COLLABORATIVE PROBLEM SOLVING IN SHARED SPACE

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ABSTRACT

The purpose of this study was to examine collaborative problem solving in a shared virtual space. The main question asked was: How will the performance and processes differ between collaborative problem solvers and independent problem solvers over time? A total of 104 university students (63 female and 41 male) participated in an experimental study. Participants were randomly assigned to four different experimental groups: individual & multi-tasking, collaborative & multi-tasking, individual & single-tasking, and collaborative & single-tasking. Results showed that the participants who collaborated and had multi-tasking activities outperformed the others. Additionally, collaboration helped to improve overall performance over time. The study offers insights for collaborative learning from both theoretical and methodological perspectives.

KEYWORDS

Collaborative learning, shared space, split attention, multi-tasking

1. INTRODUCTION

The collaborative learning has been defined as an instructional method that allows pairs or small groups of students to work together towards a common goal (Gokhale, 1995). "Collaborative learning" has been reviewed for the potential to enhance active exchange, critical thinking, and achievement (Johnson and Johnson, 1986; Totten et al, 1991). However, complex technology-mediated communications environments, increasingly employed for collaborative learning, is also thought to pose challenges for students who must split attention and engage in media-induced task switching (Rosen et al, 2013). Closer examination of the constructs within complex environments for shared space has been suggested as the key to understanding the role of the computer for effective learning collaborations in technology-mediated, virtual shared spaces (Roschelle and Teasley, 1995). Therefore, the present experimental study examines a complex, technology-based problem-solving setting for the effect on students' problem solving while participating in collaborative learning in collaborative multi-tasking and independent single-tasking modes.

2. CONCEPTUAL RATIONALE

2.1 Collaborative Learning in Context

Collaboration can be viewed as a process by which we negotiate and share meanings relevant to problem solving (Roschelle and Teasley, 1995). In the broadest terms, collaborative learning is a situation in which two or more people learn or attempt to learn something together (Dillenbourg, 1999). Kaye (2012) characterizes collaborative learning as being a secondary outcome of a task-oriented activity. However, collaboration for learning does not necessarily take place simply because students are co-present (Roschelle and Teasley, 1995; good collaborative practice will depend on the development of reciprocity and cooperation among students (Chickering and Ehrmann, 1996).

Increasingly, communications technologies provide both synchronous and asynchronous technology tools that support a more abstract view of collaborative, active learning. Technology-mediated collaborative learning extends collaborative learning beyond face-to-face environments (Alavi and Dufner, 2005) and going beyond that, supporting the flexible learning paradigms that were once dependent almost solely on email and computer conferencing (Collis and Moonen, 2001). Computer-mediated communications for new learning paradigms are also associated with shifting philosophical foundations, from objectivist to constructivist views, in fields of learning theory and instructional design (Jonassen et al, 1995). Bruffee (1999) points out that collaborative learning in higher education is creating a need for a reexamination of the role of the existing assumptions regarding knowledge, authority, and institutions within a social construction framework. Gokhale (1995) posits that collaborative learning is most effective when the primary objective of a teacher is not transmission of information but rather the development of a students' ability to learn.

2.2 Collaboration for Problem Solving

"Collaboration is a coordinated, synchronous activity that is the result of a continued attempt to construct and maintain a shared conception of a problem," (Roschelle and Teasley, 1995 pp.70). *Talk* is the primary resource in the process, allowing the production of shared knowledge, divergent understandings, and resolution of problem-solving impediments (Roschelle and Teasley, 1995) by the use of constructive dialog. Collaboration in problem solving is thought to promote creative thinking skills and to reduce problem-solving anxiety (Gokhale, 1995). Coordination is essential to problem solving. Barron (2000) conducted a study to describe the types of interaction that promote coordination. He attributed differences in the performance of problem solving to the degree to which collaborators will have 1) shared task alignment, 2) joint attention for solution, and 3) a mutuality and reciprocity of contribution.

Within the larger framework of goals in education, the skill set required to participate in teamwork and solve problems collaboratively is considered a precondition for success in many learning and working contexts (National Council of Teachers of Mathematics, 1989; National Research Council, 1996; Rummel and Spada, 2005). The ability to define and solve problems is a highly valued skill in the knowledge-based, interdisciplinary, and distributed work of today (Barron, 2000).

2.3 Virtual Shared Space

The place of learning, no longer limited to a surrounding or local space, is uniquely defined for technology-supported collaboration. Resta and Laferrière (2007) characterize collaborative learning as being a complex concept often implemented in technology-supported virtual workspaces. Stahl et al (2006) examined the complexity of computer support and collaborative learning that utilize a collaborative communication channel bridging time and space. Wegerif (2006, p.156) recognized changing patterns in contemporary work and life practices, such as student participation in online dialog in spaces of reflection. Teasley and Roschelle (1995) suggest that collaborative problem solving enables students to construct a shared conceptual structure or *joint problem space*. A joint problem space, which provides the benefits of computer-supported collaboration in a meditational framework, is dependent upon participant sharing of: 1) a common language, 2) a common situation, and 3) a joint activity (Teasley and Roschelle, 1995).

2.4 The Current Study

With the current study, we hope to obtain a better understanding of collaborative problem solving in a complex setting. In this regard, the first aim was to determine the degree to which the perception of collaboration will develop over time. We assume that collaboration will increase over the course of learning (Hypothesis 1). The second aim was to empirically document the degree to which collaboration would influence students' performance. We assume that collaboration is positively related to the overall problem solving performance (Hypothesis 2).

3. METHODS

3.1 Participants

Study participants, *N* = 104, were university students (63 female and 41 male), who were enrolled in an intermediate-level teacher education course. Their mean age was 23.49 years (*SD* = 4.22).

3.2 Materials and Instruments

The current experiment had students solve analytical reasoning (AR) problem tasks that are samples of Graduate Record Exam (GRE) problems. As shown in Table 1 below, AR problems require an understanding of a given structure of arbitrary situational relationships for subsequent deduction of new information from the given relationships for constraint-satisfaction (Kaufman et al., 2001). The AR problem questions were assigned a difficulty rating, on a scale of 1 to 6, where 1 = least difficult and 6 = most difficult, based on guidelines for analysis of content characteristics to the difficulty and discrimination of GRE problems (Chalifour and Powers, 1989).

Table 1. Two examples of sample GRE reasoning tasks from lowest and highest difficulty levels, and solutions

Task	Example	Solution
T_d1	Four of the following five are similar in a definite way and so form a group. Which one of them does not belong to the group? A. Umbrella B. Gloves C. Shirt D. Shoes E. Cap	A. Umbrella
T_d6	A pesticide producing company states that their unused pesticide that gets dumped does not pose a threat to the aquatic life in the surrounding area. If this is correct, then why have local fish been dying in this region? Due to the fact that the pesticide company is not located in a highly fish-populated area, they implicitly admit that the pesticides they produce are relatively dangerous to the nearby aquatic life. Of the following statements listed below, which one would be most likely to weaken the argument of the author if it were true? A. The possibility of pesticides filtering into the local water region was underestimated in the past. B. Funds for environmental company cleanup, which concern waste dumps that are poorly run, are reserved for rural regions only. C. It would be pointless to locate chemical dumps where they would be most harmful, unless they can be proven 100-percent safe. D. Dumps that are located in areas without large fish populations have fewer government interventions and are also less expensive. E. City people are most probable to sue the company if the dumps cause them health problems.	D. Dumps that are located in areas without large fish populations have fewer government interventions and are also less expensive.

Multiple instruments were administered to test participants' pre-dispositions and changes of dispositions over time. These include the following: 1) Verbal ability test (*r* = .96; split-half reliability; Amthauer et al, 2001); 2) Multi-tasking preference inventory or the Inventory of Polychronic Values (IPV; Bluedorn et al, 1999). The IPV has 10 items measured on a 7-point Likert response scale (anchored from *strongly disagree* to *strongly agree*) with higher values indicating a more polychronic or multi-tasking attitude. Conte et al (1999) reported Cronbach's alpha=.822 and higher as evidence for construct validity for this instrument. The retest–reliability coefficient over a 2-month interval is .78 (Conte and Jacobs, 2003); 3) Integrated communication technology learning (15 items, Cronbach's alpha = .605); 4) Formal-to-informal learning scale (12 items, Cronbach's alpha = .695; Author, 2014); 5) Technology affinity scale (22 items, Cronbach's alpha = .624; Author, 2013; and 6) Confidence, effort, motivation, collaboration, tools, and strategy inventory (5 items, Cronbach's alpha = .692).

3.3 Analysis

Initial verbal ability and multi-tasking preference scores were calculated for each student. Each participant's task solution scores were determined at each measurement point. Additional measures were also calculated, including confidence in accuracy of the solution, level of motivation, the problem-solving strategy applied, an estimated of time on task, the estimated degree of collaboration, and the method of collaboration.

4. RESULS

4.1 Development of Collaboration

We computed a repeated-measure MANOVA with the *intensity of collaboration* at five measurement points as a within-subjects factor, and *experimental groups* (CMT, CST) as a between-subjects factor. MANOVA revealed a significant main effect of time on intensity of collaboration, Wilks' Lamda = .782, $F(4, 47) = 3.28$, $p < .05$, $\eta^2 = .218$, and for time x group, Wilks' Lamda = .771, $F(4, 47) = 3.49$, $p < .05$, $\eta^2 = .229$. The sphericity assumption was met ($\chi^2(9) = 11.45$, $p = .25$). The difference between measurements was significant, $F(4, 200) = 2.43$, $p < .05$, $\eta^2 = .046$.

A pairwise comparison of intensity of collaboration at each measurement point (MP) indicated significant differences between experimental groups as follows: MP2, $t(50) = 3.61$, $p < .001$, $d = 1.00$; MP4, $t(50) = 3.17$, $p < .01$, $d = .88$; MP5, $t(50) = 4.64$, $p < .001$, $d = 1.29$ (see Table 2 for descriptive statistics).

Table 2. Means (standard deviations in parentheses) of intensity of collaboration over time

Exp. group	Measurement point				
	MP1	MP2	MP3	MP4	MP5
CMT (n = 26)	4.08 (2.17)	6.19 (2.06)	5.15 (2.03)	5.77 (2.63)	5.54 (1.96)
CST (n = 26)	3.92 (1.77)	4.15 (2.01)	4.19 (1.96)	3.62 (2.26)	3.12 (1.80)

Note. CMT: collaborative & multi-tasking; CST: collaborative & single-tasking

Further, we found a significant interaction effect of time and group on the intensity of collaboration, $F(4, 200) = 2.88$, $p < .05$, $\eta^2 = .054$. Figure 1 shows the interaction effect on the intensity of collaboration. To sum up, results showed that the participants who were confronted with multi-tasking activities outperformed the others. Accordingly, we accept Hypothesis 1.

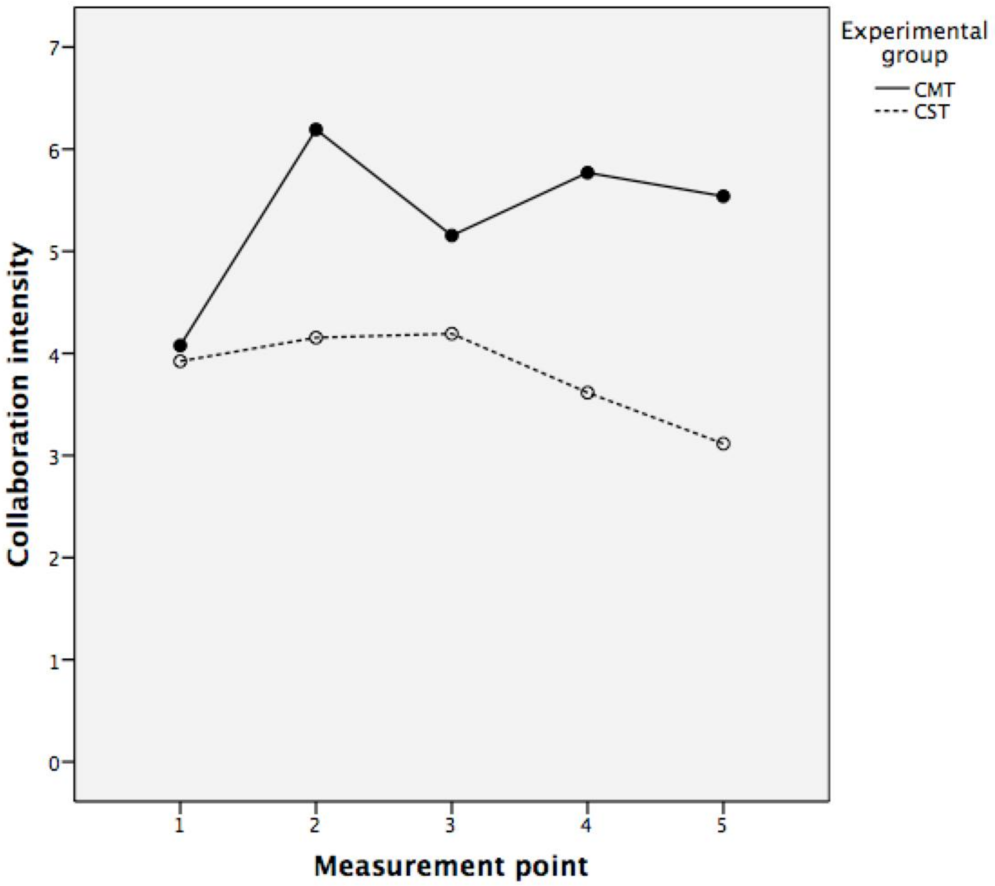

Figure 1. Interaction of experimental group x time on collaboration

4.2 Influence of Collaboration on Performance

The regression analyses results for the acceptance and use of the three examples of learning analytics systems (ALA) on problem solving performance are presented in Table 3 yielding a ΔR^2 of .319. Clearly, collaboration positively predicted the problem solving performance, indicating that the higher the perceived collaboration, the higher the overall problem solving performance. Accordingly, we accept Hypothesis 2.

Table 3. Regression analysis predicting collaboration on problem solving performance

	R^2	ΔR^2	*B*	*SE B*	*β*
	.333	.319			
Collaboration			.520	.104	.577***

Note. *** $p < .001$

5. DISCUSSION AND CONCLUSION

This study examined how technology-supported collaboration would develop over time, as well as the effects of collaboration on problem-solving performance. The results of the study showed that 1) the participants who were confronted with multi-tasking activities outperformed those who did single tasks; 2) the higher the participants perceived collaboration, the higher they demonstrated overall problem solving performance.

In general, students became increasingly more collaborative over time, and collaboration was a strong predictor for overall performance.

This study is significant in several ways. From a theoretical perspective, with the increasing complexities of learning environments being afforded by new technologies, it is important to examine aspects of collaborative learning and problem solving in flexible and multitasking environments. Methodologically, it is important to advance an understanding in this area of learning by testing hypotheses and conducting experiments to obtain results that may assist educators and learning technologists to advance understanding of how best to design and support a student's ability to coordinate, collaborate, and problem solve in new distributed workspaces.

Helping students to "develop their capacities for productive engagement in collaborative problem solving is both an educationally and socially important venture" (Barron, 2000 p.433). The new spaces of study and work are increasingly virtual and visited by individuals who are distributed in time and place (Resta and Laferrière, 2007). These technology-supported workspaces enable new models of flexible collaboration for learning and problem solving, although they could potentially increase cognitive overload as well. It is important to examine elements and dynamics of such workspaces to ensure smart learning environments for the learners.

REFERENCES

Alavi, M., & Dufner, D. 2005. Technology-mediated collaborative learning: A research perspective. In S. R. Hiltz & R. Goldman (Eds.), *Learning together online: Research on asynchronous learning networks*, pp. 191-213. Mahwah, NJ: Lawrence Erlbaum.

Amthauer, R., Brocke, B., Liepmann, D., & Beauducel, A. 2001. *Intelligenz-Struktur-Test 2000 R.* Göttingen: Hogrefe, 2.

Barron, B., 2000. Achieving coordination in collaborative problem-solving groups. *The Journal of the Learning Sciences*, Vol. 9, No. 4, pp.403-436.

Bluedorn, A. C., Kalliath, T. J., Strube, M. J., & Martin, G. D. 1999. Polychronicity and the Inventory of Polychronic Values (IPV): The development of an instrument to measure a fundamental dimension of organizational culture. *Journal of Managerial Psychology*, Vol. 14, No., pp. 205-230.

Bruffee, K. A., 1999. *Collaborative learning: Higher education, interdependence, and the authority of knowledge*. Baltimore, MD: Johns Hopkins University Press.

Chalifour, C. L. and Powers, D. E., 1989. The relationship of content characteristics of GRE analytical reasoning items to their difficulties and discriminations. *Journal of Educational Measurement*, Vol. 26, No. 2, pp.120-132.

Chickering, A. & Ehrmann, S. C., 1996. Implementing the seven principles: Technology as lever. *AAHE Bulletin*. October 3–6. Last retrieved on July 31, 2015 at http://www.tltgroup.org/programs/seven.html

Collis, B. & Moonen, J., 2001. *Flexible learning in a digital world: Experiences and expectations*. London, UK: Kogan Page.

Conte, J. M. & Jacobs, R. R., 2003. Validity evidence linking polychronicity and big five personality dimensions to absence, lateness, and supervisory performance ratings. *Human Performance*, Vol. 16, No. 2, pp.107-129.

Dillenbourg, P. 1999. What do you mean by "collaborative learning"? In P. Dillenbourg (Ed.), *Collaborative learning: Cognitive and computational approaches*. pp. 1-16. Amsterdam, NL: Pergamon, Elsevier Science.

Gokhale, A. A., 1995. Collaborative learning enhances critical thinking. *Journal of Technology Education*, Vol. 7, No.1, pp.22–30.

Johnson, D. W. & Johnson, R. T., 1986. Action research: Cooperative learning in the science classroom. *Science and Children*, Vol. No. 24, pp.31-32.

Jonassen, D. et al, 1995. Constructivism and computer-mediated communication in distance education. *American Journal of Distance Education*, Vol. 9, No. 2, pp.7-26.

Kaufman, S. B. et al, 2001. *A cognitive model of analytical reasoning using GRE problems*. Last retrieved on July 31, 2015 from http://scottbarrykaufman.com/wp-content/uploads/2013/01/Kaufman-Etal-2001-GRE-Problems.pdf

Kaye, A. R. (Ed.), 2012. *Collaborative learning through computer conferencing: The Najaden papers* (Vol. 90). New York: Springer-Verlag.

Mills, L. A., Knezek, G., & Khaddage, F. (2014). Information seeking, information sharing, and going mobile: Three bridges to informal learning. *Computers in Human Behavior, 32*, 324-334.

Mills, L. A., Knezek, G. A., & Wakefield, J. S. (2013). Understanding information seeking behavior in technology pervasive learning environments of the 21st century. *Turkish Online Journal of Educational Technology*, *12*(4), 200-208.

National Council of Teachers of Mathematics, 1989. *Curriculum and Evaluation Standards for School Mathematics*. Reston, VA: National Council of Teachers of Mathematics.

National Research Council, 1996. *The National Science Education Standards*. Washington, DC, USA: National Academy Press.

Resta, P. & Laferrière, T., 2007. Technology in support of collaborative learning. *Educational Psychology Review*, Vol. 19, No. 1, pp.65-83.

Roschelle, J. & Teasley, S. D., 1995. The construction of shared knowledge in collaborative problem solving. In C. E. O'Malley (Ed.), *Computer supported collaborative learning*, pp.69-97. Berlin, Germany: Springer-Verlag.

Rosen, L. D. et al, 2013. Facebook and texting made me do it: Media-induced task-switching while studying. *Computers in Human Behavior*, Vol. 29, No. 3, pp.948-958.

Rummel, N. & Spada, H., 2005. Learning to collaborate: An instructional approach to promoting collaborative problem solving in computer-mediated settings. *The Journal of the Learning Sciences*, Vol. 14, No. 2, pp.201-241.

Sachs, P., 1995. Transforming work: collaboration, learning, and design. *Communications of the ACM*, Vol. 38, No. 9, pp. 36-44.

Stahl, G. et al, 2006. Computer-supported collaborative learning: An historical perspective. *Cambridge Handbook of the Learning Sciences*, pp.409-426.

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

Totten, S. et al, 1991. *Cooperative Learning: A Guide to Research*. New York, NY: Garland.

Wegerif, R., 2006. Towards a dialogic understanding of the relationship between teaching thinking and CSCL. *International Journal of Computer Supported Collaborative Learning*, Vol. 1, No. 1, pp.143–157.