The Cambridge Handbook of Cognition and Education

Edited by
John Dunlosky
Kent State University

Katherine A. Rawson
Kent State University

CAMBRIDGE
UNIVERSITY PRESS

CAMBRIDGE
UNIVERSITY PRESS

University Printing House, Cambridge CB2 8BS, United Kingdom

One Liberty Plaza, 20th Floor, New York, NY 10006, USA

477 Williamstown Road, Port Melbourne, VIC 3207, Australia

314–321, 3rd Floor, Plot 3, Splendor Forum, Jasola District Centre, New Delhi – 110025, India

79 Anson Road, #06–04/06, Singapore 079906

Cambridge University Press is part of the University of Cambridge.

It furthers the University's mission by disseminating knowledge in the pursuit of education, learning, and research at the highest international levels of excellence.

www.cambridge.org
Information on this title: www.cambridge.org/9781108416016
DOI: 10.1017/9781108235631

First published 2019

Printed in the United Kingdom by TJ International Ltd. Padstow Cornwall

A catalogue record for this publication is available from the British Library.

Library of Congress Cataloging-in-Publication Data
Names: Dunlosky, John, editor.
Title: The Cambridge handbook of cognition and education / edited by John Dunlosky, Kent State University, Katherine A. Rawson, Kent State University.
Description: New York : Cambridge University Press, 2019. | Includes bibliographical references and index.
Identifiers: LCCN 2018033895 | ISBN 9781108416016 (alk. paper)
Subjects: LCSH: Cognitive learning – Handbooks, manuals, etc. | Cognition – Handbooks, manuals, etc.
Classification: LCC LB1062 .C36 2019 | DDC 371.39–dc23
LC record available at https://lccn.loc.gov/2018033895

ISBN 978-1-108-41601-6 Hardback
ISBN 978-1-108-40130-2 Paperback

20 Collaborative Learning

The Benefits and Costs

Timothy J. Nokes-Malach, Cristina D. Zepeda, J. Elizabeth Richey, and Soniya Gadgil

A ubiquitous feature of human activity is working and learning with others. Whether we are at home, school, or work we are likely to be interacting and engaging with others to accomplish our goals. Those others often include family, friends, teachers, students, and coworkers. Each of us has likely encountered situations in which these collaborative activities have gone well and we accomplished our goals or even surpassed them. Many of us have also experienced scenarios in which the collaborative activity failed or was not as efficient, effective, or productive as it could have been. What accounts for success in one scenario and failure in another? What are the key factors that support or inhibit productive collaboration? The study of collaborative learning has a long history of research in psychology to answer questions such as these. This research covers a wide array of perspectives and approaches, including cognitive, social, educational, and socio-cultural. A common aim across these different perspectives is to understand how collaborative learning works, that is, to identify the mechanisms and factors that underlie its success and failure.

Our goal for this chapter is to draw from these different perspectives and approaches to understand the potential benefits and costs of collaborative learning. We begin by providing a brief overview of the history of research on collaborative learning. Next, we define collaborative learning for the purposes of this chapter and describe three common approaches used to study it. We then review results from these approaches in which we separate the benefits from the costs and discuss the cognitive and social mechanisms proposed to account for those outcomes. Afterwards, we describe four theoretical frameworks that incorporate some of these mechanisms to account for the findings. Finally, we discuss the implications of these findings for education and future research.

A Brief History of Collaborative Learning

Collaborative learning has been a topic of interest for several thousand years. Many educational practices of the past included elements of collaborative learning. For example, the Roman rhetorician Quintilian's view of teaching focused

This work was supported by grant DUE-1534829 from the National Science Foundation and grant No. 220024083 from the James S. McDonnell Foundation. We thank the editors for very helpful comments on earlier drafts of the manuscript.

on teachers and students writing together and peers giving feedback and constructive criticism to one another (Bloodgood, 2002). Another historical precursor is the centuries-old practice of apprenticeship in learning new trades and skills. Apprenticeship is a source of inspiration to some of the ideas present in current theories of cognitive apprenticeship (Brown, Collins, & Duguid, 1989), situative learning (Greeno, 1998), and communities of practice (Lave & Wegner, 1991) developed in the 1980s and early 1990s.

We do not unpack these more distal histories of collaborative learning (though it would be fascinating to do so) but begin closer to our modern-day context and describe some major contributions of psychological research on collaborative learning in the twentieth century. The scientific study of collaboration is almost as old as the discipline of psychology itself. Classic studies such as the rope-pulling task by Ringelmann (1913; Kravitz & Martin, 1986), which showed that the individual effort exerted by each member of a group decreases linearly as the group size increases, paved the way for a rigorous study of group work.

Foundational thinkers in social psychology such as Kurt Lewin (1890–1947) set the stage for a program of research on group dynamics and the importance of interdependence of individuals in groups. Lewin examined how perceptions of interdependence affect an individual's sense of responsibility and contribution. A major focus of this work was how task interdependence, i.e., the degree to which individuals shared a joint goal, mattered to the success of the group (Lewin, 1935, 1948). Another one of his major influences was the establishment of the Research Center for Group Dynamics at the Massachusetts Institute for Technology in 1945. In 1948, the center moved to the University of Michigan where it is still active today. The center has had a major impact on many faculty and students interested in understanding group dynamics.

One of Lewin's students, Morton Deustch (1920–2017), continued this work and helped to develop a theory of cooperation and competition (Deutsch, 1949, 1973). Deutsch proposed that the interdependence of goals among group members greatly impacts their interactions and, thereby, group success. Cooperative goals were hypothesized to promote positive interdependence based on communication and exchange and lead to successful collaborative outcomes. In contrast, competitive goals were hypothesized to promote negative interdependence and hinder group success. These core ideas were then further developed and extended in many contexts, including student learning in the classroom. For example, David and Roger Johnson at the University of Minnesota have developed an impressive program of research over the past 50 years dedicated to understanding and facilitating cooperation in classroom settings (Johnson & Johnson, 1989, 2009; Johnson, Johnson, & Smith, 1998).

Jean Piaget (1896–1980) also had a large impact on collaborative learning research through his theory of learning, which focused on mechanisms of change including equilibration, assimilation, and accommodation (Piaget, 1932, 1950, 1975/1985). He defined equilibration as a driving force of cognitive change (e.g., seeking consistency and coherence in thought and understanding). Although Piaget was primarily focused on change processes *within the individual*, cognitive conflict and working with others could provide one pathway to create such change. This work had a significant impact on cognitive approaches aimed at understanding individual learning mechanisms in the context of learning and problem-solving with others (e.g., Goldbeck & El-Moslimany, 2013; O'Donnell & Hmelo-Silver, 2013; Tudge & Winterhoff, 1993). It also has had a direct impact on social approaches to understanding collaborative learning in relation to conflict regulation (e.g., Buchs et al., 2004; Butera & Darnon, 2017).

Vygotsky (1896–1934) was another pioneer of work in collaborative learning. He proposed the zone of proximal development in which interaction between a novice and a more expert adult or peer facilitates learning (Vygotsky, 1978). We see reverberations of this idea throughout modern research investigating the interaction between the individual, others, and the environment (e.g., Hakkarainen et al., 2013; Tudge & Winterhoff, 1993). A second critical feature of his work was a focus on historical-cultural aspects of learning. Vygotsky argued that learning and development do not proceed in universal stages but rather that they are directly influenced by the environment and culture of the learner. His work had a profound impact on multiple perspectives on collaborative learning, especially sociocultural views.

In this chapter, we focus on three approaches that have been firmly anchored in this historical context: social/cognitive, educational, and sociocultural. We focus on these perspectives because they provide complementary questions, methods, and results that are rarely brought together in a single paper or chapter (see Dillenbourg et al., 1996). Together they capture a wide variety of collaborative outcomes and theory to account for these results. Examining just one would likely focus on just some of the costs and/or benefits.

Approaches to Collaborative Learning

We define ***collaboration*** as an interaction among individuals in a dyad or group that aims to accomplish or achieve a common goal (Dillenbourg et al., 1996; Kirschner, Paas, & Kirschner, 2009a). Similar to a recent literature review we conducted on this topic, we focus on dyads of two people and groups between three and six people (Nokes-Malach, Richey, & Gadgil, 2015). We do not review work on larger groups ($N > 6$) or from the team performance literature in which different members have specialized complementary skills that need to be utilized to accomplish the group goal (for reviews, see De Dreu & Weingart, 2003; Stewart, 2006).

We define *learning* broadly to include situations in which there is some measure of what was learned from an earlier task or activity (see Figure 20.1 for an illustration of three common collaborative learning and performance scenarios). Each of these scenarios has been associated with a particular theoretical approach including social/cognitive, educational, and sociocultural, and each answers different questions about collaborative learning and performance.

We will describe each approach and its associated methodologies, as well as identify mechanisms that could result in benefits and/or costs of collaboration. These approaches are overlapping and without firm boundaries. They do not have

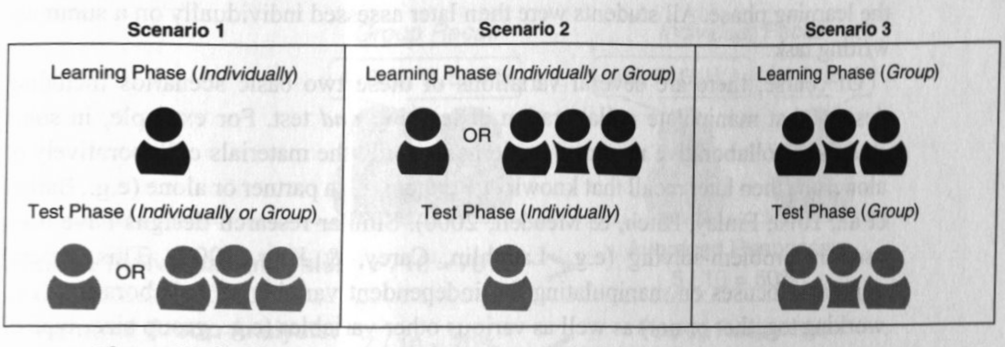

Figure 20.1 *Illustration of the three common collaborative scenarios*

distinguishing features but rather a set of features that tend to co-occur to define the approach, including the types of research questions asked, learning content (puzzle tasks, word lists, or academic content), context (lab or classroom), elements of study design (Figure 20.1), and so on. We acknowledge that some researchers use multiple approaches or combine approaches. For example, our own work is informed by all three approaches.

Cognitive and Social Approaches

Research adopting cognitive and social psychological perspectives has focused on comparing the similarities and differences in learning and performance when people work together versus alone to perform a task. Paper titles such as "When two is too many: Collaborative encoding impairs memory" (Barber, Rajaram, & Aron, 2010) and "Many hands make light the work" (Latané, Williams, & Harkins, 1979) have captured these types of questions. This work has primarily focused on tasks such as memorizing (e.g., Harris, Barnier, & Sutton, 2013; Meade, Nokes, & Morrow, 2009; Rajaram & Pereira-Pasarin, 2010), problem-solving, (e.g., Laughlin et al., 2006; Nokes-Malach, Meade, & Morrow, 2012), brainstorming (e.g., Paulus & Yang, 2000), and physical tasks like clapping or shouting (Latané, et al., 1979). Researchers from this perspective have typically conducted laboratory experiments in which they randomly assigned participants to either a group or individual condition at learning or test (see Figure 20.1, scenarios 1 and 2).

In scenario 1, all participants learn individually and then are tested either individually or in groups. This is a common design to examine the effects of collaboration on the recall of prior knowledge, and has been used extensively in the collaborative memory literature (e.g., Basden et al., 1997; Blumen & Stern, 2011; Harris, Paterson, & Kemp, 2008). In scenario 2, participants learn either individually or as a group and then are tested individually (e.g., Gadgil & Nokes-Malach, 2012; Paulus & Yang, 2000). For example, in a study in which students were learning how to write scientific summaries (Gadgil & Nokes-Malach, 2012), students were first assigned to work either with a partner or individually on an error-detection writing task during the learning phase. All students were then later assessed individually on a summary writing task.

Of course, there are several variations of these two basic scenarios including designs that manipulate collaboration at learning *and* test. For example, in some studies of collaborative memory, participants study the materials collaboratively or alone, and then later recall that knowledge either with a partner or alone (e.g., Barber et al., 2010; Finlay, Hitch, & Meudell, 2000). Similar research designs have been used in problem-solving (e.g., Laughlin, Carey, & Kerr, 2008). This general approach focuses on manipulating the independent variable of collaboration (i.e., working together or not) as well as various other variables (e.g., group size, type of collaborative scaffold, prior knowledge of collaborators) to test hypotheses about the mechanisms and factors that affect successful collaboration.

A major issue in research on collaborative learning is determining how to measure the cost or benefit of group learning and performance outcomes. Research in cognitive and social psychology has focused on the type of contrast condition or standard to which the collaborative group is compared (Hill, 1982; Lorge et al., 1958; Steiner, 1966). In this work, two levels of analysis have been identified. One level of analysis is defined by comparing the collaborative group with the average individual. Called the "average individual" comparison, this approach treats the group as the unit of analysis and assesses whether the average group performs the task more accurately or efficiently than the average individual. For example, imagine a memory task comparing group recall and individual recall after an initial study session. Participants would study a list of ten items (A–J) individually and at test they would recall that list either with their partner (dyad) or alone. The average individual comparison would be to compare the average number of items recalled by the dyads to the average number of items recalled by the individuals (see Figure 20.2). As a simplistic illustration, let's compare one dyad to two individuals. Imagine the dyad recalled seven items on the list (e.g., A, B, C, D, E, F, and J), while individual participant 1 recalled six items (A, B, C, G, H, I) and individual participant 2 recalled four items (A, D, E, J). The two individuals would have recalled on average 50 percent of the items and, thus, the dyad would have recalled more than the average individual (70% > 50%). Research has shown that there are often advantages when comparing the group to the average individual (for reviews, see Hill, 1982; Kerr & Tindale, 2004).

The second type of analysis helps answer the question of how working in a group affects learning and performance compared to the pooled outcome of working alone. In order to make this comparison, the collaborative dyad or group condition must be compared with what has been called a *nominal group*, in which performance is pooled or summed across the same number of individuals as are in the collaborative group (Rajaram & Pereira-Pasarin, 2010). There are a number of ways to create nominal groups, including summing scores to create post hoc groups or algorithms that make estimates of the nominal group based on individual performance scores (Kelley & Wright, 2010; Schwartz, 1995; Wright, 2007). For example, in our simplistic illustration of the memory recall paradigm above, we can see that if we pool together the two individuals' unique (non-redundant) responses, they would

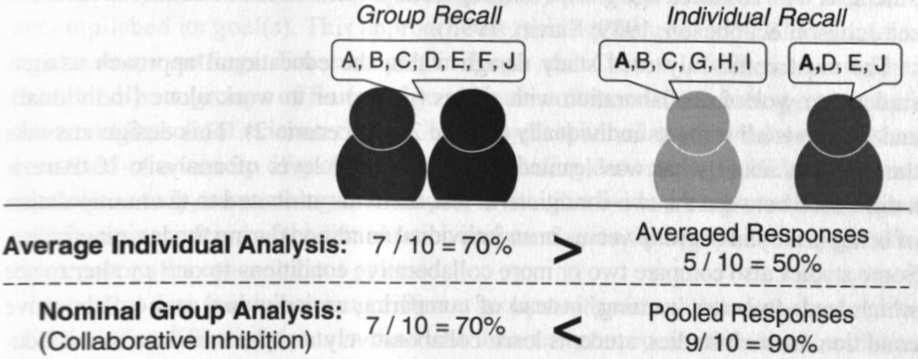

Figure 20.2 *Illustration of two levels of analysis within scenario 1*

have recalled nine items (A, B, C, D, E, G, H, I, J) out of ten, or 90 percent of the list. This example illustrates that although they recalled fewer responses when averaged (50%), the individuals actually recalled more unique responses than the dyad when summed across individuals (Figure 20.2).

When the collaborative dyad or group performs less well than the nominal dyad or group, it is called *collaborative inhibition* (Weldon & Bellinger, 1997) and has been interpreted as individuals in the group not performing up to their predicted potential. In contrast, when the collaborative group performs better than the nominal group this is called *collaborative facilitation* or *synergy* (Meade et al., 2009; Nokes-Malach et al., 2012) and is interpreted as individuals in the group performing better than their predicted potential based on individual performance. For example, imagine in our memory recall paradigm that the collaborative dyad recalls all ten items and has 100 percent recall and the individuals in the nominal group recall the same number as described above. This would be an example of collaborative facilitation because the collaborative group's recall (100%) would be better than that of the nominal group (90%). Next, we describe a second major approach to research on collaborative learning that comes from educational psychology.

Educational Psychology Approaches

Educational psychologists have used a myriad of methods to study collaborative learning. Research questions from this perspective often focus on understanding how different types of instruction can facilitate productive collaboration and learning outcomes. Much of this research has been conducted in classroom contexts, often comparing different types of instructional activities to one another. This work has covered a wide variety of content domains and tasks, including mathematics (Kolloffel, Eysink, & de Jong, 2011; Schwarz, Neuman, & Biezuner, 2000; Slavin, Leavey, & Madden, 1984), science (Kirschner, Paas, & Kirschner, 2009b; Springer, Stanne, & Donovan, 1999; Sampson & Clark, 2009), and language arts (Kim, 2008; Stevens & Slavin, 1995; Stevens, Slavin, & Farnish, 1991), among others, as well as varied age groups ranging from preschoolers to adults (for reviews, see Johnson & Johnson, 1989; Slavin, 1995).

The most commonly used study design within the educational approach assigns students to work in collaboration with others (group) or to work alone (individual), and then tests all students individually (Figure 20.1, scenario 2). This design answers the question about what was learned at an individual level of analysis. If there is a difference between the two conditions at test, then it is attributed to the manipulation of being in a dyad or group versus in an individual condition during the learning phase. Some studies also compare two or more collaborative conditions to one another to see which leads to better learning, instead of comparing an individual and collaborative condition. In such studies, students learn collaboratively and then are tested individually to understand what kinds of collaborative instructional strategies are most effective (e.g., Souvignier & Kronenberger, 2007) or what types of group compositions (e.g., same or mixed ability) lead to successful collaborative learning.

These research designs capture several features of common educational practices and curricula that encourage students to collaborate during learning and then give individual assessments. For example, in K-12 science classes, students frequently learn together in small groups (e.g., with their lab partners) but are then tested individually. When researchers investigate collaboration in the classroom, these condition assignments typically happen at the classroom level, i.e., some classrooms do group work whereas other classrooms do individual assignments (e.g., Mevarech, 1985). Occasionally, the group versus individual comparison happens within the classroom using a counterbalanced design, such that the conditions are switched for the next session and each student has the opportunity to participate in both conditions. Other types of methods include pull-out studies, interviews, and laboratory contexts (for an overview of methods and context, see Hmelo-Silver et al., 2013).

Many variables have been examined using this approach. Five key variables that Johnson and Johnson (2009) have investigated include positive interdependence (mutual goals), individual accountability within the group, promotive interaction (i.e., encouraging each other's efforts), the appropriate use of social skills, and group processing (i.e., reflecting on performance). The role of each of these variables in relation to collaborative benefits and costs has been studied extensively. Next, we describe the sociocultural approach to studying collaborative learning.

Sociocultural Approaches

A primary focus of the sociocultural approach is to understand how interactions between group members and the environment support or inhibit collaborative outcomes. This approach treats the dyad or group as the unit of analysis as opposed to the individual within the group and does not often compare groups or dyads to individuals (e.g., Barron, 2000; Engle & Conant, 2002; Greeno & MMAP, 1997; Harris, Yuill, & Luckin, 2008; Roschelle, 1992; Roschelle & Teasley, 1995). Instead, much of the work involves examining collaborative interactions for insights on the affordances and constraints that lead to more versus less successful collaborative outcomes. Success or failure is determined by whether and how the group has accomplished its goal(s). This approach has typically focused on academic content in classroom settings. For example, in Engle and Conant (2002) the researchers examined how groups of four or five students collaborated on biology projects in their middle school science classes. The project spanned many weeks of class and consisted of a variety of group activities, including determining which endangered animal to study, researching that animal, writing individual chapters of the report, collaborative writing of the introduction and conclusion of the report, and presenting the report to the other student groups.

A typical design is to compare different groups with one another or the same group with itself at different points in time and then analyze process data to assess which factors and mechanisms are associated with the benefits and costs of collaboration (e.g., Figure 20.1, scenario 3). Researchers typically video record student talk and behaviors during the learning phase (Jeong, 2013; Sawyer, 2013). This serves as the primary data source and the researchers code and analyze the discourse and behaviors for different types of interactions. In many studies, there is some later assessment taken as a group, individually, or both. However, in contrast to the previous scenarios, the test phase is not always well differentiated from the learning phase. For example, in the Engle and Conant (2002) study, the test phase can be conceptualized as the final biology report given. In other cases, researchers have looked for evidence of change whether it be in solving new problems later in the activity (e.g., Roschelle, 1992) or new thinking or reasoning about an old problem (e.g., Engle & Conant, 2002). In the next section, we review findings from these three approaches on the benefits and costs of collaborative learning.

Table 20.1 *Summary of three common approaches to examining collaborative learning*

		Methodologies		
Approach	Focus	Research Design(s)	Level of Analysis	Setting
Social and Cognitive	Comparing the similarities and differences of learning and performance when people work together versus when they work alone to perform a task	Scenarios 1 & 2, Combination of 1 & 2	Individual & Group	Mostly Laboratory
Educational	Understanding how different types of instruction can facilitate productive collaboration and learning outcomes	Scenario 2	Individual	Mostly Classroom
Sociocultural	Understanding how interactions between group members and the environment support or inhibit collaborative outcomes	Scenario 3	Group	Mostly Classroom

Reviewing the Costs and Benefits of Collaborative Learning

Collaborative Benefits

Research from these three approaches has shown a multitude of benefits from collaboration. Many of these findings come from work using the cognitive and social psychological approaches with a group level of analysis, in which groups performed better than the average individual (Figure 20.1, scenario 1). Research on collaborative memory has routinely shown this effect (for a review, see Rajaram & Pereira-Pasarin, 2010). This benefit has been observed for memory of a wide array of materials, including word lists (Andersson & Rönnberg, 1995; Experiment 1; Basden et al., 1997), stories (Weldon & Bellinger, 1997; Experiment 2), problem-solving scenarios (Meade et al., 2009), pictures (Finlay et al., 2000; Experiment 1), and videos (Andersson & Rönnberg, 1995; Experiment 2). Similar benefits for groups performing better than the average individual have been found for a variety of other tasks, including category learning (Voiklis & Corter, 2012), video game learning (Arthur et al., 1997), and problem-solving tasks (Laughlin et al., 2006).

There is also extensive evidence from the educational psychology approach for the benefits of learning in a group versus learning individually, especially outside of the laboratory in classroom contexts (Figure 20.1, scenario 2). These tasks include model-building tasks (Azimitia, 1988), hypothesis generation (Teasley, 1995), and problem-solving tasks (Kischner et al., 2009b, 2011). For example, a meta-analysis reported in Johnson, Johnson, and Smith (2007) compared cooperative groups, which they defined by positive interdependence (e.g., shared goals or rewards), with individualistic groups, which they defined by their lack of social interdependence. They found an overall positive effect ($d = 0.53$) of cooperative instruction over individualistic instruction (for similar results, see Springer et al., 1999).

In addition to finding benefits at the group level, a few studies have examined whether there is collaborative facilitation or synergy at the individual level of analysis by comparing whether the group outcomes exceed the performance of nominal groups (Figure 20.2). A few studies have shown benefits of collaborative facilitation, including Meade and colleagues (2009) and Paulus and Yang (2000). In sum, the benefits of group learning and performance at the group level of analysis are extensive. This research has mainly investigated what cognitive and social mechanisms support collaborative gains. We review these mechanisms next.

Mechanisms Underlying Benefits

Cognitive Factors

One important cognitive factor is the role of prior knowledge in promoting successful learning and performance. When individuals in a group have *complementary knowledge*, they can combine their knowledge to either improve recall or solve problems that they could not solve alone. For example, a study by Canham, Wiley, and Mayer (2012) compared two types of dyads. In one type of dyad, each learner received different background knowledge on a statistics concept and, in the other type of dyad, both learners received the same background knowledge. Those who received different background information spent more time understanding and developing a solution with their partner and performed better on transfer questions about the material than those who were given the same background information.

Similar results have been found in a study comparing older couples who reported that they were typically responsible for remembering different kinds of everyday information and couples who reported having the same responsibilities (Harris et al., 2011). Those who reported remembering different kinds of information performed better in recalling information from episodic stories and autobiographical recall tasks. Another study showed that when individuals in a group are given instructions for remembering different portions of the to-be-learned information, they remember more compared with when they are given the same material (Basden et al., 1997).

Another way prior knowledge can support collaboration is through *cross-cuing*. This is when one person in the group recalls information that then cues other group members' recall. Cross-cuing rests on the assumption that group members have *shared knowledge* that can serve as a source of cues and related target responses. For example, in the study on older couples' recall, cuing was associated with better recall performance (Harris et al., 2011). A similar result was found in the Meade and colleagues (2009) study examining expert and novice pilots' recall of prior flight scenarios. Expert dyads were more likely to elaborate on each other's contributions when recalling elements of the problem, which was related to overall better recall.

Both complementary and shared prior knowledge structures are theorized to contribute to a reduction in cognitive load (the amount of mental effort being expended in working memory). Dividing the information among collaborative partners is one way to potentially reduce any one person's cognitive load. Similarly, shared prior knowledge might reduce the cognitive load because that shared knowledge does not need to be discussed or stored in working memory as it has already been encoded into long-term memory (Ericsson & Kintsch, 1995).

Two other cognitive factors thought to support collaborative benefits are reexposure and retrieval practice. *Reexposure* is the idea that when recalling information in a group, a given individual will be reexposed to information they may have forgotten from the encoding phase (Rajaram & Pereira-Pasarin, 2010). When a partner recalls prior information, they effectively have an additional opportunity to learn that piece of information. A second beneficial memory process is *retrieval practice*, the act of attempting to retrieve information, which can promote learning and later recall (Roediger & Karpicke, 2006). Although retrieval practice is not a uniquely collaborative activity, some prior work suggests that retrieval practice is particularly beneficial when the learner is given immediate feedback on performance (Roediger & Butler, 2011). One advantage of working in a dyad or a group is that participants can provide immediate feedback to one another on the accuracy of their answers (or at least whether they agree or disagree).

Providing feedback is related to the process of *error-correction* by which individuals ask each other questions and critique each other's thinking as they recall or solve problems. Individuals may put a particular idea or hypothesis to multiple tests before settling on a solution. For example, Weigold, Russell, and Natera (2014) showed participants ten different word lists, each of which was semantically related to one word that was not presented (the non-presented critical word). Collaborative groups were least likely to recall the non-presented critical words, compared to both nominal groups and individuals. Collaborators engaged in successful error-correction by rejecting other group members' false recall, which led to higher accuracy in recall.

A powerful mechanism of individual and collaborative learning is *explanation*. Individuals who generate explanations are more likely to identify what they do not understand, and the process of generating explanations provides them an opportunity to address that lack of understanding or fill in knowledge gaps (Chi et al., 1989; Chi et al., 1994). In collaborative learning scenarios, other members in the group may benefit from hearing the proposed explanation (Webb, Troper, & Fall, 1995). For example, Okada and Simon (1997) found that dyads were more successful at discovering scientific principles than individuals and attributed their success to their greater use of explanation-guided experimentation.

Social Factors

There are also several social factors that have been hypothesized to support collaborative benefits. One is through the *joint management of attention*. Group members are more likely to succeed if they share attention than if each member focuses on different aspects of the problem. If they focus on different aspects, then they also have to take more time and effort to integrate those ideas. Teasley and Roschelle (1993) proposed the idea of a joint-problem space as the coordination of goals, knowledge about the problem or task, and awareness of possible solution steps. Barron (2003) conducted a qualitative analysis of twelve triads of 6th graders working on a problem-solving task and found that triads who were successful in establishing a joint problem-solving space had better problem-solving outcomes. Members of successful groups showed better coordination and considered proposals from all group members. Less successful groups had at least one self-focused group member who was reluctant to accept others' proposals and such groups were rarely able to establish a joint problem-solving space.

Relatedly, research on the construction of *common ground* shows that building a shared understanding facilitates collaborative success. For example, Meade and colleagues (2009) had expert, novice, and nonpilots read flight problem scenarios and then later recall those scenarios either alone or in collaboration with another participant of the same level of expertise. Expert dyads showed collaborative gains on recall compared with nominal groups where novices and nonpilots did not (see Table 20.2). Experts were also more successful than novices in establishing common ground. To understand the development of common ground, the researchers analyzed dyads' discourse patterns and found that experts were more likely than novices to acknowledge, restate, and elaborate on each other's contributions. One possible source contributing to the experts' abilities to develop common ground may be from their formal training to work with team members such as establishing common ground with the copilot and air traffic control. Another potential contribution could have been the group's high levels of shared prior knowledge, which may have reduced cognitive load.

A third social factor that impacts the success of collaborative learning concerns the *negotiating of multiple perspectives*. Understanding a partner's perspective means coming to terms with new information that one would not have been exposed to otherwise. For instance, Schwartz (1995) compared problem-solving representations of individuals and dyads across several complex science topics and found that learners who worked together produced more abstract representations. Schwartz argued that these representations likely helped learners with different perspectives to coordinate their understanding to solve the problems. In other words, creating a representation that two different individuals could both understand in a meaningful way seemed to push them toward creating a more abstract representation of the problem.

A closely related factor that can also contribute to collaborative benefits involves how an individual relates to and engages with the potential conflict that can be created when working in a collaborative group. There is a long history of work on *conflict regulation* in social psychology that has differentiated between two types of conflict regulation: epistemic and relational (Doise & Mugny, 1984; Mugny, De Paolis, & Carugati, 1984). Epistemic regulation is hypothesized to be productive whereas relational regulation is hypothesized to be detrimental to group learning and performance. We refer to epistemic regulation here and relational regulation in the "Collaborative Costs" section. Epistemic regulation involves focusing on the task and the answers and is related to improved learning (Doise & Mugny, 1979, 1984). Relational regulation focuses on relative levels of competence and demonstrating one's own superiority.

Table 20.2 *Mean proportion of segments recalled by experts, novices, and nonpilots as a function of individual or collaborative recall (after Meade, Nokes, & Morrow, 2009, p. 43. Copyright 2009 Psychology Press, an imprint of the Taylor and Francis Group. Reprinted by permission of the publisher)*

	Experts	Novices	Nonpilots
Nominal group	0.52 (0.18)	0.51 (0.13)	0.41 (0.10)
Collaborative	0.68 (0.15)	0.46 (0.08)	0.33 (0.14)
Average individual	0.33 (0.16)	0.28 (0.14)	0.23 (0.11)
Effect Size	0.97	−0.48	−0.67

Note. Standard deviations are in parentheses. Effect sizes are based on a comparison between nominal group and collaborative conditions ($N = 96$).

Collaborative Costs

Given the two levels of analysis (individual versus nominal) and the variety of study designs described in the "Approaches to Collaborative Learning" section, the results for collaborative costs can be operationalized in a variety of ways. Here, we briefly review three. The first is from the research on collaborative inhibition (Figure 20.2). As described in the previous section, collaborative inhibition is when the group performs worse than the nominal group, showing that the individuals in the group are not performing up to their predicted potential. There are many studies showing such deficits on a variety of memory recall tasks. In these experiments, participants first memorize the materials individually and then attempt to recall them either with another person or alone (Figure 20.1, scenario 1). The typical result shows that the collaborative group recalls fewer items than the nominal group, suggesting that the individuals within the group are not performing at their predicted potential. These results have been found for different age groups, including children, adults, and older adults, and across types of relationships ranging from strangers to couples and friends (for a review, see Rajaram & Pereira-Pasarin, 2010).

In addition to these memory tasks, there are a few other tasks that have shown collaborative inhibition effects. One is from the Nokes-Malach and colleagues (2012) study in which nonpilots working in dyads performed worse than those solving the problems alone. Collaborative inhibition has also been found in a classroom writing task in which students worked either with a partner or alone to find writing errors in a text (Gadgil & Nokes-Malach, 2012). Students who worked with another student were less likely to find grammatical errors in the writing than those working alone.

A second type of collaborative cost comes from collaborative memory research that has examined the acquisition of false memories. In this research, investigators have examined what they call contagion memory effects, in which one partner in a group falsely recalls a piece of information and another participant mistakenly encodes that information as being from the original study material. The majority of research exploring this phenomenon has used laboratory experiments in which a confederate in the group falsely recalls information during group recall and then later all participants are tested individually on what they remember from the original list. This work shows that false memories can spread during collaboration, and several studies have demonstrated that the contagion effect is robust even when participants are warned that false recall can be a problem in group settings (Meade & Roediger, 2002; Roediger, Meade, & Bergman, 2001). We know of no work that has examined this phenomenon in educational settings, but it would be informative to understand whether this result happens in group school work and whether there is any relation to the large literature on student misconceptions.

A third type of cost is when the group performs *equal to or worse than* the average individual. This result appears to occur less often than collaborative inhibition, but there are a few examples in the literature (Crooks et al., 1998; Kirschner et al., 2011; Leidner & Fuller, 1997; Tudge, 1989). For instance, Tudge (1989) showed that elementary students working alone performed better than students working in dyads in solving conservation balance beam problems. In another example, Leidner and Fuller (1997) found that students working alone performed better than students working in pairs in an information management course. To explain collaborative inhibition, contagion effects, and poor group performance, several different cognitive and social mechanisms have been proposed. We describe these mechanisms below.

Mechanisms Underlying the Costs

Cognitive Factors

One mechanism that negatively affects collaborative learning and performance is the *coordination costs* of working with other individuals (Clark & Brennan, 1991; Steiner, 1972). When working in a group, members typically need to figure out each individual's role. For example, in a problem-solving task, the group has to decide who will work on which aspects of the problem (e.g., who will read the problem aloud), how they will resolve differences of perspective or strategy, and how they will evaluate potential solutions and reach consensus. Figuring out the logistics of who is contributing to which component of the task and integrating those contributions creates additional cognitive demands. Ivan Steiner (1972) in his classic work on collaboration referred to this additional coordination cost as "process loss."

Similar to this view, Kirschner and colleagues (2009a) have described a cognitive load approach to understanding collaborative learning. When comparing the group with individual learning and performance, they propose that there will be collaborative costs when the task is simple and benefits when the task is complex. The idea is that when the task is simple and the individual could learn the information or solve the problem without assistance, working with others simply increases the coordination costs and cognitive load without improving outcomes. In contrast, when the task is complex it is thought to require more cognitive resources than an individual can provide and therefore they are benefited by assistance from others. Kirshner and colleagues (2009b) tested this hypothesis by comparing participants' ratings of mental effort (a measure of cognitive load) after various learning and test tasks. Participants learned in groups of three or individually on either simple or complex learning materials in biology. All students were then tested individually on a transfer test. For the simple materials, they found that participants working in groups did not differ from those working individually in their mental effort ratings at learning. However, the participants who learned individually reported lower mental effort than participants in the group condition at test. This result suggests there might be a cost for group learning when materials are simple. For the complex materials, the authors found a different pattern of results. The participants in the group reported lower levels of mental effort at learning and at test than the participants who learned individually. These results were consistent with the hypothesis that the complexity of the materials interacts with cognitive load during group work.

Another type of cognitive cost is *production blocking* (Diehl & Stroebe, 1987). This cost is based on the idea that typically only one person in a group talks at a time so that others may hear what that person is saying. When one person is speaking, it effectively blocks or prevents others from talking, causing a delay in making one's contribution. This delay may cause others to forget their ideas, decide that their contributions are no longer relevant, or be less motivated to come up with new ideas during the delay. Further, processing what another person is saying may interfere with one's thinking. For example, Diehl and Stroebe (1987) showed that when group members were only allowed to say their thoughts when given permission (i.e., blocked from stating their thoughts as they occurred), they produced fewer solutions than a group and nominal group that could say their thoughts freely. This finding suggests that if a group member dominates a collaboration, then they might be reducing the productivity of the group by limiting the others' abilities to contribute.

A closely related concept to production blocking is the *retrieval strategy disruption hypothesis* (Basden et al., 1997). This hypothesis states that as one person in a group starts recalling information aloud, this information disrupts other group members' memory retrieval processes because individuals typically vary in their recall strategies and have idiosyncratic output orders. For example, if the task is to recall a list of items and one individual attempts to recall the list in alphabetical order (apple, aardvark, bassoon, baker ...) whereas another person attempts to recall the list by category (apple, grapes, orange, kiwi ...), one strategy interferes with the other as the item order does not align across the two. Evidence for this hypothesis comes from a series of experiments showing that groups performed worse than nominal groups when the number of categories to be recalled was large rather than small (Basden et al., 1997; Experiment 1). In contrast, when the participants had nonoverlapping parts of the list to be recalled or people were forced to adopt the same recall strategy (e.g., recall a single category at a time), there were no differences between groups and nominal groups (Basden et al., 1997; Experiments 3 and 4), that is, collaborative inhibition was eliminated. Another factor that has been shown to attenuate or eliminate this cost is the type of test employed. For example, using cued recall or recognition tests as opposed to a free recall test will attenuate inhibition effects (Finlay et al., 2000). These factors aim to minimize idiosyncratic recall based on specific retrieval strategies. Two other factors that reduce inhibition are to include repeated study or test trials (Congleton & Rajaram, 2011; Pereira-Pasarin & Rajaram, 2011) or to involve a delay of two or more hours between study and test (Congleton & Rajaram, 2011).

Social Factors

Several social factors have also been proposed to account for the costs of collaborating. One factor that is often examined in group performance is *social loafing* (Latané et al., 1979). As the number of people in a group increases, each individual contributes less effort because of the belief that someone else will pick up the slack (i.e., diffusion of responsibility). Research on this topic initially focused on physical tasks such as clapping or shouting (Latané et al., 1979) but has since been replicated on other tasks, including brainstorming (Harkins & Petty, 1982), perceptual counting (Matsui, Kakuyama, & Onglatco, 1987), and evaluating poems and editorials (Petty et al., 1977). The majority of these tasks have been examined from a performance perspective and few have been examined using learning paradigms that test what has been learned. A meta-analysis by Karau and Williams (1993) found that a number of variables moderate social loafing effects, with loafing decreasing when there is potential for performance evaluation, higher task value, higher group value, when the expectations of the coparticipants were low, when group size decreased, when tasks were more complex versus simple, and when individuals perceived their contributions as unique, among others.

Another social factor that can produce detriments in group performance is *fear of evaluation*. In this case, the individual is afraid to put forward risky solutions to other group members for fear of being incorrect or not consistent with group strategies. For example, Collaros and Anderson (1969) showed that when individuals were told that one or all other members of their group were experts, they were more reluctant to offer ideas because they feared criticism, felt inhibited, or feared disapproval from others in the group. They also withheld more ideas than a control condition that was not told about the expert status of their group members. Although there is evidence for fear of evaluation on group performance in some contexts, research on the role of evaluation apprehension in brainstorming productivity failed to account for the collaborative inhibition effect (Diehl & Stroebe, 1987). A closely related idea is research on *self-attention* (Mullen 1983, 1987). This work has examined the negative outcomes of focusing on one's competence when working in groups as compared to when working alone. The idea is that working with others in particular contexts increases attention to one's performance or competence and that this increased attention to oneself leads to decreased performance.

The complement of epistemic regulation in the benefits section is relational regulation. When individuals in a group are focused on *relational regulation* they are engaged with thinking about issues of status and competence, which takes attention away from the task at hand. This type of regulation is associated with poor performance and learning outcomes (Doise & Mugny, 1984).

Theoretical Frameworks of Collaborative Learning

In this section, we point to four theoretical frameworks of collaborative learning that bring together several of the aforementioned processes to explain collaborative benefits and costs. The first is Rajaram and Pereira-Pasarin's (2010) collaborative memory framework. This framework brings together several of the cognitive mechanisms described in the benefits and costs sections (see Figure 20.3). The goal of the framework is to describe how cognitive processes that occur during collaboration create positive and negative effects on later individual learning measures. The positive influences include reexposure, relearning via retrieval (retrieval practice), and error pruning (error correction). The negative influences include social contagion errors (contagion memory effects), blocking that leads to forgetting

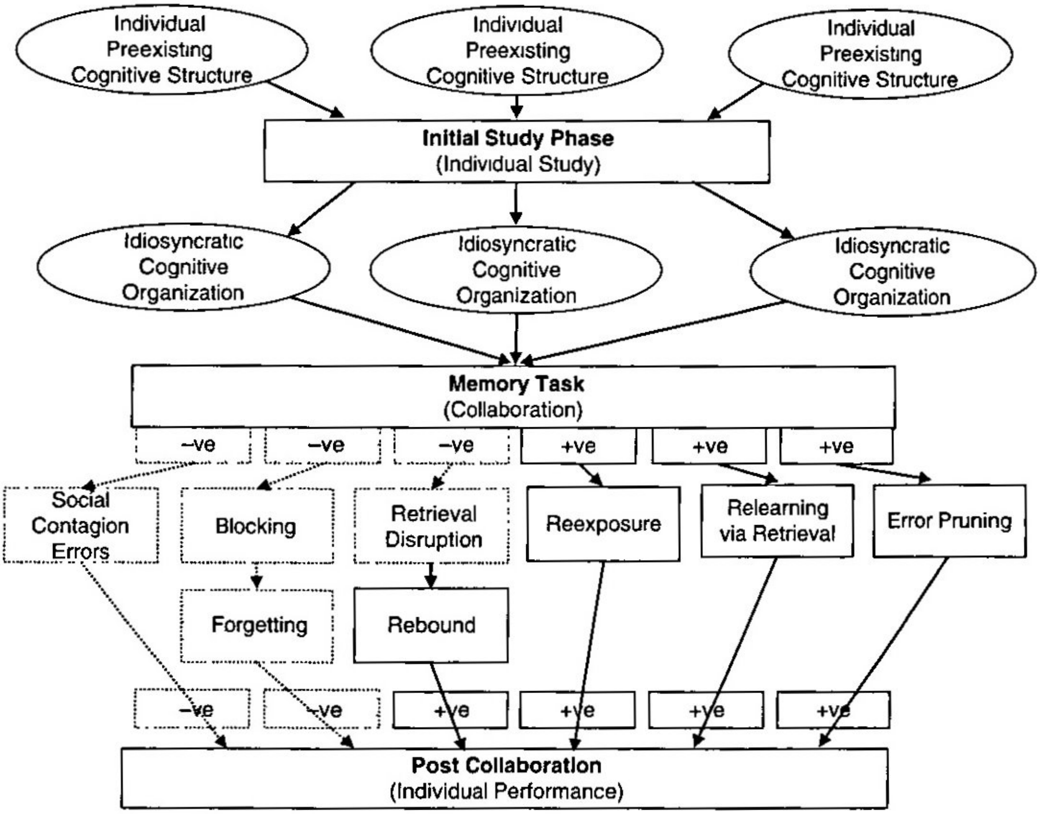

Figure 20.3 *Illustration of Rajaram and Pereira-Pasarin's (2010) theoretical framework of the cognitive mechanisms underlying effects of collaboration on memory (after Rajaram & Pereira-Pasarin, 2010, p. 651. Copyright 2010. Reprinted with permission from SAGE Publications)*

The ovals at the top and center represent three different individuals. Negative influences of collaboration are identified with a "–ve" and positive influences of collaboration are identified with a "+ve."

(production blocking), and retrieval disruption. Rebound is a mitigating process that can follow retrieval disruption once the disruptive cues of collaborators' recall are removed; when rebound occurs, items that had disappeared during collaborative recall reappear when the individual recalls the items alone. Although this framework includes several cognitive mechanisms, it does not include most of the social mechanisms.

The second is M. T. H. Chi's Interactive-Constructive-Active-Passive (ICAP) framework that relates learning activities, cognitive engagement, and learning outcomes to one another (Chi, 2009; Chi & Wylie, 2014). In this framework, Chi and colleagues hypothesize that as cognitive engagement increases so do learning outcomes. At the top of the engagement activities hierarchy are interactive behaviors defined as "dialogues that meet two criteria: (a) both partners' utterances must be primarily constructive, and (b) a sufficient degree of turn taking must occur" (Chi &

Wiley, 2014, p. 223). Chi defines constructive behaviors as learners generating outputs that go beyond the information given in the learning activity (e.g., asking questions, generating inferences). This framework captures many of the proposed mechanisms for collaborative benefits reviewed in this chapter and has related those mechanisms to student behaviors when engaging in learning activities in small group contexts.

The third and fourth frameworks are closely related in that they both examine the relation between group knowledge and task affordances. Nokes-Malach and colleagues (2012) propose the *zone of proximal facilitation*, hypothesizing that collaborative facilitation will occur when the prior expertise of the group's knowledge and the complexity of the task afford constructive and interactive processes between group members. A fourth and related proposal by Kirschner and colleagues (2009a) uses a cognitive-load analysis of the learning or problem-solving activity to develop their framework. They predicted that complex tasks will result in collaborative success because of the pooling of memory resources. In contrast, simple tasks will result in poorer performance or no gains because individuals could perform those tasks well alone and, therefore, the cost of group coordination outweighs the cognitive benefits of collaboration. These two frameworks provide explanations for why in some circumstances the cognitive/memory resources of the group lead to process loss (simple tasks) whereas in others they can lead to process gains (complex tasks).

These frameworks integrate different pieces of literature to provide a guide to understanding how, when, and why different mechanisms of collaborative learning produce beneficial processes and outcomes. However, each framework carves out only part of the underlying mechanisms. Combining these frameworks and integrating more of the social mechanisms can provide a more holistic yet fine-grained approach to understanding how all these mechanisms work together to produce efficient, effective, and productive collaborative learning outcomes. One difficulty in developing such a framework is that there are several different approaches to examining collaborative learning. In this chapter, we reviewed work from the three different perspectives, but there is also work from a self-regulated learning perspective (for an overview, see Hadwin, Järvelä, & Miller, 2011) and computer-supported collaborative learning (CSCL) perspective (see Hmelo-Silver et al., 2013, chaps. 22–28) that goes beyond the scope of this chapter. Although we have made much progress in understanding collaborative learning, there is much more work to be done to integrate these different perspectives and approaches into a larger framework or taxonomy.

Educational and Instructional Implications

As discussed in our review, research from cognitive, social, and educational psychology as well as the learning sciences has made important contributions to understanding how collaboration works. Unfortunately, findings from basic research do not often get incorporated in instructional practice (Vanderlinde & van Braak, 2010). In this section, we provide six specific strategies that teachers and instructional designers can implement to mitigate the cognitive and social costs and maximize the benefits of collaboration.

Strategy 1: Keep Coordination Costs Low to Reduce Process Loss

Reducing process loss by keeping coordination costs low leads to better learning from collaboration. There are multiple ways to keep coordination costs low, including providing a script, repeated practice, and grouping collaborators with shared expertise. Providing a script for collaboration has been shown to improve collaborative learning over nonscripted conditions (O' Donnell, 1999; Rummel & Spada, 2005). A collaboration script describes the roles of participants, their actions, and the sequence of events that they engage in during collaboration. The collaboration script eliminates the extraneous cognitive load of figuring out task logistics, thus combating process loss.

When collaborators share expertise, they may be able to establish common ground more quickly and spend less time coordinating their different areas of knowledge and assumptions (Canham et al., 2012; Nokes-Malach et al., 2012). However, combining collaborators with different areas of expertise or prior knowledge may promote deeper discussions and greater conceptual learning, highlighting the importance of considering goals of the task when deciding how to structure a collaboration.

Strategy 2: Carefully Consider Task Complexity

Collaborative success hinges upon whether the task is complex enough to warrant working in a group. Tasks that involve simple recall or rote memorization often suffer from collaborative inhibition, as the costs of collaboration may outweigh the benefits. Studies that compared individual and collaborative learning across simple and complex tasks found that while complex tasks benefited from collaboration, learning on simple tasks was actually hindered (Kirschner et al., 2011). We recommend designing collaborative activities for tasks that are complex and that require higher-order thinking or problem-solving rather than for those that involve only rote memorization. When thinking about the difficulty of the task, it is important to consider the prior knowledge of the group members, as a task that is complex for a novice may be simple for someone with greater expertise. If the group members have the opportunity to combine their different pieces of prior knowledge, then they will benefit more from the task as new knowledge will be shared and there will be more opportunities for elaboration.

Strategy 3: Minimize Fear of Evaluation

Social factors such as fear of evaluation often hinder collaborative success. Some prior research has shown that fear of evaluation or evaluation apprehension is reduced when participants are told that observers will be a source of future help (e.g., Geen, 1983). Studies have also shown that cooperation rather than competition leads to better learning in groups (e.g., Johnson & Johnson, 1994). Thus, underscoring the message that group members are not competitors, but should support each other in successfully completing the task will lead to better learning.

Another technique to minimize fear of evaluation is to include self-affirmation writing activities. For example, studies have shown asking students to write about a value that is important to them improves performance and learning and significantly reduces the racial achievement gap between African-American and white students (Cohen et al., 2006) and Latinx-American and white students (Sherman et al., 2013).

Strategy 4: Promote Use of Productive Conflict Regulation Strategies

Conflict is a natural consequence of working in a group. To the extent that such conflicts focus on the content of the material to be learned, or in other words are of an *epistemic* nature, they lead to greater motivation and successful collaborative learning outcomes. Conversely, conflicts that question a group member's competence or are *relational* in nature lead to decreased motivation and worse learning from collaboration (Darnon, Buchs, & Butera, 2002). Collaborative groups should be reminded that criticizing their peers' ideas is okay but personal attacks are not. Giving students guidelines for thinking about how the things they say affect other people might be particularly useful in these situations. Relatedly, helping students process negative feedback may be another way to alleviate this barrier. For example, instructors can make clear that making errors and receiving negative feedback are an important part of learning.

Strategy 5: Promote Motivation – Mastery Goals, Growth Mindsets, and Task Value

Students' goals for engaging in a learning activity have a profound influence on how and how much they learn. Mastery goals, wherein students are focused on learning and extending their own mastery, have been shown to be more adaptive, compared with performance goals that are focused on comparing one's performance to a normative standard. In collaborative learning, past research has shown that individuals who reported having performance goals shared less information with partners compared with those who reported having mastery goals (e.g., Poortvliet et al., 2007). Darnon and colleagues (2006) found that mastery goals are related to epistemic regulation whereas performance goals are related to relational regulation, suggesting that the induction of mastery goals during group activities may attenuate the cost of social comparison. To promote mastery goals, instructors should continually emphasize the importance of learning and growth over grades.

Additionally, feedback from teachers and peers should focus on students' growth in relation to their past competence, and normative comparisons should be avoided. One strategy to help students view their group work from a growth mindset perspective is to provide them with constructive strategies such as those described in strategy 4 (e.g., criticizing ideas but not people). The focus is not on the person's ability but on the understanding of the task.

Another way to increase student learning in collaborative contexts and attenuate the potential cost of social loafing is to help them see the value in the task and in working in a group. Prior work has shown that when students have a higher task and group value, they are more likely to engage in the task (Karau & Williams, 1993). Telling students how to approach or engage in the task is one part of the puzzle but the other parts involve telling students why they are engaging in the task and the benefits that they gain from working together.

Strategy 6: Build Social and Cognitive Factors That Support Collaboration into the Task Design

Cognitive processes such as reexposure, retrieval practice, error-correction, and explanation-generation are some of the key mechanisms underlying successful collaboration. Instructional tasks should be designed such that the cognitive processes that underlie good collaboration are key features. For example, programming is a task that often involves a significant amount of debugging and can benefit from learning collaboratively. Likewise, science concepts that involve learning about cause and effect often require generating explanations and inferences and could benefit from collaboration. Tasks that require rote learning or memorization should be avoided because they are likely to cause inhibition rather than facilitation. Key social processes such as sharing joint attention, building common ground, and negotiating multiple perspectives can also be incorporated into task design. For example, one could have students first complete an assignment individually that provides background knowledge for the collaborative task, thereby creating a shared knowledge source that students can draw from when building common ground during problem-solving (e.g., Gadgil & Nokes-Malach, 2012).

These strategies could be used alone or in combination to facilitate collaborative benefits and minimize the costs. We advocate that instructors adopt an active measurement perspective when implementing such strategies to see whether the instructional strategies are working as intended. That is, it would be helpful for the instructor to get feedback on whether the strategy is in fact improving learning by giving pre- and posttests. Also, surveys may be administered to see how students are relating to one another to resolve conflicts.

Conclusion

Much work remains in further integrating the social/cognitive, educational, and sociocultural approaches and the variety of methods, results, and mechanisms reviewed in this chapter. Bringing together these approaches is a first step toward future theoretical innovation and empirical tests to better understand how the cognitive and social mechanisms are interrelated. Research on collaborative learning presents a unique opportunity to construct a more general theory of learning that incorporates multiple psychological mechanisms working at different levels of analysis, including both the individual and the group.

References

Andersson, J. & Rönnberg, J. (1995). Recall suffers from collaboration: Joint recall effects of friendship and task complexity. *Applied Cognitive Psychology, 9*(3), 199–211.

Arthur, W., Jr., Day, E. A., Bennett W., Jr., McNelly, T. L., & Jordan, J. A. (1997). Dyadic versus individual training protocols: Loss and reacquisition of a complex skill. *Journal of Applied Psychology, 82*(5), 783–791.

Barber, S. J., Rajaram, S., & Aron, A. (2010). When two is too many: Collaborative encoding impairs memory. *Memory and Cognition, 38*(3), 255–264.

Barron, B. (2000). Achieving coordination in collaborative problem-solving groups. *The Journal of the Learning Sciences, 9*(4), 403–436.

(2003). When smart groups fail. *The Journal of the Learning Sciences, 12*(3), 307–359.

Basden, B. H., Basden, D. R., Bryner, S., & Thomas III, R. L. (1997). A comparison of group and individual remembering: Does collaboration disrupt retrieval strategies? *Journal of Experimental Psychology: Learning, Memory, and Cognition, 23*(5), 1176–1189.

Basden, D. R., Basden, B. H., & Galloway, B. C. (1977). Inhibition with part-list cuing: Some tests of the item strength hypothesis. *Journal of Experimental Psychology: Human Learning and Memory, 3*, 100–108.

Bloodgood, J. W. (2002). Quintilian: A classic educator speaks to the writing process. *Reading, Research, and Instruction, 42*(1), 30–43.

Blumen, H. M. & Stern, Y. (2011). Short-term and long-term collaboration benefits on individual recall in younger and older adults. *Memory and Cognition, 39*(1), 147–154.

Brown, J. S., Collins, A., & Duguid, P. (1989). Situated cognition and the culture of learning. *Educational Researcher, 18*, 32–42.

Buchs, C., Butera, F., Mugny, G., & Darnon, C. (2004). Conflict elaboration and cognitive outcomes. *Theory into Practice, 43*, 23–30.

Butera, F. & Darnon, C. (2017). Competence assessment, social comparison, and conflict regulation. In A. J. Elliot & C. S. Dweck (eds.), *Handbook of competence and motivation: Theory and application* (pp. 192–213). New York: Guilford Press.

Canham, M. S., Wiley, J., & Mayer, R. E. (2012). When diversity in training improves dyadic problem solving. *Applied Cognitive Psychology, 26*, 421–430.

Chi, M. T. H. (2009). Active-constructive-interactive: A conceptual framework for differentiating learning activities. *Topics in Cognitive Science, 1*(1), 73–105.

Chi, M. T. H., Bassok, M., Lewis, M. W., Reimann, P., & Glaser, R. (1989). Self-explanations: How students study and use examples in learning to solve problems. *Cognitive Science, 13*, 145–182.

Chi, M. T. H., de Leeuw, N., Chiu, M. H., & LaVancher, C. (1994). Eliciting self-explanations improves understanding. *Cognitive Science, 18*, 439–477.

Chi, M. T. H. & Wiley, R. (2014). The ICAP framework: Linking cognitive engagement to active learning outcomes. *Educational Psychologist, 49*(4), 219–243

Clark, H. H. & Brennan, S. E. (1991). Grounding in communication. In L. B. Resnick, J. M. Levine, & S. D. Teasley (eds.), *Perspectives on socially shared cognition* (pp. 127–149). Washington, DC: American Psychological Association.

Cohen, G. L., Garcia, J., Apfel, N., & Master, A. (2006). Reducing the racial achievement gap: A social-psychological intervention. *Science, 313*, 1307–1310.

Collaros, P. A. & Anderson, L. R. (1969). Effect of perceived expertness upon creativity of members of brainstorming groups. *Journal of Applied Psychology, 53*(2), 159–163.

Congleton, A. R. & Rajaram, S. (2011). The influence of learning methods on collaboration: Prior repeated retrieval enhances retrieval organization, abolishes collaborative inhibition, and promotes post-collaborative memory. *Journal of Experimental Psychology: General, 140*(4), 535–551.

Crooks, S. M., Klein, J. D., Savenye, W., & Leader, L. (1998). Effects of cooperative and individual learning during learner-controlled computer-based instruction. *The Journal of Experimental Education, 66*(3), 223–244.

Darnon, C., Buchs, C., Butera, F. (2002). Epistemic and relational conflicts in sharing identical vs. complementary information during cooperative learning. *Swiss Journal of Psychology, 61*(3), 139–151.

Darnon, C., Muller, D., Schrager, S. M., Pannuzzo, N., & Butera, F. (2006). Mastery and performance goals predict epistemic and relational conflict regulation. *Journal of Educational Psychology, 98*(4), 766–776.

De Dreu, C. K. & Weingart, L. R. (2003). Task versus relationship conflict, team performance, and team member satisfaction: A meta-analysis. *Journal of Applied Psychology, 88*(4), 741–749.

Deutsch, M. (1949). A theory of cooperation and competition. *Human relations, 2*, 129–152.

(1973). *The resolution of conflict.* New Haven, CT: Yale University Press.

Diehl, M. & Stroebe, W. (1987). Productivity loss in brainstorming groups: Toward the solution of a riddle. *Journal of Personality and Social Psychology, 53*, 497–509.

Dillenbourg, P., Baker, M., Blaye, A., & O'Malley, C. (1996). The evolution of research on collaborative learning. In E. Spada & P. Reiman (eds.), *Learning in humans and machine: Towards an interdisciplinary learning science* (pp. 189–211). Oxford: Elsevier.

Doise, W. & Mugny, G. (1984). *The social development of the intellect.* International Series in Experimental Social Psychology, vol. 10. London: Pergamon Press.

Engle, R. A. & Conant, F. R. (2002). Guiding principles for fostering productive disciplinary engagement: Explaining an emergent argument in a community of learners classroom. *Cognition and Instruction, 20*(4), 399–483.

Ericsson, K. A. & Kintsch, W. (1995). Long term working memory. *Psychological Review, 102*, 211–245.

Finlay, F., Hitch, G. J., & Meudell, P. R. (2000). Mutual inhibition in collaborative recall: Evidence for a retrieval-based account. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 26*(6), 1556–1567.

Gadgil, S. & Nokes-Malach, T. J. (2012). Overcoming collaborative inhibition through error correction: A classroom experiment. *Applied Cognitive Psychology, 26*(3), 410–420.

Geen, R. G. (1983). Evaluation apprehension and the social facilitation/inhibition of learning. *Motivation and Emotion, 7*(2), 203–212.

Goldbeck, S. L. & El-Moslimany, H. (2013). Developmental approaches to collaborative learning. In C. E. Hmelo-Silver, A. Chinn, C. K. K. Chan, & A. M. O'Donnel (eds.), *The international handbook of collaborative learning* (pp. 41–56). New York and London: Routledge.

Greeno, J. G. (1998). The situativity of knowing, learning, and research. *American Psychologist, 53*, 5–26.

Greeno, J. & The Middle-School Mathematics through Applications Project Group (MMAP). (1997). Theories and practices of thinking and learning to think. *American Journal of Education, 106*(1), 85–126.

Hadwin, A. F., Järvelä, S., & Miller, M. (2011). Self-regulated, co-regulated, and socially shared regulation of learning. *Handbook of self-regulation of learning and performance, 30*, 65–84.

Hakkarainen, K., Paavola, S., Kangas, K., & Seitama-Hakkarainen, P. (2013). Sociocultural perspectives on collaborative learning: Toward collaborative knowledge creation. In C. E. Hmelo-Silver, C., Chinn, C. K. K. Chan, & A. M. O'Donnell (eds.), *International handbook of collaborative learning* (pp. 57–73). New York: Routledge.

Harkins, S. G. & Petty, R. E. (1982). Effects of task difficulty and task uniqueness on social loafing. *Journal of Personality and Social Psychology, 43*(6), 1214–1229.

Harris, C. B., Barnier, A. J., & Sutton, J. (2013). Shared encoding and the costs and benefits of collaborative recall. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 39*(1), 183.

Harris, C. B., Paterson, H. M., & Kemp, R. I. (2008). Collaborative recall and collective memory: What happens when we remember together? *Memory, 16*(3), 213–230.

Harris, A., Yuill, N., & Luckin, R. (2008). The influence of context-specific and dispositional achievement goals on children's paired collaborative interaction. *British Journal of Educational Psychology, 78*(3), 355–374.

Harris, C. B., Keil, P. G., Sutton, J., Barnier, A. J., & McIlwain, D. J. F. (2011). We remember, we forget: Collaborative remembering in older couples. *Discourse Processes, 48*, 267–303.

Hill, G. W. (1982). Group versus individual performance: Are n + 1 heads better than one. *Psychological Bulletin, 91*(3), 517–539.

Hmelo-Silver, C. E., Chinn, C. A., Chan, C. K. K., & O'Donnell, A. (eds.). (2013). *The international handbook of collaborative learning*. New York: Routledge.

Jeong, H. (2013). Verbal data analysis for understanding interactions. In C. E. Hmelo-Silver, C., Chinn, C. K. K. Chan, & A. M. O'Donnell (eds.), *International handbook of collaborative learning* (pp. 57–73). New York: Routledge.

Johnson, D. W. & Johnson, R. T. (1989). *Cooperation and competition: Theory and research*. Edina, MN: Interaction Book Company.

(1994). *Learning together and alone: Cooperative, competitive, and individualistic learning*, 4th edn. Needham Heights, MA: Allyn and Bacon.

(2009). An educational psychology success story: Social interdependence theory and cooperative learning. *Educational Researcher, 39*(5), 365–379.

Johnson, D. W., Johnson, R. T., & Smith, K. A. (1998). *Active learning: Cooperation in the college classroom*. Edina, MN: Interaction Book Company.

Johnson, D. W., Johnson, R. T., & Smith, K. (2007). The state of cooperative learning in postsecondary and professional settings. *Educational Psychology Review, 19*(1), 15–29.

Karau, S. J. & Williams, K. D. (1993). Social loafing: A meta-analytic review and theoretical integration. *Journal of Personality and Social Psychology, 65*(4), 681–706.

Kelley, M. R. & Wright, D. B. (2010). Obtaining representative nominal groups. *Behavior Research Methods, 42*(1), 36–41.

Kerr, N. L. & Tindale, R. S. (2004). Group performance and decision making. *Annual Review of Psychology, 55*, 623–655.

Kim, Y. (2008). The contribution of collaborative and individual tasks to the acquisition of L2 vocabulary. *The Modern Language Journal*, *92*(1), 114–130.

Kirschner, F., Paas, F., & Kirschner, P. A. (2009a). A cognitive load approach to collaborative learning: United brains for complex tasks. *Educational Psychology Review*, *21*(1), 31–42.

(2009b). Individual and group based learning from complex cognitive tasks: Effects on retention and transfer efficiency. *Computers in Human Behavior*, *25*(2), 306–314.

(2011). Task complexity as a driver for collaborative learning efficiency: the collective working-memory effect. *Applied Cognitive Psychology*, *25*(4), 615–624.

Kolloffel, B., Eysink, T. H., & de Jong, T. (2011). Comparing the effects of representational tools in collaborative and individual inquiry learning. *International Journal of Computer-Supported Collaborative Learning*, *6*(2), 223–251.

Kravitz, D. A. & Martin, B. (1986). Ringelmann rediscovered: The original article. *Journal of Personality and Social Psychology*, *50*(5), 936–941.

Latané, B., Williams, K., & Harkins, S. (1979). Many hands make light the work: The causes and consequences of social loafing. *Journal of Personality and Social Psychology*, *37*(6), 822–832.

Laughlin, P. R., Carey, H. R., & Kerr, N. L. (2008). Group-to-individual problem-solving transfer. *Group Processes and Intergroup Relations*, *11*(3), 319–330.

Laughlin, P. R., Hatch, E. C., Silver, J. S., & Boh, L. (2006). Groups perform better than the best individuals on letters-to-numbers problems: Effects of group size. *Journal of Personality and Social Psychology*, *90*(4), 644–651.

Lave, J. & Wenger, E. (1991). *Situated learning: Legitimate peripheral participation*. New York: Cambridge University Press.

Leidner, D. E. & Fuller, M. (1997). Improving student learning of conceptual information: GSS supported collaborative learning vs. individual constructive learning. *Decision Support Systems*, *20*(2), 149–163.

Lewin, K. (1935). *A dynamic theory of personality*. New York: McGraw-Hill.

(1948). *Resolving social conflict*. New York: Harper.

Lorge, I., Fox, D., Davitz, J., & Brenner, M. (1958). A survey of studies contrasting the quality of group performance and individual performance. *Psychological Bulletin*, *55*, 337–372.

Matsui, T., Kakuyama, T., & Onglatco, M. U. (1987). Effects of goals and feedback on performance in groups. *Journal of Applied Psychology*, *72*, 407–415.

Meade, M. L., Nokes, T. J., & Morrow, D. G. (2009). Expertise promotes facilitation on a collaborative memory task. *Memory*, *17*(1), 39–48.

Meade., M. L. & Roediger, H. L. (2002). Explorations in the social contagion of memory. *Memory and Cognition*, *30(7)*, 995–1009.

Mevarech, Z. R. (1985). The effects of cooperative mastery learning strategies on mathematics achievement. *The Journal of Educational Research*, *78*(6), 372–377.

Mugny, G., De Paolis, P., & Carugati, F. (1984). Social regulations in cognitive development. In W. Doise & A. Palmonari (eds.), *Social interaction in individual development* (pp. 127–146). Cambridge: Cambridge University Press.

Mullen, B. (1983). Operationalizing the effect of the group on the individual: A self-attention perspective. *Journal of Experimental Social Psychology*, *19*(4), 295–322.

(1987). Self-attention theory. In B. Mullen & G. R. Goethals (eds.), *Theories of group behaviour* (pp. 125–146). New York: Springer-Verlag.

Nokes-Malach, T. J., Meade, M. L., & Morrow, D. G. (2012). The effect of expertise on collaborative problem solving. *Thinking and Reasoning*, *18*(1), 32–58.

Nokes-Malach, T. J., Richey, J. E., & Gadgil, S. (2015). When is it better to learn together? Insights from research on collaborative learning. *Educational Psychology Review*, *27*(4), 645–656.

O'Donnell, A. M. (1999). Structuring dyadic interaction through scripted cooperation. In A. M. O'Donnell & A. King (eds.), *Cognitive perspectives on peer learning* (pp. 179–196). Mahwah, NJ: Lawrence Erlbaum.

O'Donnell, A. M. & Hmelo-Silver, H. E. (2013). What is collaborative learning: An overview. In C. E. Hmelo-Silver, C. A. Chinn, C. K. K. Chan, & A. O'Donnell (eds.), *The international handbook of collaborative learning* (pp. 1–15). New York: Routledge.

Okada, T. & Simon, H. A. (1997). Collaborative discovery in a scientific domain. *Cognitive Science*, *21*(2), 109–146.

Pereira-Pasarin, L. & Rajaram, S. (2011). Study repetition and divided attention: Effects of encoding manipulations on collaborative inhibition in group recall. *Memory and Cognition*, *39*, 968–976.

Petty, R. E., Harkins, S. G., Williams, K. D., & Latane, B. (1977). The effects of group size on cognitive effort and evaluation. *Personality and Social Psychology Bulletin*, *3*(4), 579–582.

Piaget, J. (1932). *The language and thought of the child*, 2nd edn. London: Routledge and Kegan Paul.

(1950). *The psychology of intelligence*. London: Routledge and Kegan Paul.

(1975/1985). *The equilibration of cognitive structures: The central problem of intellectual development*. Chicago, IL: University of Chicago Press.

Paulus, P. B. & Yang, H. C. (2000). Idea generation in groups: A basis for creativity in organizations. *Organizational Behavior and Human Decision Processes*, *82*, 76–87.

Poortvliet, P. M., Janssen, O., Van Yperen, N. W., & Van de Vliert, E. (2007). Achievement goals and interpersonal behavior: How mastery and performance goals shape information exchange. *Personality and Social Psychology Bulletin*, *33*(10), 1435–1447.

Rajaram, S. & Pereira-Pasarin, L. P. (2010). Collaborative memory: Cognitive research and theory. *Perspectives on Psychological Science*, *5*(6), 649–663.

Ringelmann, M. (1913). Recherches sur les moteurs animes: Travail de rhomme [Research on animate sources of power: The work of man]. *Annales de l'Institut National Agronomique*, *12*, 1–40.

Roediger, H. L. & Butler, A. C. (2011). The critical role of retrieval practice in long-term retention. *Trends in Cognitive Sciences*, *15*(1), 20–27.

Roediger, H. L. & Karpicke, J. D. (2006). The power of testing memory: Basic research and implications for educational practice. *Perspectives on Psychological Science*, *1*, 181–210.

Roediger, H. L., Meade, M. L., & Bergman, E. T. (2001). Social contagion of memory. *Psychonomic Bulletin and Review*, *8*(2), 365–371.

Roschelle, J. (1992). Learning by collaborating: Convergent conceptual change. *Journal of the Learning Sciences*, *2*(3), 235–276.

Roschelle, J. & Teasley, S. D. (1995). The construction of shared knowledge in collaborative problem solving. In C. O'Malley (ed.), *Computer-Supported Collaborative Learning* (pp. 69–197). Berlin: Springer-Verlag.

Rummel, N. & Spada, H. (2005). Learning to collaborate: An instructional approach to promoting collaborative problem solving in computer-mediated settings. *Journal of the Learning Sciences*, *14*, 201–241.

Sampson, V. & Clark, D. (2009). The impact of collaboration on the outcomes of scientific argumentation. *Science Education*, *93*(3), 448–484.

Sawyer, R. D. (2013). Learning to walk the talk: Designing a teacher leadership EdD program as a laboratory of practice. *Planning and Changing*, *44*(3/4), 208–220.

Schwartz, D. L. (1995). The emergence of abstract representations in dyad problem solving. *The Journal of the Learning Sciences*, *4*, 321–354.

Schwarz, B. B., Neuman, Y., & Biezuner, S. (2000). Two wrongs may make a right . . . if they argue together! *Cognition and Instruction*, *18*(4), 461–494.

Sherman, D. K., Hartson, K. A., Binning, K. R., Purdie-Vaughns, V., Garcia, J., Taborsky-Barba, S., . . . Cohen, G. L. (2013). Deflecting the trajectory and changing the narrative: How self-affirmation affects academic performance and motivation under identity threat. *Journal of Personality and Social Psychology*, *104*(4), 591–618.

Slavin, R. E. (1995). *Cooperative learning: Theory, research, and practice*, 2nd edn. Boston, MA: Allyn & Bacon.

Slavin, R., Leavey, M., & Madden, N. (1984). Combining cooperative learning and individualized instruction: Effects on student mathematics achievement, attitudes, and behaviors. *Elementary School Journal*, *84*, 409–422.

Springer, L., Stanne, M. E., & Donovan, S. S. (1999). Effects of small-group learning on undergraduates in science, mathematics, engineering, and technology: A meta-analysis. *Review of Educational Research*, *69*(1), 21–51.

Souvignier, E. & Kronenberger, J. (2007). Cooperative learning in third graders' jigsaw groups for mathematics and science with and without questioning training. *British Journal of Educational Psychology*, *77*(4), 755–771.

Steiner, I. D. (1966). Models for inferring the relationships between group size and potential group productivity. *Behavioral Science*, *11*, 273–283.

(1972). *Group processes and productivity*. New York: Academic Press.

Stevens, R. J. & Slavin, R. E. (1995). Effects of a cooperative learning approach in reading and writing on academically handicapped students. *The Elementary School Journal*, *95*(3), 241–262.

Stevens, R. J., Slavin, R. E., & Farnish, A. M. (1991). The effects of cooperative learning and direct instruction in reading comprehension strategies on main idea identification. *Journal of Educational Psychology*, *83*(1), 8–16.

Stewart, G. L. (2006). A meta-analytic review of relationships between team design features and team performance. *Journal of management*, *32*(1), 29–55.

Teasley, S. D. (1995). The role of talk in children's peer collaborations. *Developmental Psychology*, *31* (2), 207–220.

Teasley, S. D. & Roschelle, J. (1993). Constructing a joint problem space: The computer as a tool for sharing knowledge. In S. P. Lajoie & S. J. Derry (eds.), *Computers as cognitive tools* (pp. 229–258). Hillsdale, NJ: Lawrence Erlbaum.

Tudge, J. (1989). When collaboration leads to regression: Some negative consequences of socio-cognitive conflict. *European Journal of Social Psychology*, *19*(2), 123–138.

Tudge, J. R. H. & Winterhoff, P. A. (1993). Vygotsky, Piaget, and Bandura: Perspectives on the relations between the social world and cognitive development. *Human Development*, *36*, 61–81.

Vanderlinde, R. & van Braak, J. (2010). The gap between educational research and practice: Views of teachers, school leaders, intermediaries and researchers, *British Educational Research Journal*, *36*(2), 299–316.

Voiklis, J. & Corter, J. E. (2012). Conventional wisdom: Negotiating conventions of reference enhances category learning. *Cognitive Science*, *36*(4), 607–634.

Vygotsky, L. S. (1978). *Mind in society: The development of higher psychological processes*. Cambridge, MA: Harvard University Press.

Webb, N. M., Troper, J. D., & Fall, R. (1995). Constructive activity and learning in collaborative small groups. *Journal of Educational Psychology*, *87*, 406–423.

Weigold, A., Russell, E. J., & Natera, S. N. (2014). Correction of false memory for associated word lists by collaborating groups. *The American Journal of Psychology*, *127*(2), 183–190.

Weldon, M.S. & Bellinger, K.D. (1997). Collective memory: Collaborative and individual processes in remembering. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *23*, 1160–1175.

Wright, D. B. (2007). Calculating nominal group statistics in collaboration studies. *Behavior Research Methods*, *39*, 460–470.