Developing collaborative problem-solving skills through inquiry-based learning

Meeli Rannastu-Avalos[a1], Mario Mäeots[a], Leo A. Siiman[a]

[a] *Institute of Education, University of Tartu*

Summary

There is an increasing demand in society to work collaboratively with others to solve problems. However, teachers require guidance and adequate learning resources that can develop students' collaboration skills. The current study creates and tests an inquiry science lesson for classroom implementation based on the Hesse et al. (2015) theoretical model for collaborative problem-solving. The lesson included using smart devices to interact with a collaborative inquiry simulation and followed our previous work involving asymmetric computer simulations (Rannastu et al., 2019). In this study, we included time for students to reflect on their collaboration and inquiry after interacting with the simulation. We aimed to empirically investigate how the lesson affected learners' collaborative, inquiry, and subject-related aspects. Specifically, we formulated three research questions:

1. What was the effect of the lesson on students' domain-specific and inquiry knowledge?
2. How did students reflect on their domain-specific and inquiry learning?
3. How did students assess their collaboration skills?

Hesse et al. (2015) describe collaborative problem-solving skills as involving both social and cognitive domains. The three dimensions proposed by Hesse et al. (2015) to conceptualise collaboration include participation, perspective-taking, and social management skills. Our study involved 7th-grade students (n = 44) from two classes at one Estonian public school (mean age = 13.8). Students were randomly assigned into 19 pairs and three triplets. The science lesson involved the topic of electrical circuits and was carried out by the teacher. One researcher made observations during the lesson. The simulation is available at https://leosiiman.neocities.org/simulations and allows two students to explore a virtual dollhouse. The simulation (or virtual lab) asymmetrically divides some functionality (e.g., control over certain switches, control over

[1] Institute of Education, University of Tartu, Jakobi 5, 51005 Tartu; meeli.rannastu-avalos@ut.ee.

voltage or resistance values, but not both) to each student. A worksheet was created for each student with questions requiring both to contribute to finding the correct answers since neither student had full functionality over the simulation to answer the questions alone. The worksheet questions were "Which of the three circuits most resembles the circuit of an ordinary house?" and "List all the independent/dependent variables in this simulation." The first question was associated with subject knowledge, whereas the second one was associated with inquiry knowledge. The worksheet also included the open-ended question: "What do you consider a successful collaboration?" The responses to this open-ended question were analysed using the Hesse et al. (2015) theoretical framework. After completing the worksheet, the students returned it to their teacher and then engaged in a reflection session in which the teacher demonstrated the correct answers. During this time, the students were given a questionnaire to reflect on their performance as well as on their collaboration. The questionnaire included the open-ended questions "Were your responses to the worksheet questions correct or incorrect? If correct, then how did collaboration help you be successful? If incorrect, why was your collaboration unsuccessful?" The questionnaire also included ten Likert scale items (1 = strongly disagree, 5 = strongly agree) to measure the collaborative dimensions of participation (e.g., "I worked hard to solve this task collaboratively"), perspective-taking (e.g., "I changed my mind when my partner brought up new ideas"), social regulation (e.g., "If we disagreed then I tried to find a solution") and interdependence (e.g., "My partner was dependent on me for information and advice"). The first three dimensions are from the Hesse et al. (2015) framework, whereas the interdependence items were adapted from Van den Bossche et al. (2006). All materials mentioned above were introduced to the teacher before the intervention, as well as a detailed lesson plan and presentation slides.

The first research question asked about the effect of the lesson on subject and inquiry knowledge. The results, in terms of subject learning, showed that 11 groups identified the correct circuit in the virtual dollhouse simulation, while ten groups chose an incorrect circuit. The groups who answered erroneously were generally wrong because they did not observe that switches in their chosen circuit room slightly influenced the light intensity in other rooms. The results related to of inquiry learning showed that 55% of groups correctly identified the dependent and independent variables in the simulation.

The second research question examined students' reflections on their problem-solving performance. The results revealed that many students tended to overestimate their performance when in fact, later grading of their worksheets showed significant mistakes. The open-ended reflection questions were coded and combined with the worksheet results to distinguish three categories of groups: low, medium and high. The medium and low-scoring groups had trouble identifying the dependent and independent variables (i.e., inquiry knowledge). However, the medium-scoring groups had a slightly higher average score and seemed to understand the relationship of the variables with the virtual lab after the discussion. The low-scoring groups rated their collaboration highly, as indicated by the questionnaire, even though their worksheet performance was poor.

The third research question asked about how students reflected on their collaboration. The results were assessed with the questionnaire items grouped along the dimensions of participation, perspective-taking, social regulation and interdependence. Participation and interdependence scored lower than perspective-taking and social regulation. Surprisingly, interdependence scored relatively lower than the other dimensions because the worksheet questions could not be successfully answered without a joint cooperative effort by both students. The questionnaire results showed no statistically significant differences between students using either simulation version (see Table 2).

In general, research in computer-supported collaborative learning has tended to focus on collaborating to learn rather than learning to collaborate. However, developing student collaboration skills is very important not just for scientific discovery but also in everyday life. In this study, we constructed a classroom activity following the PISA and ATC21s theoretical models for collaborative problem-solving (CPS). Care and Kim (2018) have highlighted the lack of integration of CPS theory into educational practice. Our activity was designed around the physics topic of electrical circuits and involved an inquiry-based learning approach. Notably, we included a reflection session for students to reflect on their collaboration and task performance. Reflection is an essential strategy for student learning (Runnel et al., 2013). The reflection session not only allows a teacher to review the activity with students but to collect self-report data about student collaboration which can be later verified by comparison to objective performance on the worksheet questions. Nevertheless, CPS is a complex construct, and simple measurements do not suffice. Pöysä-Tarhonen et al. (2022) have used triangulating analysis techniques to integrate multiple methods to form a deeper understanding of CPS. Triangulation is a good strategy to increase the credibility and validity of research findings and is necessary for a complex construct like collaboration. Overall, our study contributes to helping identify what exactly CPS can look like in the classroom and how collaboration skills can, in part, be measured in the school learning context. The results are useful for bridging theoretical or controlled

experimental studies of CPS with designing learning activities that teachers can use in practice to help their students develop collaboration skills. Teacher education and teacher training should also assist in understanding how to help students build collaborative skills.

Keywords: collaborative learning, collaborative problem-solving, inquiry learning, collaborative simulations