is actually presented. Hence, the benefits produced by these means would primarily be expressed in tests of near transfer, rather than far transfer. In addition, studies of dialogic argumentation have sometimes found clear evidence of improved argumentation without finding evidence of improved cognitive performance (e.g., Reznitskaya et al. 2012). We would expect the implicit effects of argumentation to be evident whenever dialogic argumentation was improved. Of course, there may well be differences in the mechanisms responsible for transfer following different kinds of argumentive discussion training, but results like these certainly raise questions about whether an implicit effect is responsible for the benefits of exploratory talk.

Mental Architecture

The "cognitive revolution" began with acceptance of the principle that human processing capacity, like the capacity of all information processing systems, is limited. Thus, effective teaching practices must reflect both the cognitive limitations of students and our understanding of the mental architecture that is involved in learning and memory. For example, the fact that the capacity of working memory depends on how information is organized (e.g., Miller 1956) means that a teacher's judgment of the cognitive load of a lesson may be far different from a student's judgment of the cognitive load of the same lesson (Moulton 2014). That is, the teacher can have an organized and coherent structure that imposes little cognitive load whereas the student struggles with a fragmented and disjointed set of facts that imposes a large cognitive load. In our view, one of the more likely sources of benefit of exploratory talk is that it explicitly teaches students how to structure an argument and therefore to organize their thoughts. Another possibility we have considered is that exploratory talk provides practice in how to manage working memory capacity more effectively and thereby reduces cognitive load. Our consideration of this possibility was prompted by two kinds of findings. First, there are the well-established associations between working memory capacity and measures of problem solving and fluid intelligence (see, e.g., Ackerman et al. 2005; Kane et al. 2005; Oberauer et al. 2005). Second, Jaeggi et al. (2008) reported that extensive training on an adaptive working memory task yielded significant improvements on the RPSM. With this result, one could speculate that if exploratory talk increased working memory capacity, the increased capacity might translate into higher levels of problem-solving ability. That would still leave the problem of explaining how exploratory talk might increase working memory capacity, but at least that problem can be addressed with a collection of known research tools (e.g., Miyake et al. 2000). That is, one could measure working memory capacity and other executive functions before and after learners are engaged in exploratory talk.

For example, exploratory talk may facilitate working memory efficiency by providing clear guidelines to achieve the goals of a good argument. Toulmin's argumentation pattern (Toulmin 2003) specifies in a straightforward manner a set of components for an argument, and how they are related to each other. The task for students using this framework becomes not one of "making an argument," but of identifying data that can offered to support a claim, establishing the assumptions needed to connect the data to the claim, acknowledging any limits to the claim, and considering counter-arguments. Breaking down the larger task into manageable components is a widely recognized strategy for solving complex problems. A germane point to consider, however, is that recent efforts to replicate Jaeggi et al.'s (2008) findings have been inconclusive. Harrison et al. (2013) and Redick et al. (2013) found no improvement in measures of fluid intelligence after extended adaptive training with working memory tasks, even though these tasks yielded substantial gains in working memory capacity. Reasons for these failures of replication remain unclear, although there are probably a number of methodological differences that have not been identified, including the particular structure of the adaptive memory task. While these findings suggest caution in assuming that acquired increases in working memory capacity will translate into better problem-solving abilities, it still seems reasonable to suggest that it would be useful and interesting to determine how working memory capacity is affected by lessons using exploratory talk and whether exploratory talk works, at least in part, through the medium of working memory.

Finally, exploratory talk might also produce benefits by increasing students' abilities to sustain their attentional focus. Research has shown that several different kinds of training reduce "mind-wandering" and lead to better learning (e.g., Mrazek et al. 2012, 2013; Szpunar et al. 2013a, b). Perhaps most intriguingly, Mrazek, Schooler, and their colleagues have shown that learning mindfulness meditation techniques not only helped reduce "mind-wandering," but led both to improved working memory capacity and improved general aptitude. Here too it would be interesting to examine whether lessons using exploratory talk diminish the amount of mind wandering seen in the students and whether the reduction of mind-wandering was a mediator for changes in fluid intelligence. The overall question is does exploratory talk have a positive effect on reasoning skills because of transfer of these skills?

Motivation and Persistence

A final domain in which exploratory talk might exert implicit effects is what Moulton terms motivation and persistence. Here he refers to the substantial literature showing benefits of achievement motivation, intrinsic motivation, goal setting, and social learning, among other motivational concepts that promote learning. Certainly it seems reasonable to suppose that one benefit of exploratory talk and other forms of argumentive discussion is to endow students with a sense of competence and confidence, or what Bandura (1977) calls self-efficacy. It also seems likely that students participating in exploratory talk would develop more of the growth mindset that Dweck (2006) has shown leads to improved performance on cognitive measures.

It is also reasonable to speculate that the social nature of argumentive discussion contributes to its beneficial effects. The importance of a social dimension in learning has been showcased in research by Michael Cole and his colleagues (e.g., Cole 2010) that complement the work mentioned previously by Wegerif and Mercer. Cole was influenced in part by studies of non-literate cultures without formal education or training institutions in which children learned through participation in the daily activities of the group (e.g., Fortes 1970). Exploratory talk clearly partakes of this social aspect of learning by engaging students in the interactive give-and-take that are essential for science discussions. However, the idea that learning is enhanced when it occurs in a supportive social context does not explain why the kind of dialogic argumentation that Reznitskaya et al. (2012) used was not effective.

As such, it appears that which domains and which mechanisms within each domain, as well as which combinations of domain and mechanism, are essential for producing the benefits of exploratory talk and related discourses requires systematic research efforts if we are to move beyond our speculative suggestions. However, there now seems to be substantial reason to believe such research will yield important benefits for understanding the nature of learning and, more importantly, its transfer to new situations.

Concluding Remarks

In Barnett and Ceci's taxonomy of transfer effects, transfer occurs along two major dimensions. One dimension involves the context of learning, which can vary from the identity of physical, social, and cognitive contexts to complete changes in each of these contexts, separately or together. The other dimension involves the content of learning, which can vary from specific associations to general strategies and heuristics. Positive transfer is more likely when the context of assessment is near to the context of learning; it is also more likely when the content of learning involves general strategies rather than specific associations. The latter appears to be the case when exploratory talk was used in the studies reported on in this paper. On the content dimension, exploratory talk emphasizes higher level strategies that also are more likely to show positive far transfer effects. This idea that exploratory talk is effective because of its emphasis on shared higher level strategies that are made verbally explicit is consistent with the claim of Kan et al. (2013) that societal demands influence the development and interaction of multiple cognitive abilities and knowledge, and that these interactions feed on each other to raise the intelligence factor *g*. While the studies considered in this paper suggest clear associations between the successful uses of exploratory talk in science classes and improved reasoning abilities as assessed by Raven's Matrices, i.e. positive far transfer effects, the challenge is to determine which one or another (or combinations thereof) of the theoretical analyses of the effects of exploratory talk is best supported by empirical research. A great deal more research on this issue is needed, but we believe that there are strong suggestions that exploratory talk can provide one fruitful mechanism for investigating this problem. We also note that there is increasing interest in pinpointing the cognitive mechanisms that give rise to the benefits of argumentive discussion, and multiple approaches are being used, as seen in the volume by Resnick et al. (2015).

At this stage, it is also important to note that the claims made in this paper are about the type of thinking that exploratory talk scaffolds and promotes; in other words it is the nature of the talk that is important. The fact that language was mentioned when describing the studies in Table 1 was meant merely to highlight the fact that the pupils were encouraged to engage in exploratory talk in the language in which they were most competent, namely their home language. This was necessary because the studies were undertaken at schools in which the language of teaching and learning was English, while the pupils were all Xhosa mother-tongue speakers and could therefore engage more deeply in exploratory talk in this language. Similarly, while the paper has relied on findings on exploratory talk and reasoning in science and mathematics settings, using exploratory talk to develop reasoning skills is not limited to these subjects. Rather further research in other disciplinary discourse situations is needed. As importantly, exploratory talk has been shown by empirical studies to promote reasoning skills in populations that have traditionally been under-served. Thus, it offers considerable promise as a means to increase reasoning skills among students who are most in need of opportunities for academic success. By focusing research on understanding how and why exploratory talk works, we can hope to enhance its effectiveness and expand that the range of people and contexts in which it could be successfully implemented.

Acknowledgments This project was kindly funded in part by incentive funding (UID 85590) from the National Research Foundation (NRF) of South Africa.

References

Ackerman, P. L., Beier, M. E., & Boyle, M. O. (2005). Working memory and intelligence: the same or different constructs? *Psychological Bulletin, 131*, 30–60.

Adey, P. (2001). Cognitive acceleration: thinking as intelligence. *Teaching Thinking, 5*, 38–41.

Adey, P., & Shayer, M. (1994). *Really raising standards*. London: Routledge.

Bandura, A. (1977). Self-efficacy: toward a unifying theory of behavioral change. *Psychological Review, 84*, 191–215.

Barnett, S., & Ceci, S. (2002). When and where do we apply what we learn? A taxonomy for far transfer. *Psychological Bulletin, 128*, 612–637. doi:10.1037//0033-2909.128.4.612.

Boschmans, S.-A. (2013). Teaching pharmacology: issues of language and learning in a multilingual classroom setting. Unpublished PhD. Nelson Mandela Metropolitan University, Port Elizabeth.

Bransford, J. D., Brown, A. L., & Cocking, R. R. (2000). *How people learn: brain, mind, experience and school*. Washington, DC: National Academies Press.

Bruner, J. (1990). *Acts of meaning*. London: Harvard University Press.

Chinn, C., & Anderson, R. (1998). The structure of discussions that promote reasoning. *Teachers College Record, 100*, 315–368.

Cole, M. (2010). What's culture got to do with it?: Educational research as a necessarily interdisciplinary enterprise. *Educational Researcher, 39*, 461–470.

Dweck, C. (2006). *Mindset: the new psychology of success*. New York: Random House.

Ericsson, K. A. (2014). *The road to excellence: the acquisition of expert performance in the arts and sciences, sports and games*. New York: Psychology Press.

Fortes, M. (1970). Social and psychological aspects of education in taleland. In M. Fortes (Ed.), *Time and social structure* (pp. 201–239). New York: Humanities Press (Original work published 1938).

Harrison, T. L., Shipstead, Z., Hicks, K. L., Hambrick, D. Z., Redick, T. S., & Engle, R. W. (2013). Working memory training may increase working memory capacity but not fluid intelligence. *Psychological Science*. doi:10.1177/0956797613492984.

Hewins, N. P. (1914). The doctrine of formal discipline in the light of experimental investigation. *Journal of Educational Psychology, 5*(3), 168–174. http://dx.doi.org/10.1037/h0070498.

Hodson, D. (2009). *Teaching and learning about science: language, theories, methods, history, traditions and values*. Rotterdam, The Netherlands: Sense Publishers.

Jaeggi, S., Buschkuehl, M., Jonides, J., & Perrig, W. (2008). Improving fluid intelligence with training on working memory. *Proceedings of the National Academy of Sciences of the United States of America, 105*(15), 6829–6833.

Jensen, A. (1998). *The g factor: the science of mental ability*. Westport, CT: Praeger.

Kan, K.-J., Wicherts, J. M., Dolan, C. V., & van der Maas, H. L. J. (2013). On the nature and nurture of intelligence and specific cognitive abilities: the more heritable, the more culture-dependent. *Psychological Science, 24*(10), 19.

Kane, M. J., Hambrick, D. Z., & Conway, A. R. A. (2005). Working memory and fluid intelligence are strongly related constructs: comment on Ackermain, Beier & Boyle (2005). *Psychological Bulletin, 131*, 66–71.

Kaplan, R. M., & Saccuzzo, D. P. (1997). *Psychological testing: principles, applications and issues*. Pacific Grove: Brooks/Cole.

Keefer, M., Zeitz, C., & Resnick, L. (2000). Judging the quality of peer-led student dialogues. *Cognition and Instruction, 18*(1), 53–81.

Kuhn, D., & Crowell, A. (2011). Dialogic argumentation as a vehicle for developing young adolescents' thinking. *Psychological Science, 22*, 545–552.

Kunda, M., McGreggor, K., & Goel, A. (2009). Addressing the Raven's progressive matrices test of general intelligence. AAAI Fall Symposium on Multi Representational Architectures for Human Level Intelligence, Washington, DC.

Locke, A., Ginsberg, J., & Peers, I. (2002). Development and disadvantage: implications for the early years and beyond. *International Journal of Language and Communication Disorders, 37*(1), 3–15.

Lynn, R., Allik, J., Pullmann, H., & Laidra, K. (2004). Sex differences on the progressive matrices among adolescents: some data from Estonia. *Personality and Individual Differences, 36*(6), 1249–1255.

Mercer, N. (1996). The quality of talk in children's collaborative activity in the classroom. *Learning and Instruction, 6*(4), 359–377.

Mercer, N., & Littleton, K. (2007). *Dialogue and the development of children's thinking: a sociocultural approach*. London: Routledge.

Mercer, N., Wegerif, R., & Dawes, L. (1999). Children's talk and the development of reasoning in the classroom. *British Educational Research Journal, 25*(1), 95–111.

Mercer, N., Dawes, L., Wegerif, R., & Sams, C. (2004). Reasoning as a scientist: ways of helping children to use language to learn science. *British Educational Research Journal, 30*(3), 359–377.

Michaels, S., & O'Connor, M. (2002). *Accountable talk: classroom conversation that works*. Pittsburg: University of Pittsburgh.

Miller, G. A. (1956). The magic number seven, plus or minus two: some limits on our capacity for processing information. *Psychological Review, 62*, 81–97.

Miyake, A., Friedman, N. P., Emerson, M. J., Witzki, A. H., & Howerter, A. (2000). The unity and diversity of "frontal lobe" tasks: a latent variable analysis. *Cognitive Psychology, 41*, 49–100.

Monaghan, F. (2005). 'Don't think in your head, think aloud': ICT and exploratory talk in the primary school mathematics classroom. *Research in Mathematics Education, 7*(1), 83–100.

Morehouse, R., & Williams, M. (1998). Report on student use of argument skills. *Critical and Creative Thinking, 6*(1), 14–20.

Moulton, S.T. (2014). Applying psychological science to higher education: key findings and open questions. Retrieved from http://hilt.harvard.edu/hilt-publications on June 18.

Mrazek, M. D., Smallwood, J., Franklin, M. S., Chin, J. M., Baird, B., & Schooler, J. W. (2012). The role of mind-wandering in measurements of general aptitude. *Journal of Experimental Psychology: General, 141*, 788–798. doi:10.1037/a0027968.

Mrazek, M. D., Franklin, M. S., Phillips, D. T., Baird, B., & Schooler, J. W. (2013). Mindfulness training improves memory capacity and GRE performance while reducing mind wandering. *Psychological Science, 24*, 776–781. doi:10.1177/0956797612459659.

Nussbaum, E. M., & Asterhan, C. S. (2016). The psychology of far transfer from classroom argumentation. In F. Paglieri (Ed.), *The psychology of argument: cognitive approaches to argumentation and persuasion*. London: College Publications.

Oberauer, K., Schulze, R., Wilhelm, O., & Suss, H.-M. (2005). Working memory and intelligence—their correlation and relation: comment on Ackerman, Beier, & Boyle (2005). *Psychological Bulletin, 131*, 61–65.

Osborne, J. (2010). Arguing to learn in science: the role of collaborative, critical discourse. *Science, 328*(5977), 463–466.

Raven, J., Court, J. & Raven, J. C. (1995). *Manual for Raven's progressive matrices and vocabulary scales*. Oxford: Oxford Psychologists Press.

Raven, J., Raven, J. C., & Court, J. H. (2003). *Manual for Raven's standard progressive matrices and vocabulary scales: section 1 general overview*. San Antonio, Texas: Pearson.

Redick, T. S., Shipstead, Z., Harrison, T. L., Hicks, K. L., Fried, D. E., Hambrick, D. Z., Kane, M., & Engle, R. W. (2013). No evidence of intelligence improvement after working memory training: a randomized, placebo-controlled study. *Journal of Experimental Psychology: General, 142*(2), 359–379.

Resnick, L. B. C., Asterhan, C. S. C., & Clarke, S. N. (2015). Introduction: talk, learning, and teaching. In L. B. Resnick, C. S. C. Asterhan, & S. N. Clarke (Eds.), *Socializing intelligence through academic talk and dialogue* (pp. 1–12). Washington, DC: AERA.

Reznitskaya, A., Kuo, L., Clark, A., Miller, B., Jadallah, M., Anderson, R. C., et al. (2009). Collaborative reasoning: dialogic approach to group discussions. *Cambridge Journal of Education, 39*(1), 29–48.

Reznitskaya, A., Glina, M., Carolan, B., Michaud, O., Rogers, J., & Sequeira, L. (2012). Examining transfer effects from dialogic discussions to new tasks and contexts. *Contemporary Educational Psychology, 37*, 288–306.

Richardson, K. (1991). Reasoning with raven in and out of context. *British Journal of Educational Psychology, 61* (2), 129–138.

Roediger, H. L. (2013). Applying cognitive psychology to education: translational educational science. *Psychological Science in the Public Interest, 14*(1), 1–3.

Rogoff, B. (1990). *Apprenticeship in thinking: cognitive development in social context*. Oxford: Oxford University Press.

Rojas-Drummond, S., & Mercer, N. (2004). Scaffolding the development of effective collaboration and learning. *International Journal of Educational Research, 39*, 99–111.

Sepeng, P. (2011). Grade nine second-language learners in township schools: issues of language and mathematics when solving word problems. Unpublished PhD. Nelson Mandela Metropolitan University, Port Elizabeth, South Africa.

Shayer, M., & Adey, P. (2002). *Learning intelligence: cognitive acceleration across the curriculum from 5 to 15 years*. Maidenhead: Open University Press.

Singley, M., & Anderson, J. (1989). *The transfer of cognitive skill* (Cognitive science series). Cambridge, MA: Harvard University Press.

Szpunar, K. K., Khan, N. Y., & Schacter, D. L. (2013a). Interpolated memory tests reduce mind wandering and improve learning of online lectures. *Proceedings of the National Academy of Sciences, 110*, 6313–6317.

Szpunar, K. K., Moulton, S. T., & Schacter, D. L. (2013b). Mind wandering and education: from the classroom to online learning. *Frontiers in Psychology, 4*, 1–7.

Taatgen, N. A. (2013). The nature and transfer of cognitive skills. *Psychological Review, 120*(3), 439–471.

Toulmin, S. (2003). *The uses of argument*. New York: Cambridge University Press.

Trickey, S., & Topping, K. (2004). Philosophy for children: a systematic review. *Research Papers in Education, 19*(3), 365–380.

Villanueva, M. G. (2010). Integrated teaching strategies model for improved scientific literacy in second-language learners. Unpublished PhD. Nelson Mandela Metropolitan University, Port Elizabeth, South Africa.

Vygotsky, L. S. (1981). The genesis of higher mental functions. In J. V Wertsch (Ed.), *The Concepts of Activity in Soviet Psychology*. New York: Sharpe.

Webb, P. (2003). Initiating classroom discussion in science classrooms: practical work, conversational texts and prompt posters. Unpublished PhD. Curtin University of Technology, Perth, Australia.

Webb, L. (2010a). Searching for common ground: developing mathematical reasoning through dialogue. Unpublished PhD. Nelson Mandela Metropolitan University, Port Elizabeth, South Africa.

Webb, P. (2010b). Science education and literacy: imperatives for the developed and developing world. *Science, 328*(5977), 448–450.

Webb, P., & Treagust, D. (2006). Using exploratory talk to enhance problem-solving and reasoning skills in grade-7 science classrooms. *Research in Science Education, 36*(4), 381–401.

Wegerif, R., Mercer, N., & Dawes, L. (1999). From social interaction to individual reasoning: an empirical investigation of a possible socio-cultural model of cognitive development. *Learning and Instruction, 9*, 493–516.

Wegerif, R., Perez, J., Rojas-Drummond, S., Mercer, N., & Velez, M. (2005). Thinking together in the UK and Mexico: transfer of an educational innovation. *Journal of Classroom Interaction, 40*(1), 40–48.

Wertsch, J. V. (1991). *Voices of the Mind*. New York: Harvester.

Wilkinson, I. A. G., Murphy, P. K., & Binici, S. (2015). Dialogue-intensive pedagogies for promoting reading comprehension: what we know, what we need to know. In L. B. Resnick, C. S. C. Asterhan, & S. N. Clarke (Eds.), *Socializing intelligence through academic talk and dialogue (pp. 1–12)* (pp. 35–48). Washington, DC: AERA.