Scaffolding in educational video games: An approach to teaching collaborative support skills

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***Abstract*—Because collaboration plays a key role in today's society, it is beneficial to prepare people at a young age for collaborative work. However, there is no academic or professional consensus on the most effective approach. To remedy this shortcoming, our research will expand on one promising method: the incorporation of collaborative scaffolding into collaborative educational video games. Although there will be several challenges, we have already made progress through the development of a multilevel taxonomy of collaboration to aid our evaluation approach. Our findings will bring academics and educators one step closer to developing methodology for the seamless integration of 21st century skills, such as collaboration and technological proficiency, into today's classroom curricula. In addition, researchers can utilize our taxonomy to more easily identify aspects of collaboration relevant to their interests, and educators can use the taxonomy to help identify collaborative skills that students lack.**

***Keywords*—computer aided instruction, electronic learning, curriculum development, career development, collaboration**

I. Introduction

21st Century Skills [1], such as collaboration and technological proficiency, are necessary in today's ever connected world, yet there remains a lack of insight into best practices when it comes to teaching collaborative skills. One option is to embed collaboration into activities, either explicitly through team formation or implicitly by assigning a goal impossible to achieve alone. A major advantage to this methodology is its seamless integration into existing curricula; there is no need to take time away from teaching traditional topics because everything is imparted concurrently. However, without explicit guidance, there is no guarantee that group members encounter and ingrain the necessary collaborative skills. Another approach is to create activities aimed purely at teaching and encouraging collaboration. In this case, potential frustration from a lack of academic understanding will not interfere with the collaborative process, but classtime must be set aside.

Although the value of collaboration has been known for some time [2], [3], technology's rapid evolution requires us to reexamine methodologies to collaboration education. An approach not yet explored is the incorporation of collaborative scaffolding into educational video games. Aside from educational benefits [4]–[6], such games have already been shown to have positive effects, such as an increase in motivation to learn [8] and improvement in self-efficacy and self-esteem [7]. Through collaborative play in particular, children have shown an increase in collaborative behaviors [9], [10], such as sharing [11], and a decrease in aggression [9]. The addition of specialized scaffolding allows educators to leverage the inherent benefits of collaborative educational games and facilitates the parallel teaching of collaboration and traditional topics.

To examine the impact of collaborative scaffolding, we built a collaborative multiplayer game and developed a pre-post study design. Through the process of creation, we encountered and predicted several challenges associated with developing study-specific technology, working with children, and running on-sight trials. To identify a focus for our evaluation, we performed an analysis of over 25 existing studies and surveys to identify the components of collaboration. We chose two facets from the resulting multilevel taxonomy for our study: performing part of a task for a group member (direct helping) and providing guidance to a group member (indirect helping). Moving forward, we plan to iterate on our materials, finalize our study design, and flesh out our data analysis so that we can examine the impact collaborative scaffolding has on these behaviors both during and after play. Aside form aiding our own work, the taxonomy can help researchers pinpoint aspects of collaboration relevant to their interests, and it can help educators identify collaborative skills that students lack.

II. Definitions

A. Collaboration

The concept of *collaboration* is not well defined in literature, and is often referenced in conjunction with *cooperation* and *teamwork*. Some researchers make an effort to distinguish between these terms [12]–[22], while others use them interchangeably [9], [23], [24]. The popularity of each term depends largely on the area of study; computer science favors *collaboration*, most prominently in the areas of Computer Supported Collaborative Learning (CSCL) [14], [15], [21], [23] and Computer Supported Collaborative Work (CSCW) [13], while *cooperation* dominates the field of psychology [3], [9], [11], [25]–[28] and *teamwork* is featured in the industry [2], [12], [29], [30] and military [19], [31] sectors.

Some researchers define collaboration by its behaviors and skills, which in turn are often defined themselves [12], [18], [32], while others define collaboration as an activity [20], [28], [33] or a context [25], [27], [34]. We developed our own definition, taking most of our wording from Roschelle and Teasley [20] and Ryan and Wheeler [27]:

> Collaboration is the mutual engagement of participants, whose goals are interdependent and positively correlated, in a coordinated effort to complete a task.

For the purposes of our work on collaborative scaffolding in educational video games, *participants* will be the children who establish a *mutual engagement* among themselves, and *coordinated effort* will refer to their self-organized approach. Because the goal of each player on a team is for the whole team to win, player goals will be *positively correlated*.

B. Helping Behaviors

The concept of a helping behavior is closely tied to backup behavior. According to Porter et al. [29], *backup behavior* is help that occurs when "it is apparent that [a] team member is failing to reach those goals [defined by his or her role]," while *helping behavior* occurs when help is not strictly necessary. Our helping behavior definition is based on Porter et al.'s backup behavior definition, sans dependence on need:

> A helping behavior can be described as the provision of resources and task-related effort to a group member intended to help that member contribute to task completion.

In contrast to Porter et al., Marks et al. base their definition of backup behavior on Dickinson and McIntyre's [35] work and define it as occurring when "(1) providing a teammate verbal feedback or coaching, (2) helping a teammate behaviorally in carrying out actions, or (3) assuming and completing a task for a teammate" [36]. Although Marks et al. call these backup behaviors, they also qualify as helping behaviors under Porter et al.'s definitions. We use two of Marks et al.'s backup behaviors as a focal point for our research on collaborative scaffolding: performing part of a task for someone (assuming and completing a task for a teammate) and providing guidance (providing a teammate verbal feedback or coaching).

C. Scaffolding

Wood et al. coined the term *scaffolding*, meaning a "process that enables a child or novice to solve a problem, carry out a task or achieve a goal which would be beyond his unassisted efforts." [37] They went on to identify six scaffolding functions that we incorporated into our collaborative scaffolding design: recruitment, reduction in degrees of freedom, direct maintenance, marking critical features, frustration control, and demonstration. As a form of direct maintenance and frustration control, our collaborative scaffolding system mentions the benefits of collaboration to players when they are stumped. To mark critical features, the system directs student attention when collaboration becomes a necessity. Because the scaffolding system is limited by the game in which it resides, Wood et al.'s other functions are more relevant to the educational game itself, which has its own educational and game scaffolding. The game's contents entice potential players (recruitment) and technology restrictions limit player input channels (reduction in degrees of freedom). In addition, mechanics are gradually introduced (direct maintenance), the difficulty level can be fine-tuned (frustration control), and in-game highlights and dialog guide the player (marking critical features).

III. Related Work

A. Collaboration among children

Since our research focuses on middle school children, it is important to understand the relationship between kids and collaboration. Studies show that young girls perform better in a collaborative environment than in a competitive one, while boys perform equally well in both [38], [39]. In addition, a collaborative classroom goal structure, when compared to a competitive one, leads to higher achievement, greater acceptance among group members, and more positive attitudes towards tasks and teachers [40]. It is also better at promoting critical thinking competency, motivating further exploration into the educational subject, and encouraging positive expectations of future inter-student interactions [41]. Even at the undergraduate level, a collaborative structure leads to groups that show more subdivision of activity, attentiveness to fellow members, and friendliness during discussions [25]. Facilitating an effective collaborative environment requires child proficiency in collaborative skills, which we aim to teach and encourage through our collaborative scaffolding system.

Aside from environment, research has also been done on comparing collaborative and competitive tasks. Ryan and Wheeler [27] found that fifth and sixth grade students given collaborative, rather than competitive, lessons exhibited more collaborative tendencies during post-lesson game play. These tendencies came in four categories: seeking help for one another, positively responding to help sought, volunteering help for others, and establishing group strategies for sharing resources with individuals in need. In our exploration of collaborative scaffolding, we are also interested in the retention of helping skills, although we distinguish categories by the help itself instead of its initiation. Moreover, rather than compare the effects of a collaborative vs. a competitive task, we concentrate on collaborative vs. neutral scaffolding during in-game collaborative missions.

B. Scaffolding

Effective scaffolding systems often incorporate the concept of *fading*: "once the learner has a gasp of the target skill, the master reduces his participation (fades), providing only limited hints, refinements, and feedback to the learner, who practices by successively approximating smooth execution of the whole skill" [42]. To this end, our system tracks player input and in-game events to identify when collaboration is advantageous but overlooked. Ideally, as players progress they begin to identify collaboration opportunities on their own. In turn, our system limits its presence to avoid providing unnecessary information. In addition to fading, we incorporate all relevant scaffolding strategies from Quintana et al.'s [43] guidelines into our scaffolding design: (1c) Embed expert guidance to help learners use and apply science content, (2a) Make disciplinary strategies explicit in learners' interactions with the tool, (5a) Embed expert guidance to clarify characteristics of scientific practices, and (5b) Embed expert guidance to indicate the rationales for scientific practices.

Traditional scaffolding systems tend to address educational topics like math and science. Research has also been done on collaborative scaffolding in general [44] and topics related to collaboration, such as exploratory talk [45], [46] and reaching

group consensus [47]. However, little of it addresses helping behaviors in particular, which is the focus of our work.

IV. Study Design

A. Focus

To inform our exploration into the impact of collaborative scaffolding in educational video games, we developed a research question based on two dyads. The first dyad is setting. Our main interest is collaboration in a classroom context, but we also aim to explore the impact of collaborative scaffolding as it appears in real time during video game play. The second dyad is type of help. We chose to concentrate on direct and indirect helping to keep our scope broad but realistic. These focal points result in the following research topic:

> Does collaborative scaffolding in an educational video game promote more instances of performing part of a task for a group member (direct helping) and providing guidance to a group member (indirect helping) than non-collaborative neutral scaffolding in the context of the game and a collaborative classroom activity?

B. Procedure

To explore collaborative scaffolding, we modified Singapore-MIT GAMBIT Game Lab's *Waker* (http://gambit.mit.edu/loadgame/waker.php), a 2009 action-puzzle Flash game that teaches displacement and velocity. We chose this game because of its light-weight nature, educational content, and potential for rapid modification. Since the game was originally single-player, we altered the code to allow simultaneous play, developed new corresponding levels, and implemented a collaborative scaffolding system.

Our mixed-factorial study design meant that we needed to create two versions of content for the scaffolding. For the treatment group, we will have collaborative scaffolding with statements such as "Remember each of your abilities, and use them to help each other." and "Sometimes things are easier to do together." We can think of these phrases as positive, in line with scaffolding's formal definition. Scaffolding can also be neutral or even negative. In the context of an educational video game, neutral collaborative scaffolding would include statements that neither help nor hinder players, including "It must have taken a long time to build this place." and "It sure is bright outside." We will use this type of scaffolding for our control group. Negative collaborative scaffolding hinders people with statements such as "You don't need anyone's help." and "Working with others is a waste of time." We chose not to use this type of scaffolding in our study.

During each trial, students will start by taking a short pretest that covers their collaborative experiences and attitudes towards collaboration, as well as their knowledge of the topics that the game will teach. They will then split into small groups and perform a simple collaborative classroom activity during which we will take note of any direct or indirect helping. To collect data during the activity, we will use audio recorders and several observers. After the activity, students will break into two groups: the control and the treatment. Students in each group will form pairs and play the appropriate version of the game before filling out a short questionnaire on engagement and motivation. They will disperse into small groups to perform another group activity, after which students will fill out a post-test once again pertaining to collaboration and knowledge of the subject area.

V. Challenges

Although our research on the effects of collaborative scaffolding in educational video games will contribute both to academics and educators, there were considerations and concerns that needed to be addressed as we developed our system and that still need to be addressed as we finalize our study design. For example, in determining an appropriate game, it was important to remember that just because an activity appears collaborative does not mean it lacks implicit incentives for competition. In the workplace, two employees with similar jobs may work on the same project but try to discredit each other because of an upcoming job opening in management. In the classroom, a teacher may try to encourage collaborative skills by randomly assigning groups for a project, but group members may compete to look better by requesting the least help or finishing their part first. Actively avoiding help and rushing to finish a task can easily lead to subpar results. The teacher may choose to have students always work in the same groups to avoid such a case, but they will not gain experience in dealing with different types of people.

Technological challenges existed beyond the collaborative nature of the game. When using school computers, reliable internet access and computer permissions for installing software are not guaranteed. We developed a stand-alone Flash game for our trials because it will not need to be installed, and we will be able to store all logging locally to avoid potential issues with the internet. We also had to carefully approach our design of the scaffolding content and levels. Because the game is collaborative, students of varying gaming experience and learning abilities will share challenges and scaffolding feedback. This imbalance will potentially prevent group members from maintaining a state of *flow*: "the state in which people are so involved in an activity that nothing else seems to matter; the experience itself is so enjoyable that people will do it even at great cost, for the sheer sake of doing it" [48]. If the levels are too easy, players will get bored, but if the scaffolding is not helpful enough, players will get frustrated and may give up. To help ensure that our system will maintain an adequate balance, we will perform preliminary testing and iterate on its design.

The logistics of running our trials will also pose challenges. Because we will be working with children, they will need additional privacy protection. To this end, we will limit our data collection to computer logging, audio recording, and direct observation to avoid storing video records. In addition, we will not refer to students by name, and all data will be anonymized before analysis.

Running trials on-site at local middle schools and after-school programs will also have implicit challenges. Recruitment opportunities will be limited by the number of schools in the surrounding area due to the logistical limitations of performing trials far away. Scheduling will also be a major concern; we will need to work around holidays, standardized

testing days, and exams, as well as periods of inactivity, such as the summer break between academic years. Another timing concern will be within the trial itself, as class length and meeting times vary among schools and programs. Often they are too short to run an extensive session, but splitting a trail into multiple days leads to lost data due to student absences. For our work in particular, curriculum timing will also have an impact. If students have just covered the academic topic our game teaches, then they will have little need for the scaffolding, as the game will be too easy.

Although we have addressed many of the challenges thus far, there remain several unanswered questions we must tackle in the near future, including:

- How should we word instructions to participants?
- How does raw in-game data correspond to helping behaviors?
- What contingencies must we implement to account for real-world imperfections during trials, such as computer errors?

VI. Evaluation

Collaboration is a broad and vague notion, yet our focus on the impact of collaborative scaffolding requires a method of evaluation. To deconstruct the concept and determine a focal point, we analyzed over 25 existing studies and surveys from a wide range of disciplines and with diverse target demographics. The resulting multilevel taxonomy is split into four components, each consisting of additional subcomponents.

The first component in our taxonomy is *group quality*: group aspects indirectly related to task completion. Even if group members are highly intelligent and capable of performing necessary functions, if members feel isolated, lack motivation, or simply do not get along, then group performance suffers. For example, when a conflict arises, ineffective conflict resolution can lead to a prolonged period of time wasted on overcoming the dispute rather than completing the task.

The next component is *coordination*: the methods that groups use to organize group members and their actions. Without coordination, a team cannot effectively distribute subtasks to maximize group performance, nor is it trivial to respond to environmental changes.

Coordination is usually achieved through effective *communication*. While this component does not encompass task-specific content, such as strategies, it does include considerations before message sending, apt response to message reception, and the appropriateness of message content. Without adequate communication skills, group members cannot articulate thoughts and opinions, which inhibits the ability to form a shared mental model and prevents the creation of an optimal strategy based on the informed opinions of group members.

The final component of collaboration is *support*: group members helping each other complete a task, satisfy a role, take on a responsibility, or understand a concept. The quality of support is based on many factors, including an individual's willingness, time, resources, and ability to help, as well as a person's understanding of the tasks assigned to groupmates. Without support, group members cannot build off of each other's experiences and knowledge, meaning time is wasted learning without a teacher or mentor and re-developing solutions for obstacles overcome in the past.

For our evaluation, we chose to focus on two subcomponents of support: direct and indirect help. *Direct help* involves explicit aid through the supply of instructions, an explanation of what to do next, or the partial or total completion of a task assigned to another group member. *Indirect help* occurs through resource sharing or by providing guidance, education, structure, suggestions, advice, or constructive feedback. Instead of keeping these subcomponents vague, we selected an example of each to use in our study: performing part of a task for a group member (direct helping) and providing guidance to a group member (indirect helping). In our trials, we will count instances and note interesting examples of these actions during group activities and video game play.

VII. Implications

Because collaboration plays a key role in today's society, it is beneficial to prepare people at a young age for collaborative work. However, there is no academic or professional consensus on the most effective methodology. Through our research, we will explore one promising option: collaborative scaffolding in educational video games. No matter the results, we will gain invaluable insight into how we can approach collaboration education, which we will encompass in future design guidelines. Our work will help shape the collaboration education design space through its application to future software products and research. In addition, it will contribute to the validation of video games as an area of study and as an educational tool.

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References

[1] "Partnership for 21st century skills," http://www.p21.org/, accessed: 2014-02-13.

[2] G. M. Parker, *Team Players and Teamwork: New Strategies for Developing Successful Collaboration*. John Wiley & Sons, 2008.

[3] R. E. Slavin, "Cooperative learning," *Rev. educational res.*, vol. 50, no. 2, pp. 315–342, 1980.

[4] M. S. Khine, *Learning to Play: Exploring the Future of Education with Video Games*, ser. New Literacies and Digital Epistemologies. Peter Lang, 2011, vol. 53.

[5] M. J. Mayo, "Video games: A route to large-scale stem education?" *Sci.*, vol. 323, no. 5910, pp. 79–82, 2009.

[6] J. P. Gee, *What Video Games Have to Teach Us About Learning and Literacy*. Macmillan, 2014.

[7] J. L. Plass, R. Goldman, M. Flanagan, and K. Perlin, "RAPUNSEL: Improving self-efficacy and self-esteem with an educational computer game," in *Proc. 17th Int. Conf. Comput. in Educ.*, 2009, pp. 682–689.

[8] R. Rosas *et al.*, "Beyond Nintendo: design and assessment of educational video games for first and second grade students," *Comput. & Educ.*, vol. 40, no. 1, pp. 71–94, 2003.

[9] A. K. Bay-Hinitz, R. F. Peterson, and H. R. Quilitch, "Cooperative games: A way to modify aggressive and cooperative behaviors in young children," *J. Appl. Behavior Anal.*, vol. 27, no. 3, pp. 435–446, 1994.

[10] T. Orlick, J. McNally, and T. OHara, "Cooperative games: Systematic analysis and cooperative impact," in *Psychological Perspectives in Youth Sports*, F. L. Smoll and R. E. Smith, Eds., 1978, pp. 126–135.

[11] T. D. Orlick, "Positive socialization via cooperative games." *Developmental Psychol.*, vol. 17, no. 4, pp. 426–429, 1981.

[12] D. P. Baker, E. Salas, H. King, J. Battles, and P. Barach, "The role of teamwork in the professional education of physicians: Current status and assessment recommendations," *Joint Commission J. Quality and Patient Safety*, vol. 31, no. 4, pp. 185–202, 2005.

[13] B. Barros and M. F. Verdejo, "An approach to analyse collaboration when shared structured workspaces are used for carrying out group learning processes," in *Proc. 1st Int. Conf. Artificial Intell. in Educ.* IOS Press, 1999.

[14] C. A. Collazos, L. A. Guerrero, J. A. Pino, and S. F. Ochoa, "Improving the use of strategies in computer-supported collaborative processes," in *Groupware: Design, Implementation, and Use*, ser. Lecture Notes in Computer Science. Springer, 2003, vol. 2806, pp. 247–260.

[15] C. A. Collazos *et al.*, "Evaluating collaborative learning processes using system-based measurement," *Educational Technol. & Soc.*, vol. 10, no. 3, pp. 257–274, 2007.

[16] R. Flin *et al.*, "Development of the NOTECHS (non-technical skills) system for assessing pilots' CRM skills," *Human Factors and Aerospace Safety*, vol. 3, no. 2, pp. 95–117, 2003.

[17] B. B. Morgan Jr, A. S. Glickman, E. A. Woodard, A. S. Blaiwes, and E. Salas, "Measurement of team behaviors in a navy environment," Defense Technical Information Center, Tech. Rep., 1986.

[18] J. A. Olmstead, "Battle staff integration," Defense Technical Information Center, Tech. Rep., 1992.

[19] R. L. Oser, G. McCallum, E. Salas, and B. B. Morgan Jr, "Toward a definition of teamwork: An analysis of critical team behaviors," Defense Technical Information Center, Tech. Rep., 1989.

[20] J. Roschelle and S. D. Teasley, "The construction of shared knowledge in collaborative problem solving," in *Comput. Supported Collaborative Learning*, ser. NATO ASI Series F: Computer and Systems Sciences, C. O'Malley, Ed., 1995, vol. 128, pp. 69–97.

[21] A. Soller, B. Goodman, F. Linton, and R. Gaimari, "Promoting effective peer interaction in an intelligent collaborative learning system," in *Intelligent Tutoring Syst.*, ser. Lecture Notes in Computer Science, 1998, vol. 1452, pp. 186–195.

[22] C. Zsambok, G. Klein, M. Kyne, and D. Klinger, "How teams excel: A model of advanced team decision making," in *Proc. 1993 Nat. Soc. for Performance and Instruction Conf.*, 1993, pp. 135–145.

[23] C. A. Collazos, L. A. Guerrero, J. A. Pino, and S. F. Ochoa, "A method for evaluating computer-supported collaborative learning processes," *Int. J. Comput. Applicat. in Technol.*, vol. 19, no. 3, pp. 151–161, 2004.

[24] L. A. Guerrero, R. Alarcón, C. Collazos, J. A. Pino, and D. A. Fuller, "Evaluating cooperation in group work," in *Proc. 6th Int. Workshop Groupware at 6th Int. Conf. Collaboration and Technol.* IEEE Publishing, 2000, pp. 28–35.

[25] M. Deutsch, "The effects of cooperation and competition upon group process," Ph.D. dissertation, Massachusetts Institute of Technology, 1948.

[26] C. E. Rosen, "The effects of sociodramatic play on problem-solving behavior among culturally disadvantaged preschool children," *Child Develop.*, vol. 45, no. 4, pp. 920–927, 1974.

[27] F. L. Ryan and R. Wheeler, "The effects of cooperative and competitive background experiences of students on the play of a simulation game," *J. Educational Res.*, vol. 70, no. 6, pp. 295–299, 1977.

[28] J. A. Wagner, "Studies of individualism-collectivism: Effects on cooperation in groups," *Academy Manage. J.*, vol. 38, no. 1, pp. 152–173, 1995.

[29] C. O. L. H. Porter *et al.*, "Backing up behaviors in teams: The role of personality and legitimacy of need." *J. Appl. Psychol.*, vol. 88, no. 3, pp. 391–403, 2003.

[30] E. J. Thomas, J. B. Sexton, and R. L. Helmreich, "Translating teamwork behaviours from aviation to healthcare: development of behavioural markers for neonatal resuscitation," *Quality and Safety in Health Care*, vol. 13, no. suppl 1, pp. i57–i64, 2004.

[31] R. M. McIntyre and T. L. Dickinson, *Systematic Assessment of Teamwork Processes in Tactical Environments*. Department of Psychology, 1992.

[32] G. Fletcher *et al.*, "Anaesthetists' non-technical skills (ANTS): evaluation of a behavioural marker system," *Brit. J. Anaesthesia*, vol. 90, no. 5, pp. 580–588, 2003.

[33] S. D. Teasley and J. Roschelle, "Constructing a joint problem space: The computer as a tool for sharing knowledge," in *Comput. as Cognitive Tools*, S. P. Lajoie, Ed. Routledge, 1993, pp. 229–258.

[34] M. Garaigordobil, C. Maganto, and J. Etxeberría, "Effects of a cooperative game program on socio-affective relations and group cooperation capacity." *Eur. J. Psychological Assessment*, vol. 12, no. 2, pp. 141–152, 1996.

[35] T. L. Dickinson and R. M. McIntyre, "A conceptual framework for teamwork measurement," in *Team Performance Assessment and Measurement: Theory, Methods, and Applicat.*, M. T. Brannick, E. Salas, and C. W. Prince, Eds. Psychology Press, 1997, pp. 19–43.

[36] M. A. Marks, J. E. Mathieu, and S. J. Zaccaro, "A temporally based framework and taxonomy of team processes," *Academy Manage. Rev.*, vol. 26, no. 3, pp. 356–376, 2001.

[37] D. Wood, J. S. Bruner, and G. Ross, "The role of tutoring in problem solving," *J. Child Psychol. and Psychiat.*, vol. 17, no. 2, pp. 89–100, 1976.

[38] K. Inkpen, K. S. Booth, M. Klawe, and R. Upitis, "Playing together beats playing apart, especially for girls," in *Proc. 1st Int. Conf. Comput. Support for Collaborative Learning*. L. Erlbaum Associates Inc., 1995, pp. 177–181.

[39] J. Goldstein and S. Puntambekar, "The brink of change: Gender in technology-rich collaborative learning environments," *J. Sci. Educ. and Technol.*, vol. 13, no. 4, pp. 505–522, 2004.

[40] D. W. Johnson and R. T. Johnson, "Instructional goal structure: Cooperative, competitive, or individualistic." *Rev. Educational Res.*, vol. 44, no. 2, 1974.

[41] ——, "The socialization and achievement crisis: Are cooperative learning experiences the solution?" *Appl. Soc. Psychol. Annu.*, vol. 4, pp. 119–164, 1983.

[42] A. Collins, J. S. Brown, and S. E. Newman, "Cognitive apprenticeship: Teaching the crafts of reading, writing, and mathematics," Defense Technical Information Center, Tech. Rep., 1986.

[43] C. Quintana *et al.*, "A scaffolding design framework for software to support science inquiry," *J. Learning Sciences*, vol. 13, no. 3, pp. 337–386, 2004.

[44] J. Zumbach, J. Schönemann, and P. Reimann, "Analyzing and supporting collaboration in cooperative computer-mediated communication," in *Proc. 2005 Int. Conf. Computer-Supported Collaborative Learning*. International Society of the Learning Sciences, 2005, pp. 758–767.

[45] J. O'Connor, L. Kerawalla, and R. Luckin, "Using discussion prompts to scaffold parent-child collaboration around a computer-based activity," in *Artificial Intell. in Education: Supporting Learning Through Intelligent and Socially Informed Technol.*, ser. Frontiers in Artificial Intelligence and Applications, C.-K. Looi, Ed. IOS Press, 2005, vol. 125, pp. 176–183.

[46] S. Rojas-Drummond and N. Mercer, "Scaffolding the development of effective collaboration and learning," *Int. J. Educational Res.*, vol. 39, no. 1, pp. 99–111, 2003.

[47] M. Nussbaum *et al.*, "Technology as small group face-to-face collaborative scaffolding," *Comput. & Educ.*, vol. 52, no. 1, pp. 147–153, 2009.

[48] M. Csikszentmihalyi, *Flow: The Psychology of Optimal Experience*. Harper & Row, 1990.