Pearson

Skills for Today:

What We Know about Teaching and Assessing Collaboration

P21 PARTNERSHIP FOR 21ST CENTURY LEARNING

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About Pearson

Pearson is the world's leading learning company. Our education business combines 150 years of experience in publishing with the latest learning technology and online support. We serve learners of all ages around the globe, employing 45,000 people in more than seventy countries, helping people to learn whatever, whenever and however they choose. Whether it's designing qualifications in the UK, supporting colleges in the United States, training school leaders in the Middle East or helping students in China learn English, we aim to help people make progress in their lives through learning.

About P21

P21 recognizes that all learners need educational experiences in school and beyond, from cradle to career, to build knowledge and skills for success in a globally and digitally interconnected world. Representing over 5 million members of the global workforce, P21 is a catalyst organization uniting business, government and education leaders from the United States and abroad to advance evidence-based education policy and practice and to make innovative teaching and learning a reality for all.

Introduction to the Series

This paper is the first in a series to be jointly released by Pearson and P21 entitled, "Skills for Today." Each paper summarizes what is currently known about teaching and assessing one of the Four Cs: collaboration, critical thinking, creativity, and communication. Our partnership on this series signifies a commitment to helping educators, policy-makers, and employers understand how best to support students in developing the skills needed to succeed in college, career, and life.

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Foreword

As both of us reflect on our jobs over the years, it is clear that collaboration has been a consistent demand in all our positions. The skills Dave needed to be a successful member of a high-school football team were nearly identical to those required on his weekend job, where he worked as the assistant manager of a convenience store. Collaboration has been at the center of every work engagement for Leah—from executing the freshman orientation program while at the University of New Mexico to crafting public-relations speeches as an intern for a utility company. Skills in reaching consensus, negotiating with others who have differing opinions, and working together to achieve shared goals have all been clearly important to our success within major organizations.

The education and business communities have been talking about the importance of collaboration and teamwork for a number of years now. Educators have been espousing the benefits of collaborative learning while the business community has been expressing disappointment in the collaboration skills of incoming employees. As pointed out in this paper, this seeming contradiction is likely because collaborative learning has often been used as a means to teach other content rather than as a means to improve collaboration skills themselves.

Despite differing definitions and points of view, progress has been made in investigating the best ways to teach and assess collaboration skills. Technology, including the possibility of automated scoring of dialogue, has opened doors for assessment. At the same time, basic ideas like providing explicit feedback and peer review have been shown to be successful in improving skills. We are excited that Pearson and P21 can partner to produce this summary of the current state of the field.

Of course, collaboration isn't the only personal and social capability of importance. This is the first of four papers that P21 and Pearson will release. Papers on critical thinking, communication, and creativity will follow. In order to see large-scale change in student proficiency on these, teachers from K through to college will need to find ways to teach these skills in their already full schedules of content. We will need to find ways to support them in this process and hope both the business and policy communities can contribute to these solutions. Guiding students toward becoming good collaborators in both their work and civic lives will depend on both local and system-level change.

Leah Jewell, Managing Director, Career Development and Employability, Pearson, and David Ross, CEO, P21

Introduction

Collaboration is increasingly identified as an important educational outcome, and most models of twenty-first-century skills include collaboration as a key skill (e.g., Griffin, McGaw, & Care, 2012; Pellegrino & Hilton, 2012; OECD PISA Collaborative Problem Solving Expert Working Group, 2013; Trilling & Fadel, 2009). The P21 Framework for 21st Century Learning (www.P21.org/Framework) includes collaboration as one of its four key concepts (the Four Cs), along with creativity, critical thinking, and communication.

In other words, having better collaboration skills yields better results in collaborative learning contexts.

Such widespread emphasis on collaboration skills can be traced to several factors. First, research suggests that people with good collaboration skills enjoy better performance in school. For example, one study found that interpersonal understanding and proactivity in problem-solving, both part of good collaboration, are significant predictors of group performance and learning in university programs (Druskat & Kayes, 2000). Another study found that training college students how to work together (e.g., plan, make decisions as a group, set objectives, manage time, agree on roles, and create a positive group environment) increased the effectiveness of collaborative learning (Prichard, Stratford, & Bizo, 2006). In other words, having better collaboration skills yields better results in collaborative learning contexts.

Second, research suggests that those with more developed collaboration skills earn recognition on the job from their managers and peers. For example, individuals with greater knowledge of conflict-resolution strategies, collaborative problem-solving, communication, goal-setting, and planning and task coordination are rated as more individually effective within professional teams by both colleagues and external raters (McClough & Rogelberg, 2003). Indeed, Stevens and Campion (1999) found that knowledge of these aspects of collaboration predicted supervisory ratings of performance above and beyond general cognitive ability. One of the only studies available in the research literature linking collaboration skill and individual outcomes found that, in Taiwan, self-reported skills in adaptability, coordination, decision-making, leadership, and interpersonal skills were positively associated with performance appraisal scores, salaries, and bonuses (Chen, 2002). Thus, developing collaboration skills can contribute to one's personal success in the workplace.

Beyond supporting future academic and workplace performance, improving the collaboration skills of young learners can enhance civic discourse and promote a healthy democracy. Kahne and Westheimer (2003) studied ten educational programs whose stated purpose was to teach good citizenship. The authors concluded that the most successful programs—those associated with significant improvements in students' commitment to civic participation—shared three broad priorities, one of which was connection to others within communities of support. As the authors state, "Students need to know that civic engagement is not an individual, private endeavor"; rather, it is "enabled and shaped through interactions and connections among individuals within a community" (Kahne & Westheimer, 2003, p. 63). Collaborative problem-solving skills enable individuals to collectively pursue common social goals. Indeed, Althof and Berkowitz (2006) define civic competence as including collaborative behaviors, arguing that democracy "is not only a form of government … but also a mode of living together (which requires citizens prepared to solve differences in mutual deliberation in a respectful way and to engage responsibly in the common interest)" (p. 501).

Instilling good collaboration skills also benefits employers. As Dede (2010, p. 2) has observed:

> [T]he nature of collaboration is shifting to a more sophisticated skillset. In addition to collaborating face-to-face with colleagues across a conference table, 21st century workers increasingly accomplish tasks through mediated interactions with peers halfway across the world whom they may never meet face-to-face. … [C]ollaboration is worthy of inclusion as a 21st century skill because the importance of cooperative interpersonal capabilities is higher and the skills involved are more sophisticated than in the prior industrial era.

Increasingly, over the past two decades, we have seen companies move to greater emphasis on new organizational structures that encourage and facilitate team-based work. These structures are dependent on networks of cross-functional teams and technology-related or technology-inclusive job descriptions (Stuart & Dahm, 1999). The nature of how work is now being accomplished has required a workforce of flexible and collaborative individuals with complex cognitive skills (American Management Association, 2010). Indeed, Jerald (2009, p. 14) argues that perhaps the greatest change in the American workplace is the increased emphasis on what he calls "horizontal collaboration," or "self-managing work teams" that select their own members, define their own work assignments, and are compensated based on their performance.

Research suggests that the collaboration knowledge and skills of individual team members, including conflict resolution, goal-setting, performance management, and planning and task coordination, are a stronger predictor of team success than generic social skills or personality characteristics (Morgeson, Reider, & Campion, 2005). In other words, when building teams, selecting individuals who have better collaboration knowledge and skills will lead to more successful teams. For this reason, we use the terms "collaboration" and "teamwork" interchangeably—because the skills that help people create positive and productive collaborations are the same skills that contribute to effective teams.

Findings such as these have led employers to value these skills in hiring. Indeed, recent large-scale surveys of employers reveal that collaboration and teamwork are among the most important employability skills for new hires. For example, in a 2014 online survey on behalf of the Association of American Colleges and Universities (AACU) of 400 employers whose organizations have at least twenty-five employees, 83 percent of respondents rated teamwork as very important for recent college graduates (Hart Research Associates, 2015). Similarly, according to the National Association for Colleges and Employers 2016 Job Outlook Survey, nearly 80 percent of respondents said they look for evidence that the candidate is able to work in a team (National Association for Colleges and Employers, 2016), and 94 percent of employers surveyed as part of the MetLife Survey of the American Teacher characterized working in teams as either "very important" or "absolutely essential" (Markow & Pieters, 2011). Casner-Lotto and Barrington (2006) also found 94 percent of employers in their sample identifying teamwork and collaboration as "very important" for four-year college graduates, and 74 percent of respondents said they expected teamwork skills to increase in importance over the next five years.

Despite the importance of teamwork and collaboration skills, however, there is a long-standing concern that institutions of higher education are not producing graduates with the collaboration skills needed to succeed on the job. In recent years, the issue of the skills gap has attracted attention from think tanks (Dews, 2013), Congress

(Foulkes, 2013), and state legislatures (DeRenzis, 2015). A further indication of the concern of young adults needing collaboration skills is reflected through the fact that OECD included collaborative problem-solving as part of its 2015 PISA international assessment of fifteen-year-olds in order to encourage more focus on those skills within national curricula (OECD PISA Collaborative Problem Solving Expert Working Group, 2013). Only 37 percent of employers in the AACU survey perceived new graduates as well prepared to work in teams (Hart Research Associates, 2015). In Casner-Lotto and Barrington's (2006) survey, only 25 percent of employers characterized four-year college graduates' teamwork skills as "excellent"; these numbers were even smaller for graduates of two-year colleges and high school. Chen, Donahue, and Klimoski (2004) speculate that the cause of the teamwork skills gap is that many faculty do not value teamwork skills as highly as employers do and thus do not teach them. In at least one university attempting to integrate employability skills (such as collaboration) into the curriculum, there is evidence that some faculty do not feel prepared to teach these skills and do not feel it is their responsibility (De La Harpe, Radloff, & Wyber, 2000).

It is important to distinguish between the increasing focus on improving learners' collaboration skills and the significant body of research on cooperative learning. This research addresses both the effectiveness of cooperative learning for increasing achievement (Bowen, 2000; Springer, Stanne, & Donovan, 1999), along with investigation of implementation models for cooperative learning (Johnson, Johnson, & Stanne, 2000; Slavin, 1983). Cooperative learning should not be confused with teaching the actual skill of collaboration. Cooperative learning is a teaching method used to teach a variety of academic skills. In contrast, collaboration is a constellation of knowledge and skills including the ability to work effectively in diverse teams, assuming shared responsibility, and other characteristics explored in the definition section below. There is no reason to believe that engaging in cooperative learning aimed at instruction of other skills on its own will actually increase students' skill in collaboration. This paper addresses the skill of collaboration and is not an effort to discuss cooperative or collaborative learning as an instructional technique.

There is no reason to believe that engaging in cooperative learning aimed at instruction of other skills on its own will actually increase students' skill in collaboration.

As with other twenty-first-century skills, we can no longer assume that collaborative competence is something our students will learn "on their own." In this paper, we will discuss current conceptual approaches to collaboration, research on interventions, and promising assessment strategies.

Definitions and Models

In defining collaboration, it is important to clarify whether collaboration is viewed as a means to an end—a way of organizing instruction whose primary objective is to teach other knowledge and skills—or whether collaboration is viewed as an end in itself. Kuhn (2015) distinguishes research on collaboration as falling into one of these two categories. As Kuhn argues, the dominant paradigm has been to view collaboration as a means to enhance learning of academic content and problem-solving. This approach captures much of the literature on cooperative and collaborative learning in which students are required to work in groups in order to support more effective learning of academic content and skills.

The second approach views collaboration as an important and valued set of skills in its own right—Kuhn associates it with the twenty-first-century skills movement. Under this paradigm, students are required to work in groups for the express purpose of improving their ability to work with others. It is this second approach that we take, focusing on research that defines collaboration as an important learning outcome and investigates effective strategies for teaching and assessing those collaboration skills.

Another important clarification is that we are interested in defining, teaching and assessing collaboration or teamwork skills at the level of the individual rather than the group or team level. There is a wide body of literature that researches the development of team effectiveness (Mathieu, Maynard, Rapp, & Gilson, 2008), team potency (Gully, Incalcaterra, Joshi, & Beaubien, 2002), and team cognition (Salas, Cooke, & Rosen, 2008). What distinguishes these approaches is that the unit of analysis is the group or team rather than the individual. In contrast, our focus here is on defining, teaching, and assessing skills at the individual level.

Finally, although we define collaboration as a general set of knowledge and skills, not tied to any particular discipline or domain, we recognize the importance of having relevant domain knowledge in order to effectively engage in collaborative tasks. As Rotherham and Willingham (2010) put it, skills and knowledge are not separate. Without relevant background knowledge, you cannot effectively exercise your collaboration skills. Moreover, it is not the case that a person's collaboration skills can be equally well developed across all types of domain content. Not all content is created equal. As Rotherham and Willingham (2010, p. 18) point out, "to think critically, students need the knowledge that is central to the domain." Likewise, to collaborate, students need to engage in content that is debated in the field and on which multiple perspectives exist. This approach is consistent with the Deeper Learning movement, which posits that people develop specialized expertise within a particular discipline, and this intertwining of content knowledge and skills in the form of competencies supports transfer of learning to new contexts (Pellegrino & Hilton, 2012).

One of the most widely cited definitions of collaboration comes from Roschelle and Teasley (1995, p. 70), who characterize it as, "coordinated, synchronous activity that is the result of a continued attempt to construct and maintain a shared conception of a problem." Similarly, Riebe, Girardi, & Whitsed (2016, p. 621) define teamwork as "a process involving two or more students working toward common goals, through interdependent behavior with individual accountability." Hughes and Jones (2011) further clarify that real collaboration refers to a process involving how team members interact more than to the team's ultimate success or the quality of its end product. As Hughes and Jones point out, there are many reasons why a group can succeed in its objective, and not

always because they interact effectively. In fact, the most efficient way to achieve the group's objective may entail dividing up a task into subcomponents, letting everyone complete their subparts independently, and then putting them all together at the end. However, this way of working together does not exhibit Riebe et al.'s emphasis on "interdependence" or Roschelle and Teasley's focus on "coordination." Thus, our definition of collaboration and teamwork focuses on the process of interacting and requires individuals to work together toward a common goal.

Several organizations have developed twenty-first-century skills frameworks that define competencies such as collaboration and teamwork. For example, the Partnership for 21st Century Skills (P21) considers collaboration a learning and innovation skill comprising subskills such as the ability to:

- work effectively and respectfully with diverse teams;
- exercise flexibility;
- make necessary compromises to accomplish a common goal;
- assume shared responsibility for collaborative work;
- value the individual contributions made by each team member.

These subskills reflect the communicative aspects of collaboration, the ability to compromise or negotiate, and responsibility for making an individual contribution toward accomplishing the group objective. The Assessment and Teaching of 21st Century Skills Project (or ATC21) characterizes collaboration and teamwork as a "way of working" and outlines a set of associated knowledge, skills, and attitudes. According to this framework, interacting effectively with others, working effectively in diverse teams, and managing projects all have knowledge, skill, and attitude components. In addition, the framework calls out the skill of guiding and leading others and an attitude of being responsible to others (Binkley, Erstad, Herman, Raizen, Ripley, Miller-Ricci, & Rumble, 2012).

One of the most widely cited conceptualizations of collaboration and teamwork in higher education comes from Stevens and Campion (1994), who identify two main dimensions: interpersonal skills and self-management skills. Under interpersonal skills, they include:

- conflict resolution: recognizing constructive versus destructive conflict and applying conflict-resolution strategies;
- collaborative problem-solving: optimizing group participation during problem-solving;
- communication: using open and supportive communication.

Under self-management skills, they include:

- goal-setting and performance management: setting specific and challenging goals, monitoring performance, and providing feedback;
- planning and task coordination: planning, coordination of information and schedules, and ensuring equitable distribution of labor.

Collaboration in Practice

Eean Crawford has taught Intro to Management for the past six years. The primary objectives are to impart a broad understanding of what's involved in managing: learning the demands that managers face, how to talk and think like a manager, and gaining some hands-on experience of actually being a manager. This is where group projects come in. Over the semester, students complete four projects as part of a four-person, instructor-selected team. All four projects require students to apply management theory and concepts to real-world business problems. For example, one project requires teams to develop a business plan, including a mission statement, competitive analysis, and business strategy. Teams pitch their plans to their peers, who vote for the best pitches.

Crawford's course has a few unique aspects. He spends a whole week explicitly teaching teamwork, including strategies for working successfully with others. Each student plays the role of "manager" during one project, organizing task work, scheduling meetings, monitoring progress, and resolving conflicts. Crawford uses observations of team interactions, along with peer ratings, to provide feedback. And teams have real-world capabilities to handle social loafing; they can institute improvement plans for team members not contributing and ultimately "fire" teammates unable to improve.

Business Communication and Protocol

Pamela Bourjaily has directed all sections of the Business Communication and Protocol course for the past eight years. The main objectives are to polish students' writing and oral presentation skills. Students transition from writing like students to writing as professionals, tailoring messages by audience, making claims, and providing justification for those claims. Since 2012 the course has integrated an explicit focus on teamwork to help address the perception that American and international students (who make up over 20 percent of undergraduates in the College of Business) were too insulated within their respective communities.

Bourjaily favors open-ended and ill-structured teamwork problems that make it difficult for students to take a "divide and conquer" approach. Rather, these projects force students to work together to develop a group strategy. For

example, the Capstone Project features a realistic business-communications scenario. In one version of the assignment, teams have to generate recommendations regarding the best city in which to locate a new business. This requires them to conduct research on a set of factors, like natural resources, education, and local tax laws that could impact the success of the business. Bourjaily's course also features some unique approaches to teaching teamwork. Like Crawford, Bourjaily does not allow students to choose their own groups but has instructors make these decisions after observing students in the classroom for three weeks. In forming teams, instructors balance factors like sex, ethnicity, major, expected graduation date, and previous team experience. Activities are structured so there is a shared group component and an individual component. Team engagement grades are based on the quality of team products, observations of team interactions, and "experience reports," which require each student to describe their contribution to the team. Bourjaily doesn't use formal roles but does encourage students to vary their team involvement over the semester, to take risks and to improve their skills with something they may not already be good at.

Teaching for Academic Success and Beyond

Both Crawford and Bourjaily believe their efforts are improving students' teamwork skills. Kenneth Brown analyzed peer evaluations collected in the Intro to Management class over the past four years, and results suggest that students are not only improving their collaboration skills over the semester but are also recalibrating their understanding of what it means to be a good teammate, holding their peers to increasingly higher standards over time. Crawford's former students often share with him that they apply principles learned in his class to their upper division classes. He has also received feedback from colleagues that his students have better teamwork skills than those who have not taken the Intro to Management course. Spending so much time working in teams also gives students a leg up as they enter the job market. Crawford and Bourjaily believe their students will be able to deliver a much stronger response to the ubiquitous interview question: "Tell me about a time when a coworker wasn't pulling his or her own weight. What did you do about it?" These educators emphasize that the principles they teach aren't just for business management: They are principles that students can immediately put to use in their personal lives to become more successful people.

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There are many other skills frameworks outlining slightly different subskills or dimensions of collaboration and teamwork.

However, the elements that appear to be shared across multiple frameworks relate to interpersonal communication, negotiation or conflict resolution, and task management/team regulation.

DEVELOPMENT OF COLLABORATION SKILL

How does collaboration skill develop over time? There is some research on the development of collaboration skills in infants and toddlers (Tomasello & Hamann, 2012). However, there does not appear to be a research basis for a broader developmental trajectory of collaboration skills across the lifespan, although Zhuang, MacCann, Wang, Liu, and Roberts (2008) found teamwork skills measured by self-report and situational judgment tasks to increase with age in adolescents. Instead, a few researchers have put forth performance scales that identify different levels of collaboration skill. For example, Schellens, Van Keer, and Valcke (2005) characterized five levels of collaborative knowledge construction that represent individual contributions to team dialogue, with the higher levels signaling more developed negotiation skill:

- **Level 1** Sharing or comparing information, with a focus on observation, agreement, corroboration, clarification, and definition.
- **Level 2** Dissonance or inconsistency, with a focus on identifying and clarifying conflicts.
- **Level 3** Co-construction, with a focus on negotiating and proposing new ideas that resolve conflicts.
- **Level 4** Testing tentative constructions, with a focus on validating new ideas against other resources and perspectives.
- **Level 5** Application of newly constructed knowledge, with a focus on confirming co-constructed knowledge.

As a result of our own reviews of the literature and several small-scale, qualitative research activities, we have developed our own view of collaboration and teamwork performance levels as part of Pearson's Personal and Social Capabilities Framework. The levels are similar to roles one might play in a group setting. As you move from left to right in Table 1, the level of collaboration sophistication required to fill that role increases.

NON-PARTICIPANT	PARTICIPATOR	COOPERATOR	COORDINATOR	CONFLICT RESOLVER
■ Does not participate in the task or is so often off-task that he/she makes no contribution to the group goal	■ Participates in the task, but does not cooperate with others or with the group process ■ Participates in discussions ■ Voices own opinion and views ■ Remains focused on the topic ■ Completes some tasks independently	■ Cooperates with the group process, but does not coordinate his or her contributions with those of others ■ Listens without interrupting ■ Actively solicits others' ideas ■ Accepts assigned tasks ■ Goes along with group consensus ■ Builds on others' ideas	■ Coordinates both processes and products with those of teammates, but does not resolve major conflicts ■ Actively listens ■ Gives and receives constructive feedback ■ Adapts ideas/process to accommodate teammates ■ Seeks consensus ■ Resolves minor conflicts effectively	■ Student coordinates processes and products with those of teammates ■ Resolves both major and minor conflicts effectively ■ Expresses disagreements honestly but tactfully ■ Supports group decisions even if not in total agreement ■ Compromises and negotiates to reach solution

Table 1 Collaboration and teamwork performance levels.

The role a person plays in a given context will depend not only on their collaboration skill but also on the roles that other team members play as well as the task demands. The roles reflect differences in the extent to which a person considers the views of others, allows those views and opinions to affect their own ideas and processes, and can both communicate about and resolve minor and major conflicts with honesty, tact, and diplomacy. A single task may not elicit all roles. For example, if a task simply requires groups to generate a lot of ideas but not to prioritize those options or make any selections, there will be little need for coordination or conflict resolution. Clearly, task demands are an important consideration in interpreting performance, a topic we return to in the assessment section.

Teaching Collaboration Skills

Given the potential benefits of collaboration and teamwork skills on their own and as a pathway to achieve other skills, there is a need to understand how to teach or coach students in developing these skills. There is no evidence that simply having students engage in more group work will actually improve their skills in collaborating. Rather, as noted by Rotherham and Willingham (2010), giving students experience working in groups is not the same thing as having students practice their collaboration skills; practice implies "noticing what you are doing wrong and formulating strategies to do better" (Rotherham and Willingham, 2010, p. 19). Practice also requires receiving feedback from someone more skilled than you are.

Below we will review the evidence for interventions and techniques that have sought to improve collaboration and teamwork skills in primary and secondary schools and higher-education environments. We will then review features of collaborative activities that are likely to lead to improved skills.

PRIMARY AND SECONDARY SCHOOLS

Although there have not been numerous reports of research evaluating attempts to teach collaboration skills in primary and secondary schools, those that do exist have shown promise for interventions that explicitly teach these skills. In a year-long investigation, fourth-graders were initially assigned to either cooperative training groups or no training groups (Gillies, 1999). The training consisted of two hour-long training sessions over two days that provided explicit instruction on:

- learning to share tasks fairly;
- encouraging group members to be responsible for their task;
- using appropriate social skills;
- sharing resources.

The study continued into a new school year in which the only refresh of skills was having students in the new groups formed in the new year generate their own list of behaviors that would be appropriate for working together. All students were observed working in groups for one week in each of three subsequent school terms. The videos of these observations were coded and revealed that students in the trained group exhibited more cooperative behavior and provided more explanations in response to both explicit and implicit requests for help across all three terms. In other words, the training appeared to improve group work, and that improvement persisted over time.

Positive results were also reported in a study with explicit instruction followed closely by the opportunity to practice (Andrusyk & Andrusyk, 2003). This study involved a twelve-week study in which the key element was explicit instruction followed by the opportunity to practice that skill in a group. The skills taught were:

- group listening skills;
- encouragement of teammates;
- disagreeing appropriately and avoiding "put-downs";
- resolving conflicts.

The activities in the group work involved one nonacademic task and one mathematics task. The results of the intervention, assessed via a teacher observation checklist administered to five teams over the twelve weeks, demonstrated an increase in listening to teammates, encouraging teammates, and disagreeing with ideas rather than people. There was a decrease in the use of put-downs. The changes in behaviors coincided with the weeks in which that skill was taught and then persisted through the study. A student survey also indicated students saw an increase in positive collaborative behaviors.

There are a number of collaboration skills that overlap with skills needed for other tasks. Researchers providing training on peer tutoring found the effects of the intervention translated into improved collaborative behavior (Nath & Ross, 2001). Specifically, the training was a seven-week course on peer tutoring and focused on teaching immediate feedback, prompting techniques, and communication skills to students in Grades 2–6. Students were then observed by outsiders engaged in academic group work every three weeks for twenty-four weeks using a behavioral checklist. Students who received training were more likely to disagree constructively, to ask questions of one another, to encourage one another verbally, to praise one another, and nine other collaborative behaviors. The researchers did find that after a semester break, a "refresher" session was needed to get back to pre-break behavior levels. It is not clear whether this was because of the content of the original tutoring, the young age of some participants, or some other factor.

The programs above contain a number of components, and it is not possible to determine whether it is the combination of them or individual pieces that produce the largest effects. Johnson and Johnson (1990) provide very specific steps by which to teach skills needed for collaboration, including:

- explaining why the skill is important;
- displaying it on bulletin boards;
- creating a chart with the physical and verbal actions that are key to the skill;
- role-playing;
- group processing;
- practice.

All of these are likely good techniques, but the authors do not cite specific research supporting them. Research with students who have social-skills deficits compared the effectiveness of coaching, modeling, a mixed model, and no intervention (Gresham & Nagle, 1980). All three interventions were better at increasing social skills than no intervention, and there were no differences in the outcomes between them, suggesting each method is similarly effective at improving social skills.

In summary, it appears that explicitly teaching the discrete skills required for collaboration over a period of weeks can result in those skills being applied in collaborative situations in the classroom.

HIGHER EDUCATION

There are several examples of interventions at the higher-education level focused on improving students' collaboration and teamwork skills, with some studies demonstrating more rigorous designs than others. For example, Chen et al. (2004) describe an undergraduate course on teamwork skills for the workplace. Components of the course included:

- explicit teaching of teamwork skills and collaboration strategies;
- use of in-class team activities for one to two hours every week;
- completion of three assessment-center exercises that simulate more "real-world" collaboration experiences;
- student-created teamwork goals and regular monitoring of progress toward those goals;
- a relatively large weight given to the collaborative components in terms of course grade.

The performance of students in this course was compared to the performance of students in two different control groups. Control Group 1 completed two of the assessment-center exercises but received none of the other elements of the intervention; and Control Group 2 received no intervention. Based on Stevens and Campion's (1994) teamwork skills assessment, students in the treatment group outperformed students in both control groups with respect to their teamwork knowledge. Treatment students also outperformed students Control Group 1 in terms of expert ratings of their teamwork skills demonstrated during the third assessment-center exercise, particularly in their management of task conflict and in appropriately promoting their own perspectives.

Ellis, Bell, Ployhart, Hollenbeck, and Ilgen (2005) describe an introductory management course that had a particular focus on teaching collaboration and teamwork skills. The intervention consisted of an hour-long training session focused on declarative knowledge of teamwork. Students then completed a command-and-control simulation in which teams of four students were charged with monitoring activity in a particular geographic region and defending it against incursions from unfriendly ground or air attacks. Students randomly assigned to the training condition outperformed those assigned to the control condition on a test of teamwork knowledge on questions that specifically related to aspects of the training—but not on questions that were not addressed during the training. Teams in the treatment condition also demonstrated better teamwork behaviors during the simulation performance, in terms of better planning and task coordination, collaborative problem-solving, and communication. It should be noted that the training in this study was conducted on an individual rather than a group basis. It is unknown whether the training would have been as effective if conducted at the group level.

Rummel and Spada (2005) conducted an experiment with advanced psychology and medical students in which students were placed into dyads and asked to

collaborate virtually to analyze a case and to come to a diagnosis and treatment recommendation. Subjects were randomly assigned to one of four conditions:

- **1** a learning phase with worked collaboration examples;
- **2** a learning phase with scripted prompts;
- **3** a learning phase with collaboration practice;
- **4** a group with no learning.

The condition using worked examples presented students with audio recordings of another dyad working on a case; students could also see the text editors of the partners as they talked, so they could watch the development of the solution unfold. The condition with scripted prompts used a very detailed structure for the interaction outlining specific phases of the problem-solving process, and even recommending time segments for each phase (e.g., "Spend seven minutes asking your partner any clarifying questions you might have"). In the condition involving practice, dyads worked freely on a case, with no guidance. Following the learning phase, dyads were asked to work on a second case.

Results on the second case showed that in groups with no scripting (practice only and no learning), there was less activity overall and significantly less coordination of content-related division of labor. Dyads in the no-learning group showed poorer turn-taking behaviors (i.e., more interruptions and fewer explicit handovers). Participants in both treatment conditions outperformed the others in terms of their declarative collaboration knowledge, as indicated by their performance on a post-test. The lack of differences in either collaboration knowledge or skill between the practice and no-learning groups suggests that unstructured practice is not better than no practice at all (Rummel & Spada, 2005).

Finally, McKinney and Denton (2006) describe an introduction to programming course that utilized team-based activities. There was also an overt attempt to teach students collaboration skills, as instructors incorporated a semester-long group project, group-based lab activities, instructor-chosen teams with an attempt to balance across student characteristics, reading assignments and classroom discussion focused on explicitly teaching students about collaboration skills and strategies, and regular peer and instructor feedback on collaboration skill. Although no control or comparison group was used in this study, the instructor documented a significant and substantial improvement (effect size of 0.71) in peer ratings over the course of the semester. Qualitative analysis of open-ended comments about each student's performance also supported an improvement trend over the course of the semester.

[I]t seems reasonable to conclude that including some support and guidance for collaborating will enhance student learning.

In summary, similar to research in K-12, collaboration interventions often involve a complex mix of instructional components, such as direct and explicit instruction in the skills of collaboration, opportunities to practice collaborating, and feedback from instructors and peers. In these complex interventions, it is not possible to attribute improved collaboration skill to any one particular element. However, a common theme across the studies is that some amount of structure or guidance is needed—either in the form of direct instruction in declarative collaboration knowledge and strategies, or in the form of scripting, through the use of worked examples or scripted prompts. Thus, it seems reasonable to conclude that including some support and guidance for collaborating will enhance student learning.

Activity Features

Although there is not evidence that engaging in collaborative activity by itself will improve collaboration skills over time, there are ways that collaborative activity can be structured to support use of those skills.

GROUP FORMATION

The size of groups can impact the interaction patterns within the group. In an experimental study of communication in groups of three versus six individuals, participants rated the appropriateness, openness, and accuracy of communication higher in three-person groups than in six-person groups (Lowry, Roberts, Romano, Cheney, & Hightower, 2006). Other research shows that smaller groups are less likely to demonstrate free-rider or social-loafing problems (Karau & Williams, 1993; Lam, 2015). There are also a number of studies examining the effect of group size on ultimate group performance (e.g., Lam, Karim, & Riedl, 2010; Veerman & Veldhuis-Diermanse, 2001) that demonstrate there is likely not a "best" group size for group performance, but it depends on the goal of the task and the type of work to be accomplished. However, it should be noted that this line of research seeks to maximize group decisions rather than improve student skills.

Another issue related to group formation is whether groups are self-selected or instructor-assigned. Several studies have examined whether the performance, satisfaction, or interactions among students in self-selected versus instructor-assigned groups are better. For example, one study found that above-average achievers (A or B students) tend to perform better in self-selected groups than in instructor-selected groups, whereas there was no difference in performance across group-formation types for lower-achieving students (van der Laan Smith & Spindle, 2007). Another study found that students in self-selected teams had higher reported levels of participation, more equitable distribution of labor, more supporting behaviors, and used strategies of organizing their work to create greater interdependencies than did students in instructor-assigned groups (Hilton & Phillips, 2010). Lam (2015) found that there was no significant difference in the incidence of social-loafing behavior for self-selected versus instructor-assigned teams. However, a survey of over 6,000 computer-science and engineering students found that students on instructor-formed teams reported lower levels of satisfaction with their group work and a greater incidence of free riders (Oakley et al., 2007). Again, it is worth noting that most of these studies did not examine whether instructor-assigned or self-selected teams were more effective in helping students improve their collaboration skills.

ROLE ASSIGNMENT

There is evidence that assigning roles to students can make them more likely to exhibit desirable behaviors within the group. A study of college students assigned individuals to one of the following roles prior to group work:

- source searcher;
- theoretician;
- summarizer;
- moderator;
- starter; or
- no role.

They then observed the student groups and coded the content of the group members' messages on an online discussion board (De Wever, Schellens, Van Keer, & Valcke, 2008). Many of the moderating activities are those laid out in our definitions of collaborative skill. Results of the study demonstrated that students assigned to the moderator role engaged in more content moderation and organizational moderation than students in the no-role condition. Each of the other roles followed this pattern, with students assigned a role being more likely to engage in the target behavior in their communications. This suggests that one way to increase the use of a particular collaboration skill may be to explicitly assign a role to a person that requires them to exhibit it.

In another study involving assigned roles, half of the student groups in government and policy courses were assigned to use functional roles, such as project planner, editor, communicator, and data collector, whereas the other half were not. Researchers found that those in the role condition made significantly more task-coordination comments compared to the no-roles group. Although the roles group did not differ in their performance compared to the no-roles group, students in the roles group reported higher levels of perceived group efficiency (Strijbos, Martens, Jochems, & Broers, 2004).

Schellens et al. (2005) describe an experiment in which students enrolled in an instructional-sciences course were randomly assigned to discussion groups that either did or did not use assigned roles. Within the treatment group, four students from each discussion group were assigned specific roles, which were similar to the roles used in the De Wever et al. (2008) study: moderator, theoretician, summarizer, and source searcher. Results suggest that, although role assignment had no significant effect on the mean level of knowledge construction achieved by the group, the assignment of specific roles did result in different levels of knowledge construction. In this study, knowledge construction was viewed as a process of social negotiation, with higher levels of knowledge construction representing more skillful social negotiation. Students assigned the roles of searcher and moderator scored significantly lower than students in the no-roles group, whereas students assigned the role of summarizer scored significantly higher in terms of levels of knowledge construction. The authors concluded that some roles may afford more opportunities to exercise collaborative skill than others.

PROVIDING FEEDBACK

Feedback on collaborative skill can be provided in many forms. Several studies suggest that this may be an effective method for supporting development of teamwork competencies. For example, automated feedback provided within an intelligent tutor for collaborative problem-solving can address both the problem-solving skills and the collaboration skills. Baghaei, Mitrovic, and Irwin (2007) describe a study in which treatment students in an introductory software engineering course

Collaboration in Practice

Teachers often begin the year with "team building" activities designed to help students get to know each other and become comfortable working on group tasks. These team challenges often reinforce mere cooperation because teachers do not debrief the experience in a way that leads to establishing common definitions of what true collaboration is and the expectations students should hold each other to when the real work gets hard.

On the first day of school, within fifteen minutes of walking in the door, Kevin Armstrong puts students into groups of four to five people and hands them twenty-five index cards and two feet of tape. Their task, as a group, is to build the tallest card tower possible, using only the given materials, and they must be able to support a tennis ball on the top of the tower. The time limit is twelve minutes. Some groups share design ideas before even touching the cards, but most begin feverishly folding cards, cutting tape and crafting their hodge-podge tower. Armstrong calls out time updates for them, and groups inevitably put the ball on top in the last few seconds—and the towers come crashing down. Not all towers fail, but most do.

Kids aren't supposed to fail the first day of school, right? As Armstrong explains, "What most students don't realize about collaboration is that the struggles and failures they face together are what help build a true team and ultimately lead them to success." Armstrong leads the class through a debriefing of the process by first sharing out and recording what characteristics or approaches made them successful. Then he asks them to identify challenges they faced and how they might approach the task differently if given another try. Finally, he asks each group to reflect on this experience as well as other successful teams they have been on.

Armstrong uses a Y chart to map out what an ideal team should look like, sound like and feel like. These concrete descriptors, based on experiences, provide the necessary scaffold to co-create group norms that can then be applied to future work. Throw in a collaboration rubric for peer and self-assessment and students can even begin to write personalized learning targets for collaboration. According to Armstrong, "Students inherently see the values we hold most dear based on the amount of time and intention we place on the tasks we ask them to engage in." What message might this send on the first day?

Kevin Armstrong, 4th Grade Teacher, Katherine Smith Elementary School, San Jose, CA

participated in a short training session on the types of collaborative behaviors their instructors were looking for. They were then put into pairs and required to collaborate (synchronously but physically separated), using the intelligent tutor interface. The treatment group received feedback on their collaboration skills and their programming skills, whereas the control group only received feedback on their programming skills. Students in the treatment group contributed significantly more to the group solution and also performed significantly better on a post-test question on collaboration behaviors. During interaction, they participated more in group-maintenance and task-management activity. On the other hand, the control group exhibited twice as much off-task discussion. It should be noted that random assignment to condition was not used, and it is unclear whether the two groups could be considered equivalent.

Peer evaluation is another commonly used means for providing feedback about collaborative skill to students. Brutus and Donia (2010) tested a peer-evaluation system in a sequence of undergraduate business courses. During the first course, instructors trained students in several sections to use an online peer-evaluation system to rate themselves and each of their teammates on their teamwork skills. Students could then see their own ratings. Matched comparison students in other sections of the same course taught by the same instructor did not use the peer evaluation system. During the second course in the sequence, all students were required to use the peer evaluation system. For those in the treatment group, this constituted their second exposure, whereas for the control group this was their first exposure to peer evaluation. Based on the average peer ratings collected during the second course, students in the treatment group significantly improved their ratings from the first course and also outperformed their counterparts in the control group.

Turner and Schober (2007) describe a study in which teams of four students enrolled at the Parsons School of Design met three times for thirty minutes each, with the goal of designing a T-shirt representing the program. Six teams anonymously evaluated their peers at the end of each design session, whereas the other teams did not. This feedback was provided to teammates within twenty-four hours of the ratings being collected. After the first session, students in the peer-evaluation condition were observed using a significantly greater percentage of "I" and "we" words, whereas members of the non-evaluation team used fewer self-related words over time. Students on the peer-evaluation teams also significantly decreased their use of affect words over time, whereas students in the non-evaluation team significantly increased their use of such words. In addition, students in the evaluation group tended to submit more proposals than their peers in the non-evaluation group. Once again, students were not randomly assigned to groups, and it is unclear whether students in the two conditions could be considered equivalent.

Even simple evaluation tools can be reliable and support valid inferences about collaboration skills.

Each of the peer-evaluation tools used in the studies above was different, although most were quite simple, consisting of a small number of criteria or statements and some kind of Likert-type scale. Even simple evaluation tools can be reliable and support valid inferences about collaboration skills. Ohland et al. (2012) developed a behaviorally anchored peer-evaluation instrument that included five dimensions of teamwork. Composite ratings correlated 0.64 with another well-known peer evaluation tool and 0.51 with final course grades. Peer ratings also constituted 26 percent of the variance in likability and 58 percent of the variance in willingness to work with that person again in the future. The authors did recommend providing training on the peer-evaluation instrument, as there was some evidence of rater effects—both leniency and range restriction. Similarly, Chalupa, Chen, and Sormunen-Jones (2000) created a peer-rating instrument including eleven criteria, each rated on a five-point Likert scale. Factor analysis results suggest the instrument is unidimensional, and Cronbach's alpha was estimated to be at least 0.87.

Assessment

TASK MODELS

Given the nature of collaboration and teamwork skills, what kinds of tasks will elicit evidence that students have mastered them? Task models are tools for representing the features of assessment activities likely to yield evidence of the targeted constructs (Mislevy, Steinberg, & Almond, 1999). Task models can include information related to task demands—what the student is required to do for successful performance—as well as structural and organizational features of the task.

TASK DEMANDS

Social psychologists who study small-group interactions have long studied features of group tasks that tend to affect the degree and nature of interaction and group outputs. For example, Hackman (1968) first characterized intellective tasks as those requiring the creation of a written product, and within this broad category, further distinguished three task types:

- **1** production tasks, which require the generation of ideas;
- **2** discussion tasks, which require discussion of issues and group consensus on a position;
- **3** problem-solving tasks, which require a solution to a specific problem.

According to Hackman, the distinction in task types concerns the objects of interaction, with production tasks addressing ideas, discussion tasks addressing issues, and problem-solving tasks addressing proposed solutions. Hackman found that type of task was systematically related to quality of the group outputs. In particular, work products for problem-solving tasks were significantly higher than those for production tasks in "action orientation," meaning they were more likely to explicitly propose a particular course of action. On the other hand, production tasks tended to elicit higher levels of originality in group responses than other task types. Moreover, Hackman concluded that the different task types tended to elicit different processes: production tasks tended to elicit presentation processes, discussion tasks encouraged evaluation processes, and problem-solving tasks afforded instruction processes.

Building on Hackman's work, McGrath (1984) recognized four main task categories, organized by task demand:

- **1** Generate tasks require production of ideas (e.g., creativity or planning tasks).
- **2** Choose tasks require selection of a correct solution (intellective task) or most preferred solution (judgment task).
- **3** Negotiate tasks require resolution of conflicting viewpoints (cognitive conflict task) or conflicting interests (mixed motive task).
- **4** Execute tasks require physical skill (such as an athletic competition).

These categories are arrayed along two dimensions:

- 1 the extent to which they require cognitive versus behavioral performance (with "choose" tasks located on the extreme cognitive side and "execute" tasks located along the extreme behavioral side);
- 2 the extent to which the task is cooperative or conflictual, which can also be conceptualized as the level of interdependence among team members implied by the task demands (McGrath, 1984).

Focusing primarily on the cognitive task types (generate, choose, and negotiate), these can be arrayed in terms of the level of interdependence (and hence the complexity of successfully collaborating) as follows:

- Generate: represents cooperation, no need for consensus, so low interdependence.
- Choose: represents coordination, requires consensus, so a moderate degree of interdependence.
- Negotiate: represents conflict resolution, requires consensus amidst inherent conflict, so high level of interdependence.

Strauss (1999) tested three of McGrath's task types (creativity, intellective, and judgment), finding that they elicited different types of group interactions. In particular, Strauss found higher levels of agreement, disagreement, and process communication for the tasks that demand more interdependence. This is consistent with McGrath's framework because one would expect that the need to agree, disagree, and discuss process would increase for tasks where consensus and coordination were required.

Consistent with the notion that requiring consensus is a useful feature for eliciting evidence of collaboration, Garcia-Mila, Gilabert, Erduran, and Felton (2013) conducted an experiment to determine the effect on argumentative discourse of different kinds of prompts. Students working in dyads were assigned to either a consensus prompt (where students were told they had to reach consensus) or a persuasive prompt (where students were told they had to convince their partner). Results suggested that consensus prompts elicited more claim/rebuttal statements than did persuasive prompts. Analysis of transcripts revealed that students assigned to persuasive prompts were more likely to repeat the same claims and evidence and to dismiss counterarguments out of hand. On the other hand, students responding to consensus prompts were more likely to consider counterarguments and adapt their own views in light of their partner's contributions. The authors concluded that this was evidence of what they called "two-sided reasoning" (Garcia-Mila et al., 2013, p. 514), resulting in a more balanced and less polarized discourse.

STRUCTURAL FEATURES

In addition to task demands, there are other considerations in designing collaboration assessment tasks, such as group size, identifiability of individual contributions, and group composition. For example, there is a wide body of literature on social loafing, also known as the free-rider problem, which posits that when working in groups individual accountability diminishes, which can decrease individual motivation and result in less effort expended than when working alone. Surveys of students indicate that social loafing is a problem in group assignments at the higher education level and that it causes a fair amount of student frustration with group assignments (Hall & Buzwell, 2012; Hubbard, 2005; Oakley, Hanna, Kuzmyn, & Felder, 2007). Task setup characteristics, such as group size, may affect the level of social loafing experienced by a group. For example, in a meta-analysis of seventy-eight studies, Karau and Williams (1993) found that larger groups tended to experience higher levels of social loafing compared to smaller groups. Similarly,

Task setup characteristics, such as group size, may affect the level of social loafing experienced by a group.

Lam (2015) found that the larger the group the higher the perceived level of social loafing.

On the other hand, aspects of the task structure that make individual contributions more identifiable may combat social loafing and enhance the measurement of individual collaboration skill. For example, Williams, Harkins, and Latané (1981) found that even when participants were simply told that their individual contributions would be identifiable, they exerted more effort and demonstrated less social loafing. Task incentive structures that require students to articulate individual contributions and consider them alongside group or team performance may elicit more desirable group interactions. Results from an experiment suggest that college students prefer such a hybrid evaluation model to one that emphasizes either group performance or individual performance, but not both (Hoffman & Rogelberg, 2001).

In terms of student characteristics, in a meta-analysis of seventeen studies on collaborative learning, Webb (1991) found that interaction patterns tended to vary by gender and relative ability level. The results of this study led Webb to conclude that in forming groups it is desirable to balance gender as much as possible and to create mixed-ability groups with a narrow range of ability (e.g., matching high ability with medium ability and medium ability with low ability).

EVIDENCE MODELS

The final piece in the assessment puzzle is identifying and aggregating evidence from these activities so we can make inferences about collaboration and teamwork. An evidence model (e.g., Mislevy, Steinberg & Almond, 1999) describes the specific types of behaviors that should be measured to assess collaborative skill and how the behaviors link to the competencies. Gathering evidence of collaborative skills, however, is often not as straightforward as gathering evidence of individual cognitive skills (e.g., von Davier & Halpin, 2013). First, there is interdependence between multiple collaborating individuals, which can cause interactions and dependencies on other team members (e.g., one student loafing on a team). Second, the higher-order skills in collaboration are often not evident in the work product but emerge from the process and thus require continuous monitoring of the process throughout the tasks. Finally, many of the behavioral variables needed to assess the skill are not typically captured by traditional standardized tests (e.g., multiple choice or essays). These variables include listening and responding behaviors, organizing roles and work tasks, and discussing perspectives. Thus, the evidence model for collaboration must specify how to identify the behaviors and how they tie to the constructs that need to be measured.

A number of studies have specified the types of behaviors tied to collaborative skills. A sample of these behaviors is illustrated in Table 2. While a majority focus on extracting information from the language in the communication stream during the collaborative process, others examine events or actions taken during the task to infer collaborative behaviors.

BEHAVIORS	SOURCE
Questioning and listening to address miscommunication conflicts, collective brainstorming, searching for common goals, exchanging offers, counteroffers, and concessions to reach compromise, forging of integrative (win–win) solutions, inquiring about others' goals and interest, properly structuring team meetings, soliciting input from everyone, and active listening strategies, such as probing (encourage speaker to clarify meaning), reflecting (paraphrasing a message to ensure comprehension), deflecting (relating analogies and examples to help the speaker understand a problem), engaging in small talk	Stevens & Campion, 1994
Number and type of sentence starters used, asking for help, providing help, providing elaborated explanations	Baghaei, Mitrovic, & Irwin, 2007
Use of different types of sentence starters as indicative of different cognitive levels—e.g., use of reasoning to provide justification for a point of view was valued higher than asking clarifying questions to remember or understand	Gogoulou, Gouli, Grigoriadou, & Samarakou, 2005
Changes or modifies position if a defensible argument is made by another team member, recognizes and praises other team members' efforts, employs "win–win" negotiation strategies to resolve team conflicts, and identifies the important elements of a problem situation	Chen, Donahue, & Klimoski, 2004
Planning and task coordination in the form of the number of times teammates assisted one another by engaging enemy tracks in their teammates' quadrant and evidence of communication skills in the form of the number of times teammates shared task-related information	Ellis, Bell, Ployhart, Hollenbeck, & Ilgen., 2005
Use of rebuttals in argumentative discourse as evidence of "two-sided reasoning," which demonstrates an openness to considering other viewpoints and a willingness to negotiate/make concessions to reach consensus	Garcia-Mila et al., 2013

Table 2

THE SCORING MODEL

Evaluating evidence of collaboration and teamwork skill can be achieved through behavioral observation by instructors or experts, through behavioral ratings by peers, or through automated systems that monitor the process and outcomes. Each approach provides differing advantages and disadvantages in measurement precision, timeliness, and amount of effort.

Behavioral observation is the most common approach to assessing collaborative skills.

Behavioral observation is the most common approach to assessing collaborative skills. An instructor or rater observes a team and uses a rubric to assess different behaviors and their level of performance. Rubrics clearly outline the behaviors required and provide instructors with guidelines for what to look for and how to assess the behaviors. For example, the AACU has created a teamwork rubric (https://www.aacu.org/value/rubrics/teamwork), recognizing four levels of performance ranging from benchmark to capstone. The rubric dimensions include:

- contributes to team meetings: the benchmark performer shares ideas whereas the capstone performer articulates pros and cons of various alternatives;
- facilitates the contributions of team members: the benchmark performer takes turns speaking and doesn't interrupt others, whereas the capstone performer builds on and synthesizes the ideas of others, as well as actively solicits others' perspectives;
- individual contributions outside of team meetings: the benchmark performer completes assigned tasks by the deadline, but the capstone performer completes tasks to a high degree of excellence and helps others finish their tasks;

- fosters constructive team climate: the benchmark performer is inconsistent in the use of supportive communication whereas the capstone performer consistently uses supportive communication;
- responds to conflict: the benchmark performer passively accepts conflicting viewpoints, whereas the capstone performer addresses conflict directly and effectively resolves it.

Other rubrics have emphasized slightly different dimensions, such as interpersonal and self-management skills (e.g., Taggar & Brown, 2001) and team decision-making in complex tasks (Smith-Jentsch, Cannon-Bowers, Tannenbaum, & Salas, 2008). While teacher-based observation using such rubrics can be highly reliable and valid, the approach requires a high degree of effort of observing teams in real-time or reviewing audio, video, or event logs later. This can be difficult to perform in cases where there are multiple teams in a classroom or where collaboration is happening asynchronously, or when the collaboration cannot be fully monitored because it occurs over online collaborative tools.

Behavioral observations can also be made by peers during or after collaboration tasks using the same rubrics as those used by instructors.

Behavioral observations can also be made by peers during or after collaboration tasks using the same rubrics as those used by instructors. Such peer evaluations can be as reliable and valid as instructor ratings (Loughry, Ohland & Moore, 2007; Taggar & Brown, 2001). Peer ratings have the further advantage that the students may also learn about the appropriate behaviors through the process of monitoring their peers. However, students performing peer ratings may be susceptible to demand characteristics, such as rating team members highly in order to receive a higher overall grade from the instructor, and may be too close to the task and interactions to always rate objectively.

Evidence can also be processed automatically through computers. Computer-based administration of collaborative tasks can provide some level of controls over collaborative situations, providing the materials, media, and means for the students to interact. The computers also provide a means to automatically collect and analyze the evidence. With the ubiquity of student use of computers, there has been increased development of environments that support and/or train collaboration. These environments include shared writing platforms (e.g., Google Docs), MOOCs (Massive Open Online Courses; e.g., Bergner & Pritchard, 2013), Intelligent Tutoring Systems for multiple students (e.g., Graesser, VanLehn, Rosé, Jordan, & Harter, 2001; Koedinger & Corbett, 2006), and collaborative gaming environments around academic domains (e.g., Metcalf, Kamarainen, Tutwiler, Grotzer, & Dede, 2011; Zapata-Rivera et al., 2017). In each of these computer-based environments, the events and student actions are logged. Statistical models can then be used to analyze the process data (e.g., von Davier, 2013; Hao, Liu, von Davier, & Kyllonen, 2015). Typically these models include either hard-coded or statistically derived rules for how the events and actions combine to characterize individual and team behaviors.

Most recently, artificial-intelligence technologies have been used for assessing collaboration skills. The approaches have primarily been used for systems with computer-based agents and for automated natural language analysis of the communication stream. Computer-based agents or avatars can serve as simulated collaborators and interact with the students through language and/or actions. The agents can be programmed to take on different roles and abilities working with the student and other computer agents, thereby exposing students to different types of collaborative situations (Dede, 2009; Graesser, Forsyth, & Foltz, 2016; Metcalf et al., 2011). For example, if students need to be assessed on their ability to handle conflict, two agents can disagree over a particular path to a solution, and the system can monitor the behavior of how the student resolves the situation. As such, an agent-based system provides more control over the

assessment situation and allows more refined collection of evidence. This approach has been incorporated into the 2015 OECD PISA assessment of collaborative problem-solving, since it is compatible with doing controlled assessment across diverse student populations (OECD PISA Collaborative Problem Solving Expert Working Group, 2013). Although students may not be interacting with other humans, research has shown that the assessments can be as reliable and valid as human-to-human collaborative situations (Grieff, Herborn, Schweither, & Mustafic, 2016; Rosen & Foltz, 2014; von Davier & Halpin, 2013).

Because language is the primary means of extracting behaviors in collaborative situations, automated analyses have been applied to classify behaviors and score the quality of collaborations. For example, research has shown that automated approaches can assess both spoken and written discourse and accurately classify types of interactions (e.g., Cooke, Duchon, Gorman, Keyton, & Miller, 2012; Martin & Foltz, 2004; Rosé et al., in press), predict the overall scores of individuals and teams in complex problem-solving situations, and alert instructors when students are drifting from effective collaborative patterns (Foltz & Martin, 2008).

Overall, automated techniques allow more control over the collaborative situations and provide mechanisms for automatically capturing behaviors and converting them into scores and feedback.

Overall, automated techniques allow more control over the collaborative situations and provide mechanisms for automatically capturing behaviors and converting them into scores and feedback. This approach is obviously labor-intensive in terms of developing scoring models and may be more costly to develop than approaches requiring less control over the conditions of the interaction. Whether this level of standardization is required for any given context will depend on the purpose of the assessment, whether to support summative, high-stakes inferences about individual skill or to provide more formative feedback for adjusting instruction.

Automated approaches cannot detect all the subtleties that can be extracted from human observation, and their use requires all information (e.g., actions and speech) to be recorded through computers. Nevertheless, the field is moving fast, and, with further developments in natural language processing, speech recognition, and machine learning, we see this as an area that will continue to grow, both for having students interact with agents through natural language and for automatically assessing multiple students who are talking or writing to each other.

Conclusions and Recommendations

The research on collaboration reviewed in this report leads to a number of important conclusions and implications for classroom practice, delineated in Table 3.

CONCLUSION	IMPLICATION	TIPS FOR CLASSROOM PRACTICE
Collaboration skills are associated with more effective performance at school and on the job, and are highly valued by employers	Educators should develop collaboration skills in students as an end in themselves, not simply as a teaching method by which to learn other skills.	Establish learning objectives for collaboration. Plan for and use group activities as opportunities to reinforce and practice these skills.
The elements of collaboration shared across multiple frameworks include: interpersonal communication, conflict resolution, and task management.	When teaching and assessing collaboration, educators should see the skill as multidimensional, looking at the elements both individually and together.	Show and explain what good collaboration looks like. Design activities that require learners to use the elements of collaboration in concert but provide feedback on each element individually.
It is possible to define less and more sophisticated levels of collaboration skill.	Educators should use these levels when assessing and teaching collaboration.	Help learners understand their own skill level in terms of observable behaviors.
There are different types of collaborative tasks that require greater or lesser degrees of collaboration skill.	Educators should select and design the appropriate task type for the situation and the learners.	Make sure group activities require students to work together and negotiate to forge consensus.
Assessment of collaboration requires collecting evidence of group interactions and team processes such as language used for communication, reactions to obstacles, planning documents, and approaches to decision-making.	Educators should capture group interactions and processes either through observation (by the instructor or peers) or by using technology that captures and automatically analyzes verbal communication and group decision-making.	Pick and choose from a diverse mix of evidence, including your own in-class observations, peer ratings, chat logs, discussion boards, email threads, documentation of task planning and organization of labor, and the group product during various stages of drafting, commenting, and revising.
Collaboration skill does not tend to develop in the absence of explicit instruction.	If students' collaborative skills are to improve, educators need to provide some combination of direct instruction in the skills of collaboration, opportunities to practice collaborating, and feedback.	Spend time in class directly teaching collaboration skills, including strategies for interacting productively with others, resolving conflicts, and managing taskwork.
Peers can reliably rate others' collaboration skill and these ratings can result in skill improvement.	Peer evaluation using defined rubrics or scales can be implemented as part of an effort to increase collaboration skills.	Create your own peer rating scale that aligns to the definition and levels of collaboration and train students to use the rating scale. Model how to provide constructive feedback on collaboration.
Aspects of forming groups (size of the group, group composition, and method of forming groups) may affect students' interactions and experiences. Although students may prefer self-selected groups, group composition is more difficult to control when teams are self-selected.	Generally, educators should use smaller, mixed-ability groups. Educators should consider using self-selected teams for learning activities but instructor-selected teams for assessment purposes.	Rotate groups so that students gain experience working with different types of individuals and teams.
Assigning specific roles (e.g., moderator, summarizer) may be one way of encouraging students to demonstrate desirable collaboration behaviors.	Instructors should experiment with embedding specific functional roles into collaboration tasks, particularly roles that emphasize desirable collaboration behaviors.	Allow students to choose which of the defined roles in a task they would like to play, but encourage them to practice playing different roles over time.

Table 3 Conclusions and implications for classroom practice.

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