Paper Title Playful and Collaborative Inquiry Into Adaptive Cruise Control

Author(s) Ethan P. Valentine, The University of Iowa; Yile Zhou, The University of Iowa; Benjamin M Devane, The University of Iowa; Joyce L. Moore, University of Iowa

Session Title Poster Session: Research on Innovations in Learning Technologies

Session Type Poster Presentation

Presentation Date 4/16/2018

Presentation Location New York, NY

Descriptors Collaboration, Computers and Learning, Learning Environments

Methodology Mixed Method

Unit Division C - Learning and Instruction

DOI 10.302/1317563

Playful and Collaborative Inquiry into Adaptive Cruise Control

Objectives

The present research is part of a larger project to design, implement, and assess learning materials for new technology-based driver safety systems. A 2014 U.S. survey that found that "the internet" (57%) and "friends and family" (41%) were the most frequently used sources of information for driver safety systems (McDonald et al., 2016). Consequently, this study compares the reasoning of dyads and individuals who are given publicly-available educational materials about adaptive cruise control (ACC), including an online interactive simulation, and asked to solve problems using the simulation. In addition to comparing group performance on these problems, we compare the collaborative reasoning processes of dyads who performed well on the simulation-based problems with those who performed poorly. This paper presents the results of this analysis, including a code set for analyzing collaborative interaction that is based on a framework for collaborative problem-solving skills developed by Hesse et al. (2015). Using this code set to analyze video data of dyadic interactions, we suggest that persistent, collaborative relationship building and negotiation were integral to a well-developed understanding of ACC when learning using this computer-based simulation.

Theoretical Framework

This paper draws on literature in two areas: a) collaboration and collaborative problem solving; and b) the development of conceptual models of driving safety systems in informal settings using open educational materials.

Collaboration & Collaborative Problem-Solving. Long an important area of research on learning, collaboration has increasingly been recognized by policymakers and business leaders as an important feature for learning in schools and informal settings (e.g., Lai, 2011; Johnson et al., 2014). Consequently, there has been a renewed scholarly focus on collaborative problem-solving as a specific kind of endeavor that has found special favor among advocates of 21st-century learning and skills (Hesse et al., 2015). In their collaborative problem-solving skills framework, Hesse and collaborators define collaborative problem-solving as a "joint activity where dyads or small groups execute a number of steps in order to transform a current state into a desired goal state..." such that "...collaboration each of these steps is directly observable." (Hesse et al., 2015, p. 39)

Developing conceptual models of driver safety systems in less-structured settings. Many drivers develop poor conceptual understandings of new driver safety systems (Jenness et al., 2008), including adaptive cruise control (ACC). ACC is an enhancement of conventional cruise control that automatically adjusts speed based on traffic ahead. Many ACC owners are unsure when the system is operating, and a majority are unaware of any system limitations (Jenness et al., 2008). While ACC can improve safety through reducing overall speed and increasing time headway (time between two vehicles traveling in the same direction), a well-developed understanding of system limitations may help prevent drivers from using the technology in dangerous ways.

One reason that drivers often have poor conceptual understanding of ACC is that few informational or instructional materials about these systems exist aside from car manuals, and few drivers read manuals to completion (Mehlenbacher et al., 2002). Drivers learning to use ACC systems, especially those who learn 'on the road,' are at risk of developing inaccurate conceptual models of ACC system functions, and therefore dangerously overtrusting system performance (Kazi et al., 2007).

Methods

Study participants were 80 traditional college-aged students who said they were not familiar with ACC during screening. Participants were randomly assigned to either the Individual or Dyad condition, with 40 Individuals and 20 Dyads. Dyads were randomly paired, resulting in nine female pairs, three male pairs, and eight female/male pairs.

There are three phases to the study, illustrated in Table 1. First, participants read instructional material about ACC, which described what it is, how to use it, and how it works. Second, they interacted and solved problems with a computer-based simulation about ACC. Third, participants were asked to solve four text-based scenario problems about ACC.

The participants were video recorded throughout. Two cameras were setup to record the participants, with one camera recording the computer screen over the shoulder of the participants, and the other recording participants' heads and shoulders from the front.

Data Sources

Instructional Materials. There are three sections of ACC instructional materials that we refer to as Understand, Play, and Challenge. First, in the Understand section, participants read through traditional text-based materials in order to gain a basic understanding of ACC. Second, in the Play section, participants used the systems-perspective plAyCC simulation, illustrated in Figure 1, to explore how multiple, changing factors affect ACC function in hazardous situations. Third, the Challenge section involves scenario-based problems presented from a driver's perspective. The current study focuses only on the plAyCC problem section, on which dyads performed significantly better than individuals.

plAyCC Simulation. plAyCC is a computer-based simulation of ACC which allows users to change multiple aspects of traffic and road conditions in order to explore ACC system functioning. It is not a traditional driving simulator, but a systems-level simulation of an ACC-enabled car interacting with other cars on the road, as well as the curviness of the road. Using sliders, participants are able to change the average traffic speed, the speed of the fastest car on the road, and the curviness of the road, as well as the overall speed of the simulation. During the Play portion of this study, participants were given three problems with potentially dangerous settings, illustrated in Table 2. To solve the problems, participants had to adjust a subset of the plAyCC parameters in order to make the driving conditions safe.

Selection of High- and Low-Performing Dyads. Participants' answers for the three plAyCC problems were scored for accuracy. The five dyads who received the highest scores and the five dyads who received the lowest scores were selected for additional analysis.

Results

Individuals vs. Dyads. One-tailed independent *t*-tests were conducted to compare performance of the Individuals and Dyads on the plAyCC and Challenge problems. Participants' answers were scored for accuracy. The independent sample *t*-test showed that Individuals had significantly lower total scores than Dyads on the plAyCC problems ($t[58] = -1.7$, $p < .05$, $d = .47$), indicating that the Dyads performed significantly better on these tasks. Table 3 includes descriptive statistics for Individuals and Dyads on the plAyCC problems. However, there were no differences between the groups on the Challenge problems ($t[58] = -.290$, $p = .387$).

Top vs. Bottom Dyads. We further analyzed the collaborative reasoning processes of the Top dyads (the five dyads who formed the top quartile) and Bottom dyads (the five dyads who formed the bottom quartile). The ten video recordings from the Top and Bottom dyads were analyzed using a coding scheme we adapted from four major areas of Hesse et al.'s (2012) framework for collaborative problem solving - *Negotiation* (SR-N), *Hypothesis Creation* (LKB-HC) and *Relationships* (LKB-R), and *Organization*, (TR-O). Our coding scheme is illustrated in Table 4. For Negotiation codes, we distinguished between high, medium, and low quality interactions. For Hypothesis Creation, Relationships, and Organization codes, we distinguished between correct and incorrect interactions.

As shown in Table 5, the Top dyads engaged in more collaborative problem-solving events on average than the Bottom dyads. The frequencies of Organization and Hypothesis Creation were similar among Top and Bottom dyads, but the Top dyads engaged in more Negotiation and Relationship compared to the Bottom dyads. In addition, in all of the four coded areas, the percentages of correct codes were higher for the Top dyads compared to the Bottom dyads. For the purposes of this comparison, we counted high and medium Negotiations as correct, and low Negotiations as incorrect. In particular, the Top dyads engaged in substantially more correct Relationship building and Hypothesis Creation than the Bottom dyads, despite overall frequencies being similar.

Table 6 displays the average number of high, medium, and low Negotiation codes for the Top and Bottom dyads, as well as the percentage of Negotiation codes that were high, medium, and low. Although the differences are not large, the proportion of low Negotiation codes was higher for the Bottom group, while the proportion of medium Negotiation codes was higher for the Top group. While the Top group engaged in more high-level Negotiation, the Bottom group had a higher percentage of high-level Negotiation due to fewer overall cases of Negotiation.

Table 7 displays the average number, average number correct, and percentage correct of high and low Organization, Relationship, and Hypothesis Creation codes for the Top and Bottom dyads. The percentage correct is lower for the Bottom group for all codes except for high-level Relationships, however, this was because there was only one case of a high-level Relationship code for the entire Bottom group. The largest difference can be seen in Hypothesis Creation, where the percentage correct for the Bottom group is around half that of the Top group for both high and low categories.

Time course of collaborative processes. Table 8 displays the average number of minutes for the Top and Bottom groups to complete each plAyCC question. On average, the Bottom group spent about 30 seconds longer solving the first problem, which may be the result of having a harder time understanding the simulation and how to use it. On the other hand, the Top group spent about two more minutes solving the second problem and about two and a half more minutes on the third problem.

The additional time that the Top group spent solving the second and third problems resulted in higher levels of correct Hypothesis Creation and Relationship building, as shown in Figures 2 and 3. After a minute of problem solving had elapsed, Top dyads had dramatically more utterances and events judged correct in the Hypothesis Creation and Relationship codes than Bottom dyads across all problems.. In the first minute, however, there was little numerical distinction in the comparative number of codes between Top and Bottom groups.

Table 9 shows the average number of codes per minute and average number of correct codes per minute for the Top and Bottom dyads. For the Negotiation and Relationship codes, the Top group had a slightly higher average number of codes per minute as well as a slightly higher average of correct codes per minute. The Bottom group has a higher average number of Organization codes per minute, as well as a higher average number of correct Organization codes per minute. This is due to the Bottom dyads often re-reading the problem statement because of difficulties understanding the task. While the Bottom group engaged in more frequent Hypothesis Creation, the Top group engaged in more frequent correct Hypothesis Creation.

Scientific Significance

With the proliferation of open educational materials, it is important to better understand how individuals learn from these materials. This project is part of a national campaign, *MyCarDoesWhat.org*, to help educate drivers on new vehicle safety technologies designed to help prevent crashes. This study indicates that collaborative learning improved understanding of ACC when using open educational materials. This is an important design consideration for the creation of open educational materials, where there is often an implicit assumption of an individual learner. This research also provides insight about the features of effective collaborative problem solving when learning with a system-level simulation. Our analyses indicate that the high-performing dyads engaged in longer problem-solving sessions that included more Negotiation and Relationship building than the low-performing dyads. In addition, high-performing dyads tended to have higher quality interactions. We assume that higher performance solving problems using the computer simulation is a reflection of greater conceptual understanding of ACC.

Table 1. *Sequence of study procedures.*

Sequence	*1*	*2*	*3*
Stage	*Understand (Explanatory text)*	*Play (System-level simulation problems)*	*Challenge (Scenario problems)*

Table 2. *Simulation-based (plAyCC) problems.*

Question	**Description**	**Simulation Parameters**	**Answer**
Q1	Straighten the road the minimum amount necessary to make it safe for the ACC-enabled vehicle. (ACC speed = 70; Traffic speed = 55)	**Road curve** (originally 7)	**Curve** = 4
Q2	Change the average traffic speed only enough to make it safe for an ACC vehicle traveling quickly. (ACC speed = 55; Traffic speed = 35)	**Traffic speed** (originally 35)	**Traffic speed** = 47
Q3	Within a budget, redesign both the curve and the average traffic speed limit to make it safe for a quick-moving ACC vehicle (ACC speed = 65)	**Road curve** (originally 7) **Traffic speed** (originally 45)	**Curve** = 6; **Traffic speed** = 59 *OR* **Curv**e =5; **Traffic speed** = 53/54

Table 3. *The average scores and standard deviations for each plAyCC problem for Individuals and Dyads.*

	Individuals			Dyads		
	N	*Mean*	*SD*	*N*	*Mean*	*SD*
PlAyCC 1	40	.35	.41	20	.43	.44
PlAyCC 2	40	.24	.41	20	.48	.50
PlAyCC 3	40	.91	.91	20	1.20	.83
PlAyCC total	40	1.50	1.30	20	2.10	1.27

Table 4. *Coding scheme for collaborative problem solving.*

Code	Definition	Incorrect	Level
SR-N	**Social regulation-Negotiation**: Participants talk about different opinions to reach a resolution or compromise.	NA	Low: Participants talk about different opinions without reaching a resolution or compromise.
			Medium: Participants discuss different opinions and one partner compromises.
			High: Participants achieve a resolution after a discussion with rationale(s) provided for opinions.
TR-O	**Task regulation-Organization**: Participants analyze and describe the problem.	Participants misinterpret the problem.	Low: Participants reiterate the problem in their own words or restate/reread the problem.
			High: Participants identify sub-tasks/sub-goals, analyze the problem, and/or identify key elements of the problem solution.
LKB-R	**Knowledge building-Relationships**: Participants identify connections between multiple pieces of information.	Participants link different variables, but the connections are incorrect.	Low: Participants mention several elements of the problem, but do not specify a relationship between them.
			High: Participants identify the connections and patterns between several elements of the problem solution.
LKB-HC	**Knowledge building-Hypothesis creation**: Participants create a hypothesis and test it on the simulation.	Participants use hypotheses that have previously been seen to be incorrect or provide incorrect explanations.	Low: Participants make changes to the parameters of the problem without a rationale or without verbalizing.
			High: Participants state a hypothesis and provide justification for that hypothesis.

Table 5. *Averages of total codes, averages of correct codes, and percentages of correct codes for Top and Bottom dyads.*

	Negotiation			Organization			Relationship			Hypothesis		
Group	Avg	Avg Corr	%C	Avg	Avg Corr	%C	Avg	Avg Corr	%C	Avg	Avg Corr	%C
Top	2.8	2.2	79%	9.6	9.6	100%	5.0	4.6	92%	14.2	13.8	97%
Bottom	1.6	1.0	63%	9.8	7.8	80%	2.8	2.0	71%	14.2	7.0	49%
Total	2.2	1.6	73%	9.7	8.7	90%	3.9	3.3	85%	14.2	10.4	73%

Table 6. *Average number and percentage of high, medium, and low Negotiation codes for Top and Bottom dyads.*

	Top		Bottom	
	Avg	%	Avg	%
High	0.6	21%	0.4	25%
Medium	1.6	57%	0.6	37.5%
Low	0.6	21%	0.6	37.5%

Table 7. *Average number, average correct, and percentage correct of high and low Organization, Relationship, and Hypothesis Creation codes for Top and Bottom dyads.*

		Organization			Relationship			Hypothesis		
		Avg	AvgC	%C	Avg	AvgC	%C	Avg	AvgC	%C
Top	High	3.4	3.4	100%	1.8	1.4	78%	8.4	8.2	98%
	Low	6.2	6.2	100%	3.2	3.2	100%	5.8	5.6	97%
Bottom	High	2.6	1.8	69%	0.2	0.2	100%	5.6	2.6	46%
	Low	7.2	6	83%	2.6	1.8	69%	8.6	4.4	51%

Table 8. *Average question completion time in minutes for Top and Bottom groups.*

	Question			
Group	1	2	3	Total
Top	3.68	5.57	5.18	14.43
Bottom	4.23	3.60	2.92	10.75

Table 9. *Average number of codes and average number of correct codes per minute for Top and Bottom dyads.*

	Negotiation		Organization		Relationship		Hypothesis	
Group	Avg	AvgC	Avg	AvgC	Avg	AvgC	Avg	AvgC
Top	0.19	0.15	0.67	0.67	0.35	0.32	0.98	0.96
Bottom	0.15	0.09	0.91	0.73	0.26	0.19	1.32	0.65

Figure 1. *plAyCC simulation.*

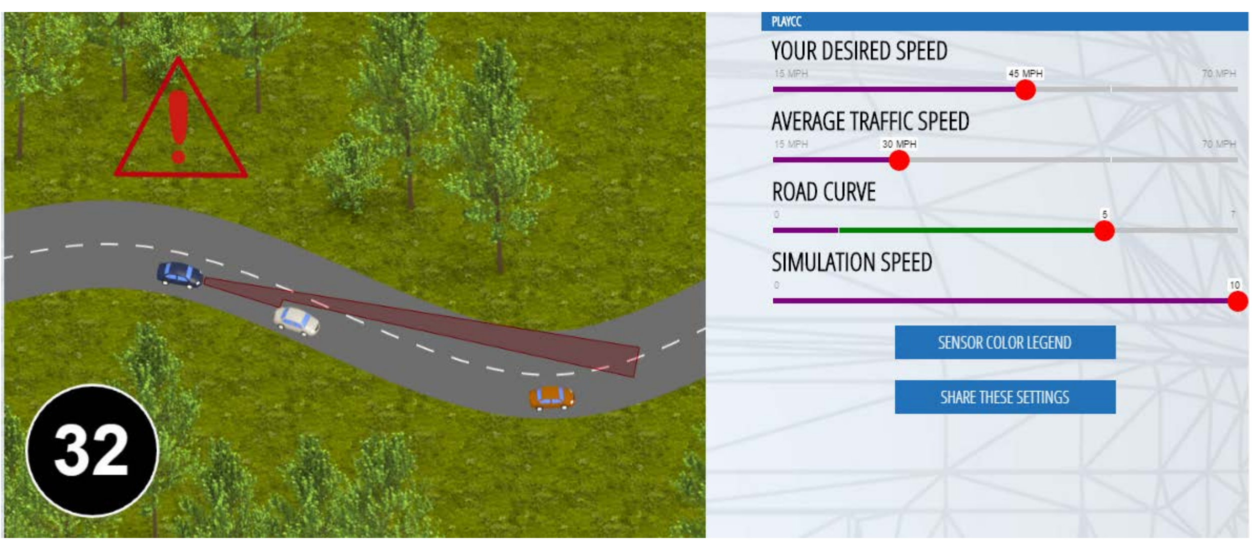


Figure 2. *Number of correct Hypothesis Creation codes over time for Top and Bottom groups.*

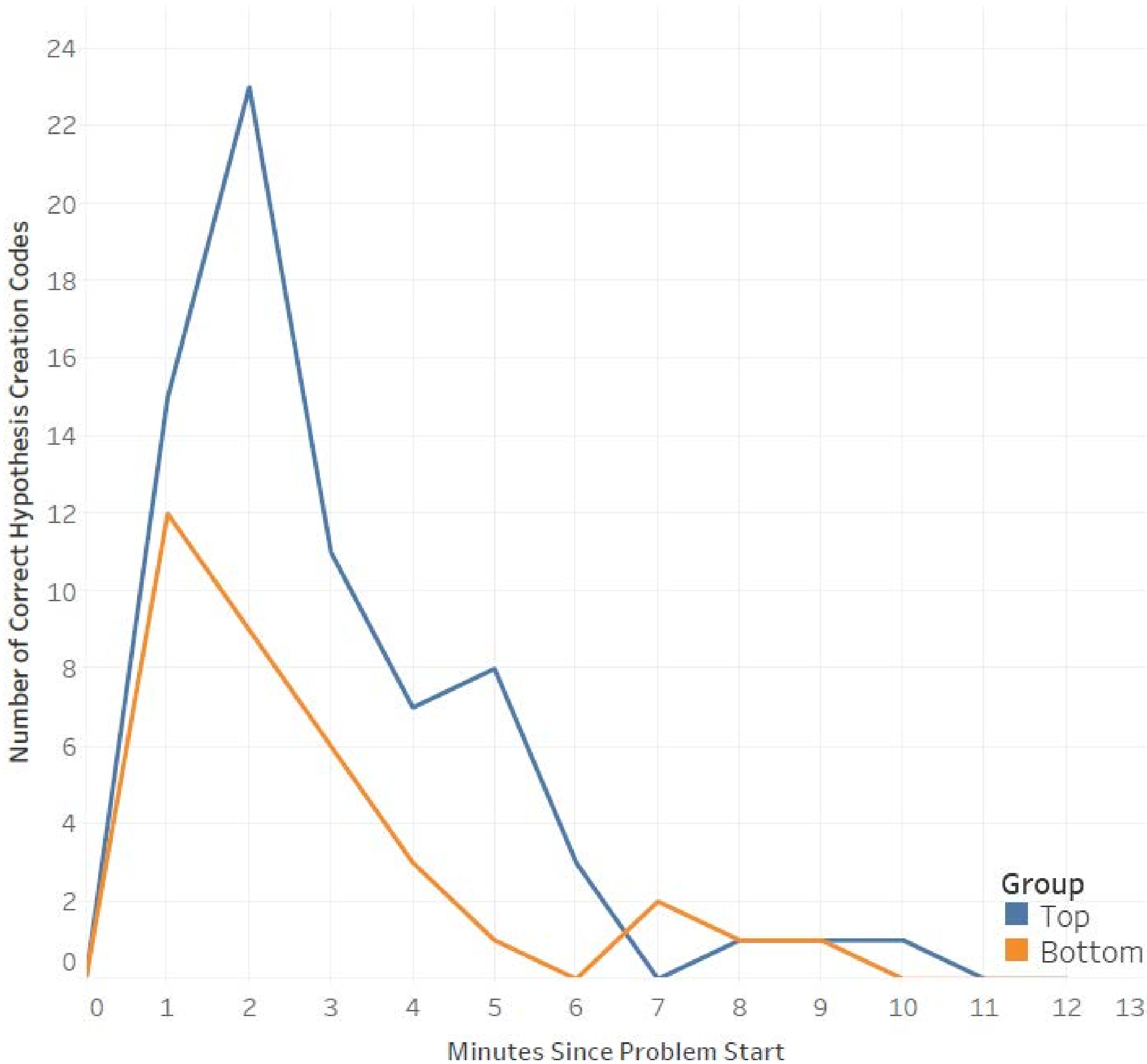
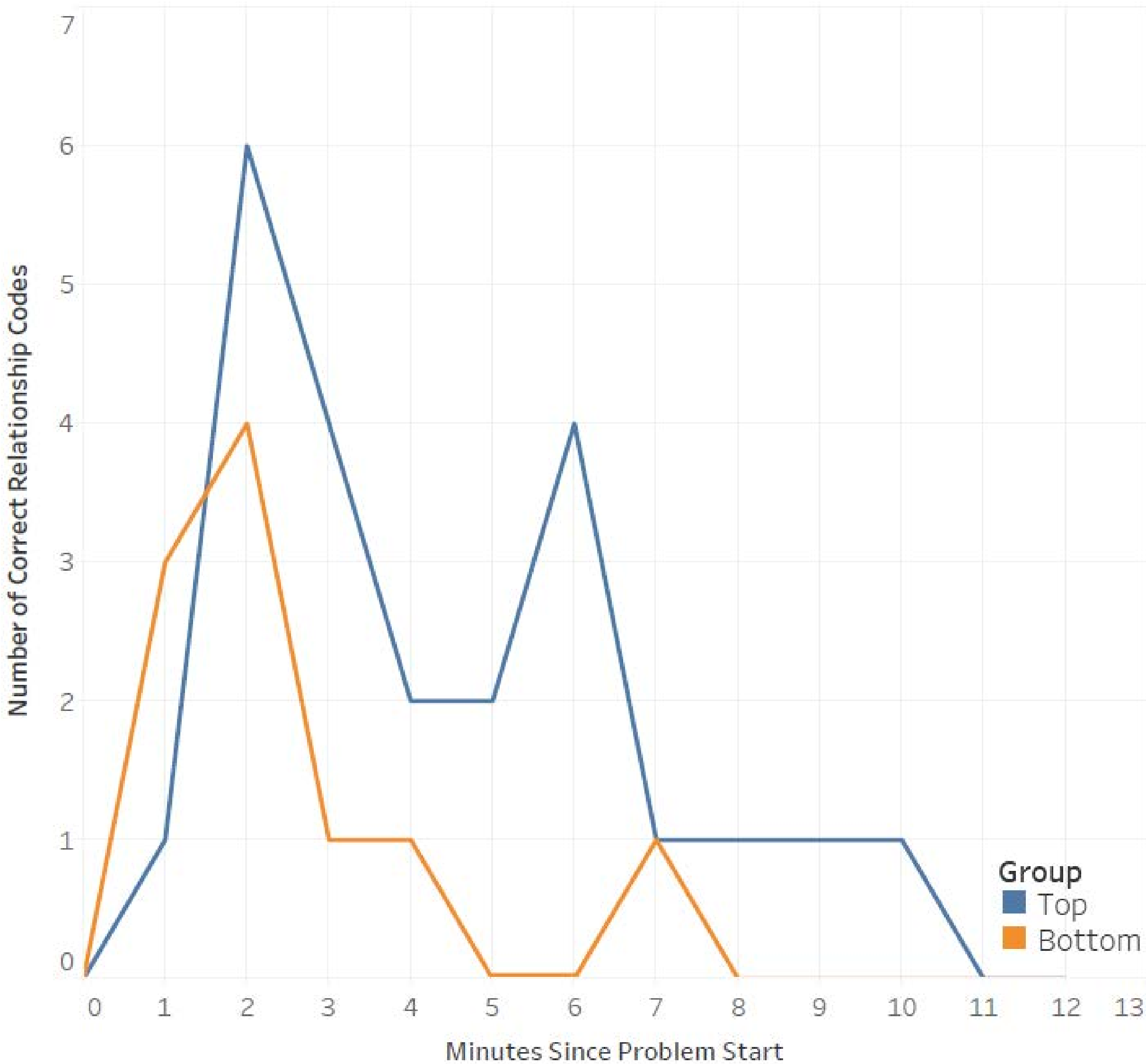


Figure 3. *Number of correct Relationship codes over time for Top and Bottom groups.*



References

Hesse, F., Care, E., Buder, J., Sassenberg, K., & Griffin, P. (2015). A framework for teachable collaborative problem solving skills. In *Assessment and teaching of 21st century skills* (pp. 37-56). Springer: Netherlands.

Jenness, J. W., Lerner, N. D., Mazor, S., Osberg, J. S., & Tefft, B. C. (2008). *Use of advanced in-vehicle technology by young and older early adopters: Survey results on adaptive cruise control systems.* (# DOT HS 810 917). Springfield, VA: Dept. of Transportation.

Kazi, T. A., Stanton, N. A., Walker, G. H., & Young, M. S. (2007). *Designer driving: Drivers' conceptual models and level of trust in adaptive cruise control*. International Journal of Vehicle Design, 45(3), 339–360.

Lai, K-W. (2011). Digital technology and the culture of teaching and learning in higher education. *Australasian Journal of Educational Technology*, *27*(Special issue, 8), 1263-1275.

Johnson-Glenberg, M. C., Birchfield, D. A., Tolentino, L., & Koziupa, T. (2014). Collaborative Embodied Learning in Mixed Reality Motion-Capture Environments: Two Science Studies. *Journal of Educational Psychology*, *106*(1), 86 –104.

McDonald, A. B., McGehee, D. V., Chrysler, S. T., Askelson, N. M., Angell, L. S., & Seppelt, B. D. (2016). National survey identifying gaps in consumer knowledge of advanced vehicle safety systems. *Transportation Research Record: Journal of the Transportation Research Board* (2559), 1-6.

Mehlenbacher, B., Wogalter, M. S., & Laughery, K. R. (2002). *On the reading of product owner's manuals: Perceptions and product complexity* (Vol. 46, pp. 730–734). Presented at the Proceedings of the Human Factors and Ergonomics Society Annual Meeting, SAGE Publications.

Meier, A., Spada, H., & Rummel, N. (2007). A rating scheme for assessing the quality of computer-supported collaboration processes. *International Journal of Computer-Supported Collaborative Learning*, *2*(1), 63-86.

Rummel, N., Spada, H., & Hauser, S. (2009). Learning to collaborate while being scripted or by observing a model. *International Journal of Computer-Supported Collaborative Learning*, *4*(1), 69-92.

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