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Collaborative Problem Solving: Social and Developmental Considerations

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Mary Gauvain
Department of Psychology, University of California, Riverside

Skill at solving complex problems in teams of people with varying backgrounds and expertise is needed to address many of the pressing social, environmental, health, resource, and economic problems in the world today. There are several indicators of this new reality. Social collaborative skills are increasingly valued in the workplace, and people with these skills make up a substantial part of the changing labor market in the United States (Deming, 2015). Team science is seen as instrumental for tackling real world "grand challenge" problems (National Academy of Sciences, National Academy of Engineering, and Institute of Medicine, 2005; National Science Foundation Directorate for Social, Behavioral, and Economic Sciences, 2011; Social and Behavioral Science Team Annual Report, 2016). And collaborative learning in the classroom is being used effectively for student learning across the curriculum, including the science, technology, engineering, and mathematics (STEM) fields (National Academy of Sciences, National Academy of Engineering, and Institute of Medicine, 2018; Sawyer, 2014). In this light, Graesser and his colleagues (2018) concentrate on the need to train young people in collaborative problem solving (CPS) in order to prepare them for the 21st century workforce. They describe two ways that psychological science can contribute to this endeavor: by conducting basic research on CPS, including the design and implementation of CPS training for youth and by working in interdisciplinary teams that use CPS to reach productive ends.

So what might be effective ways of imparting CPS skills to young people? I say "ways" because it is unlikely that any single method will suffice in engendering such a large set of skills across a sizable and diverse range of problems. Moreover, support for developing and using these skills will need to be sustained over time and to accommodate changes in knowledge, technology, and personnel; new methods will supplant ones that no longer work. Research conducted in laboratory and classroom settings, which forms the basis of my remarks and was cited by Graesser et al. (2018), offers some useful ideas and some cautionary tales for designing this training. However, it is important to state at the outset that this research concentrates mainly on face-to-face interaction and the learning of classroom-based subject matter—both of which differ from the type of training envisioned by Graesser and his colleagues. Nonetheless, I believe this research offers useful insights, particularly regarding the social and developmental aspects of CPS training, that warrant attention as this work proceeds. But first, it is important to mention some distinctions between collaboration in the classroom and the workplace.

Practical Learning and CPS

There is a long history of research in the educational, developmental, and learning sciences on the role of practical experience in classroom learning (Dewey, 1959; Sawyer, 2014). Much of this research is rooted in a social constructivist theory of cognitive development that emphasizes the dynamic nature of human interaction and how socially shared cognitive activities lead to learning (Göncü & Gauvain, 2012). The use of collaborative learning in the classroom was informed by this theory on the basis of the understanding that when young people work together to solve a problem, they gain content knowledge *and* experience with the kind of activity that scientists and other professionals use in their own work (National Academy of Sciences, National Academy of Engineering, and Institute of Medicine, 2018). That is, the students are practicing an authentic problem-solving activity, one that resonates with how trained adults engage in these types of problems. It is assumed that the students will learn about the interpersonal skills that are useful for effective collaboration

Corresponding Author:
Mary Gauvain, Department of Psychology, 2111F Psychology Building, 900 University Ave., University of California, Riverside, Riverside, CA 92521
E-mail: mary.gauvain@ucr.edu

through their participation. That is, collaborative skills are not explicitly taught. Rather, students learn them as they engage firsthand in this form of social learning. There are many possible learning outcomes. Social learning of this sort provides opportunities for learners to observe how the social process works, how it affects the outcome or problem solution, and how group members respond to one another's contributions. All of this information is useful for an individual's subsequent participation in CPS.

This type of collaboration has been shown to be effective in helping students learn class content in a range of subjects or disciplines (Sawyer, 2014). Some recent research suggests that it is especially beneficial for students in middle school and higher grades (Leman, 2015). There are likely to be multiple reasons for this pattern. The social and cognitive skills that develop around these ages give young people ways of engaging in, managing, and learning from collaboration that were not possible when they were younger. The type and complexity of class material may also play a role. For instance, to learn the type of complex material taught in the upper grades, students may benefit from hearing multiple perspectives or points of view on these topics, the very type of information that collaborative learning provides. These social and developmental points will be developed further in the following sections. Now I turn to some ways that CPS in the workplace differs from collaboration as practiced in the classroom. This information is directly relevant to evaluating whether students will generalize CPS experiences from school to work settings.

During workplace collaborations, knowledge about and responsibility for the activity are usually distributed across team members and guided by one goal: to solve the problem at hand (Brown & Duguid, 2000; Hutchins, 1995). Think about the teamwork at NASA during the Apollo 13 crisis after the oxygen tank in the spacecraft exploded ("Apollo 13," 2009). The astronauts and ground crew worked together to figure out how to use the materials onboard the space capsule to get the astronauts safely back to earth. Individuals and small groups worked on different parts of the problem. For instance, some worked on how to sustain electrical power, others focused on the removal of carbon dioxide from the capsule, and others concentrated on temperature because the capsule was rapidly losing heat. Team members worked on their assigned parts of the problem and coordinated their activities when needed; again, their joint actions were aimed at one goal—getting the astronauts safely back to earth.

This solution-oriented approach differs greatly from collaborative learning in the classroom (Gauvain, 2016; Miyake & Kirschner, 2014). Although some aspects of a classroom collaborative learning activity may be distributed across students in a group (Greeno & Engeström, 2014), each and every student is expected to come away from the experience with a clear understanding of the problem and with the knowledge and skills needed to solve it. In other words, students are simultaneously solving the immediate problem with the group while they are building individual competence in the discipline(s) and techniques involved. Collaboration in the classroom needs to be designed to provide support and direction for both of these goals. Naturally, individual learning and performance is sometimes superior to group learning and performance, but here I focus on how each student's learning can be maximized in the context of a group.

To this end, the various components of the problem at hand need to be well defined and shared with all group members. Explicit exchange of ideas needs to occur while the project is under way, and individual roles and responsibilities should rotate during the activity so that all group members have access to, and the potential to learn about, key elements of the project (Alfieri, Brooks, Aldrich, & Tenenbaum, 2011; Kirscher, Sweller, & Clark, 2006; Mayer, 2004; Wirkala & Kuhn, 2011). These practices can be effective in promoting the engagement and learning of all the students, and they may foster greater participation of female students and underrepresented minority students in the activity. Earlier research involving students from diverse social and ethnic backgrounds demonstrated that collaborative peer arrangements can be designed to challenge students' preconceived notions about each other's competencies and promote a more productive and respectful setting for learning (Cohen, 1972).

Although these various social dynamics might be possible to simulate in computer-based models of training for CPS, as proposed by Graesser et al., the feasibility is presently unknown. Moreover, even if the social dynamics are simulated, further study is needed to determine whether and how this experience promotes the learning, and subsequent effective use, of collaborative skills in the workplace. In other words, both learning and transfer are at issue. Graesser et al. (2018) are well aware of these concerns, and my read of their article is that they would welcome more research along these lines.

For now, however, they are drawn toward large-scale projects that use computer-based learning and assessment, often with cross-national samples. This research will yield valuable findings. However, smaller scale and more detailed investigations with secondary students, both in laboratory and naturalistic settings, are needed. Ideally, longitudinal research that probes whether the skills learned in training are evident later in the

workplace, or perhaps in further training contexts, would be of great use. These painstaking types of studies can determine whether and how CPS skills learned in the school context generalize to real-world problem-solving situations. It should be noted that such skills often do transfer, but science requires testing of this claim.

To be clear, this type of research exists neither in the more established research on classroom collaboration mentioned earlier nor in the research described in the present article. It will be part, I hope, of the next generation of research in this area. The authors are correct in stating that such research is complex and likely to be conducted on small samples relative to studies with computer-based designs. Nonetheless, it will provide valuable information that complements the computer-based assessments described by Graesser et al. (2018); consequently, it will help to move this research forward. Next, I remark on what has been learned about the social dynamics of collaborative learning from the classroom research that may be instructive as research on CPS advances.

Social Aspects of CPS

Although most human beings are primed to learn socially (Tomasello, 1999), not all social situations are conducive to learning and constructive problem solving. Decades of research on social approaches to learning and cognitive development offer several important ideas for the development and design of CPS. Gains are enhanced if the social context is carefully arranged; the social process is closely monitored; feedback is provided, especially at critical junctures; participants are encouraged to work out examples and explain their solutions to one another; and adjustments are made if the activity strays too far from the goals (Alfieri et al., 2011; Greeno & Engeström, 2014; Klahr, 2009; Mayer, 2004; National Academy of Sciences, National Academy of Engineering, and Institute of Medicine, 2018; Wirkala & Kuhn, 2011).

As this list suggests, the design of an effective social setting for learning involves attention to both social organization and social process. Social organization includes the activity itself; the participants and their respective interests, skills, and motivation to learn; and the leader, the person who identifies, organizes, and oversees the group and its activities. Social process includes the interactions of the participants, the leader's guidance and support in directing the activity, and the materials or tools that are used to support the activity. In designing CPS education, it is important to consider how these types of social components can enhance or impede the learning environment. From this view, these are the primary questions: What social processes will promote individual learning in CPS education? Can these social processes be implemented in a systematic and effective way in CPS education? Some ideas for answering these questions follow.

Research suggests that how participants are involved in the problem-solving activity will be as central to the design of CPS education as the problems themselves. This is because the social process will determine the type of learning that occurs. People cannot be assigned to groups with the expectation that social processes will emerge that foster learning. Group activity needs to be set up so that all participants can be active and contributing members. Opportunities need to be created to articulate and build on the individuals' current understanding in the problem domain and to steer their developing knowledge. Conversation, argument, note-taking, and other recording and review activities should be explicit parts of the activity. These techniques encourage active participation by individual group members and help engage both the mind and the body (sensory and motor systems) in learning (Robbins & Aydede, 2009).

Use of a distributed learning approach may be a way of engaging individuals in that each group member has a meaningful role to play (Greeno & Engeström, 2014). However, individual learning requires careful attention in a distributed learning context. Rotating roles and using regular peer instructional exchanges are important to include. In addition, explicit and specific learning outcomes for individuals in relation to the various aspects of the problem, along with clear means of assessing these gains, are needed. As mentioned previously, a distributed learning approach may also be useful for addressing issues related to equity and diversity in the setting: Collaborative approaches can be used to create opportunities for participants to observe and engage with others as competent and contributing members of the group.

Experience with the "tools" of culture, both symbolic and material, is part of complex problem solving and will play a key role in CPS education (Cole, 1996). Individual competence of all group members in understanding and using the tools should be ensured. To develop skill with these tools, learners need to understand that they are part of the problem-solving process itself. Encouraging learners to identify the tools that support problem solving and to examine the role these tools play in the specific problem along with other possible uses for these tools can promote analytical understanding of the role of tools of thinking in achieving activity goals.

Finally, learning together in CPS should occur in the context of meaningful, goal-directed activity. Moreover,

the activities in which the learners engage should have local goals and an overarching societal purpose—and participants should have clear understanding of both. In other words, it is important that the learners realize that what they are learning is not an end in itself but is part of a larger set of skills that can be used to solve problems both inside and outside of school. This position is consistent with the chief aims of CPS education to create team members who are confident in their own knowledge and willing to build new knowledge with others.

Developmental Aspects of CPS

From a social constructivist perspective, CPS is fundamental to learning (Göncü & Gauvain, 2012). Even very young children have the capability to respond to and interact with other people in the course of goal-directed action that supports learning. However, what someone learns from collaborative activity depends greatly on the developmental status and experience of the individual. For instance, whereas young children benefit from assistance in understanding problems, following rules, and manipulating materials, older children gain more when others help them with complex thinking and the development and use of strategy. Better understanding is needed of how youth in middle and secondary school, who differ both socially and cognitively, comprehend the nature and purpose of CPS learning—and how that understanding is reflected in learning outcomes.

At present, addressing these issues faces serious limitations because research on collaborative learning lacks a clear developmental perspective (Gauvain, 2012). Other than reporting the ages or grade levels of participants, much of the extant empirical literature on collaborative learning in childhood and adolescence has paid little attention to age-related and developmental factors. And in many instances, the theory used to guide the research is based on prior research with adults that was often conducted in controlled settings and then extended with little or no modification to groups of children and youth in the classroom. Controlled settings are essential to making cause-and-effect inferences about what works, but this rigor needs to be extended to research with participants of different ages and developmental levels.

The distinction between learning and development is also important to mention. To appreciate the distinction, consider the following example. A teacher would probably be disappointed but not terribly worried if a student forgot something he or she had previously learned. However, this same teacher would be alarmed if this student regressed developmentally: behaved or responded to a learning situation in a less developmentally mature way than prior experience had led the teacher to expect. The point is that not that all findings pertaining to learning are developmental. However, in any given study, this is an empirical issue, and careful attention to the developmental status of the participants in research on the CPS approach is important. On this point, much of the data used by Graesser et al. is drawn from the Programme for International Student Assessment (PISA) sample and involves 15-year-old youths. That data set provides little to no developmental analysis of the sample or examination of how findings from this age group, collected in the classroom context, pertain to collaboration in the adult workplace. Fifteen-year-olds are not adults, as research in cognitive neuroscience has demonstrated (Albert, Chein, & Steinberg, 2013; Reyna, Chapman, Dougherty, & Confrey, 2012). They are particular types of learners, decision makers, and social actors. In sum, lack of consideration of relevant developmental factors limits the interpretation and extension of results from the PISA project, but adding a younger and/or older comparison group—even a smaller sample—would greatly enhance the usefulness of these data for improving educational and economic outcomes.

Final Thoughts

Theory will be important for guiding this work as it moves forward. Although Graesser et al. (2018) describe various models or frameworks about how CPS may impart collaboration skills in youth, a deeper theoretical account of the nature of cognition in social context is needed. This information will help researchers move beyond specific group factors to understanding why these factors are important in human cognition and also why they take the shape they do in a particular problem-solving situation. Given the social nature of CPS, the theory must include a view of human cognition that connects the individual mind with the minds of others. Social constructivist theory offers ideas that would be useful in this regard (Cole & Engeström, 2007). As stated earlier, given the age-related factors in this training, any ensuing theory needs to include the cognitive and social skills of the participants. Motivation is also important to consider. All of these processes undergo significant change during adolescence, the very age period targeted for CPS training.

A related, critical issue is transfer (i.e., the adaptation of what has been learned in one situation to a different problem context). To aid this process, prompts or exercises for transferring newly learned CPS skills could be built into the approach. For instance, queries at the outset (e.g., "What does this problem remind you of?") and during group activity (e.g., "How could you use

this 'tool' to solve other problems?") can be used to encourage transfer. Simply hoping that transfer will emerge without any support for it during learning is not enough.

Transfer is not just desirable; it is essential: No patient is exactly like the ones presented in medical school, no case is exactly like the ones presented in law school, no intelligence threat is exactly like those that have occurred in the past, and skilled tradespeople often have to adapt learned knowledge to new situations to fix problems. Not teaching for transfer is expensive (skills have to be taught over and over) and results in lower quality reasoning and problem solving.

Finally, an implicit assumption of this research is that schools will welcome, or perhaps be charged with, teaching CPS skills to students. This suggestion cuts close to a question that educators confront on a regular basis: What is the job of schooling? Or, stated in a more direct way, is it the job of schools to teach youth workplace skills that might be needed after these individuals sort themselves out as adults? And if so, when is the best time to do it and, importantly, who will benefit from this practice? These questions are acutely important today given the vast body of knowledge and skills that teachers are expected to impart to young people, the ever-decreasing funds put toward education, and the sheer time available in the school day—which, as it is wise to remember, is set by state and local policy. In short, any proposed changes to the curriculum, regardless of their worth, will need to grapple head-on with many societal and practical realities concerning the education of children and youth.

Declaration of Conflicting Interests

The author(s) declared that there were no conflicts of interest with respect to the authorship or the publication of this article.

References

Albert, D., Chein, J., & Steinberg, L. (2013). The teenage brain: Peer influences on adolescent decision making. *Current Directions in Psychological Science*, *22*, 114–120.

Alfieri, L., Brooks, P. J., Aldrich, N. J., & Tenenbaum, H. R. (2011). Does discovery-based instruction enhance learning? *Journal of Educational Psychology*, *103*, 1–18.

Apollo 13. (2009). Retrieved from National Aeronautics and Space Administration website: https://www.nasa.gov/mission_pages/apollo/missions/apollo13.html

Brown, J. S., & Duguid, P. (2000). *The social life of information*. Boston, MA: Harvard Press.

Cohen, E. G. (1972). *Designing groupwork: Strategies for the heterogeneous classroom*. New York, NY: Teachers College Press.

Cole, M. (1996). *Cultural psychology: A once and future discipline*. Cambridge, MA: Harvard University Press.

Cole, M., & Engeström, Y. (2007). Cultural-historical approaches to designing for development. In J. Valsiner & A. Rosa (Eds.), *The Cambridge handbook of sociocultural psychology* (pp. 484–507). New York, NY: Cambridge University Press.

Deming, D. J. (2015). *The growing importance of social skills in the labor market* (Working Paper No. 21473). Retrieved from National Bureau of Economic Research website: http://www.nber.org/papers/w21473

Dewey, J. (1959). *Dewey on education*. New York, NY: Teachers College Press.

Gauvain, M. (2012). *The social context of learning and iSTEM Education*. Unpublished manuscript, National Academies Board on Science Education, Committee on Integrated STEM Education.

Gauvain, M. (2016). Peer contributions to cognitive development. In K. R. Wentzel & G. B. Ramani (Eds.), *Handbook of social influences in school contexts: Social-emotional, motivation, and cognitive outcomes* (pp. 80–95). New York, NY: Routledge.

Göncü, A., & Gauvain, M. (2012). Sociocultural approaches to educational psychology: Theory, research, and application. In K. R. Harris, S. Graham, T. Urdan, C. B. McCormick, G. M. Sinatra, & J. Sweller (Eds.), *APA educational psychology handbook, Vol. 1: Theories, constructs, and critical issues* (pp. 123–152). Washington, DC: American Psychological Association.

Graesser, A. C., Fiore, S. M., Greiff, S., Andrews-Todd, J., Foltz, P. W., & Hesse, F. W. (2018) Advancing the science of collaborative problem solving. *Psychological Science in the Public Interest*, *19*, 59–92.

Greeno, J. G., & Engeström, Y. (2014). Learning in activity. In R. K. Sawyer (Ed.), *The Cambridge handbook of the learning sciences* (2nd ed., pp. 128–147). New York, NY: Cambridge University Press.

Hutchins, E. (1995). *Cognition in the wild*. Cambridge, MA: MIT Press.

Kirscher, P. A., Sweller, J., & Clark, R. C. (2006). Why minimal guidance during instruction does not work: An analysis of the failure of constructivist, discovery, problem-based, experiential, and inquiry-based teaching. *Educational Psychologist*, *41*, 75–86.

Klahr, D. (2009). "To every thing there is a season, and a time to every purpose under the heavens": What about direct instruction? In S. Tobias & T. M. Duffy (Eds.), *Constructivist theory applied to instruction: Success or failure?* (pp. 291–310). New York, NY: Taylor & Francis.

Leman, P. J. (2015). How do groups work? Age differences in performance and the social outcomes of peer collaboration. *Cognitive Science*, *39*, 804–820. doi:10.1111/cogs.12172

Mayer, R. E. (2004). Should there be a three-strikes rule against pure discovery learning? The case for guided methods of instruction. *American Psychologist*, *59*, 14–19.

Miyake, N., & Kirschner, P. A. (2014). The social and interactive dimensions of collaborative learning. In R. K. Sawyer (Ed.), *The Cambridge handbook of the learning sciences* (2nd ed., pp. 418–438). New York, NY: Cambridge University Press.

National Academy of Sciences, National Academy of Engineering, and Institute of Medicine. (2005). *Facilitating interdisciplinary research*. Washington, DC: The National Academies Press. doi:10.17226/11153.

National Academy of Sciences, National Academy of Engineering, and Institute of Medicine. (2018). *How people learn II: Learners, contexts, and cultures*. Washington, DC: The National Academies Press. doi:10.17226/24783

National Science Foundation Directorate for Social, Behavioral, and Economic Sciences. (2011). *Rebuilding the mosaic: Fostering research in the social, behavioral, and economic sciences at the National Science Foundation in the next decade*. Arlington, VA: National Science Foundation. Retrieved from https://www.nsf.gov/pubs/2011/nsf11086/nsf11086.pdf

Reyna, V. F., Chapman, S. B., Dougherty, M. R., & Confrey, J. (2012). *The adolescent brain: Learning, reasoning, and decision making*. Washington, DC: American Psychological Association.

Robbins, P., & Aydede, M. (2009). A short primer on situated cognition. In P. Robbins & M. Aydede (Eds.), *The Cambridge handbook of situated cognition* (pp. 3–10). New York, NY: Cambridge University Press.

Sawyer, R. K. (2014). *The Cambridge handbook of the learning sciences* (2nd ed.). New York, NY: Cambridge University Press.

Social and Behavioral Science Team Annual Report. (2016). Washington, DC: Executive Office of the President, National Science and Technology Council. Retrieved from https://sbst.gov/download/2016%20SBST%20Annual%20Report.pdf

Tomasello, M. (1999). *The cultural origins of human cognition*. Cambridge, MA: Harvard University Press.

Wirkala, C., & Kuhn, D. (2011). Problem-based learning in K-12 education: Is it effective and how does it achieve its effects? *American Educational Research Journal*, *48*, 1157–1186.