To Improve The Planning Skill In Chemistry Investigation Through Knowledge Building And Virtual Laboratory

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Abstract

The eduLab-vl project is initiated by four secondary schools in Singapore (Beatty Secondary, Chung Cheng High, Regent Secondary and Yishun Town Secondary). It is an educational research project seeking to combine the technology of virtual laboratories (vl) and the pedagogy of Knowledge Building (KB) together. The objectives of the project are to investigate the effects of vl and KB on students' planning skills of scientific investigation.

Two classes (one treatment class and one control class) with equivalent standard and background were selected from each participating school. Students from the treatment class were enculturated in the use of virtual laboratory and knowledge building for three months. The computer-based Knowledge Forum (KF) was used as a collaborative workspace, which allowed students to contribute theories, build on new ideas and provide evidence to support their hypothesis. We observed that the students' knowledge in science was advanced and the planning of scientific investigation was improved during the KB enculturation.

Content analysis on students' discussions postings was performed. Pre-tests and post-tests were conducted with the same rubric. Surveys on self-directed learning (SDL) and collaborative learning (CoL) were conducted. The analysis of the results illustrated that the diversity of ideas, the competencies in planning of scientific investigation, and the CoL of the treatment classes were significantly improved and were better than the control classes.

Key words

Knowledge Building, Knowledge Forum, Virtual-lab, Collaborative learning, Chemistry

TO IMPROVE THE PLANNING SKILL IN CHEMISTRY INVESTIGATION THROUGH KNOWLEDGE BUILDING AND VIRTUAL LABORATORY

1. Introduction

With the shift towards a knowledge-based economy in the 21st century, most countries have revamped their education policies and curriculum to meet the needs of the new economy. Emphasis has been placed on the learner's ability to perform knowledge work, especially in the area of dynamic and continual knowledge creation. Knowledge building (KB) is a way to integrate different approaches into an overarching learning environment that provides fuller and more authentic immersion in the actual life of a knowledge society (Bereiter et al., 2006).

One of such educational reforms in Singapore was the implementation of the Science Practical Assessment (SPA), to replace the one-time practical examination in secondary and pre-university levels. In the revised SPA framework for secondary schools, students are assessed on three key aspects of practical skills (Ministry of Education Singapore, 2005).

- Skill 1:Using and organizing techniques, apparatus and materials; and observing, measuring and recording.
- Skill 2:Handling experimental observations and data.
- Skill 3:Planning Investigations.

With the intention to have an inquiry based science curriculum, SPA allows students to plan and design their own investigations, moving away from the traditional 'cookbook' style practical assessments. Students are exposed to a wider range of topics in practical, such as Energy Changes and Speed of Reactions as compared to just Qualitative and Volumetric Analysis in the one-time practical examination. Ow and Goh (2010) commented that SPA offered teachers greater flexibility in the choice of topics to assess the students. However, as highlighted by Towndrow (2008), implementation at the frontline has not been as successful as what SPA has intended. Many teachers are still engaged in the traditional methods of teaching practical work.

Our project investigated the effects on the use of virtual laboratories - knowledge building (KB) pedagogy in helping students to acquire the SPA skill 3 – Planning Investigations, in the chemistry practical work. Critical reflections on tasks and in-depth build-ons in discussions were emphasized. To enhance the understanding on the tasks and the discussions, relevant computer animations (virtual laboratory) were supplemented. In this paper, we reported the chemistry-based KB lessons from two of our participating schools. We compared the differences in students' learning between the knowledge building - virtual laboratory approach and with the traditional method, which emphasizes on knowledge transmission.

2. Knowledge Building

Scardamalia and Bereiter (2006) described Knowledge Building (KB) as a way to address the contemporary emphasis on knowledge creation and innovation. It is a kind of community knowledge advancement rather than individual achievement, an idea improvement to open new possibilities rather than idea sharing, and a procedural knowledge of management rather than a declarative knowledge of knowing about. KB is a collaborative discourse on problem solving, a constructive use of authoritative information, and an emergent understanding. The philosophy of KB focused on the building up of community knowledge rather than individual learning. Scardamalia (2002) proposed 12 Principles of Knowledge Building and claimed that the shared knowledge would lead to innovation and growth of the community. The 12 Principles of KB are:

1) Real ideas and authentic problems

2) Improvable ideas

3) Idea diversity

4) Rise above

5) Epistemic agency

6) Community knowledge, collective responsibility

7) Democratizing knowledge

8) Symmetric knowledge advancement

9) Pervasive Knowledge building

10) Constructive uses of authoritative sources

11) Knowledge building discourse

12) Concurrent, embedded, and transformative assessment

Scardamalia, Bereiter and their team had designed the Knowledge Forum (KF), [15] a computer program for collaborative learning and knowledge building. The KF enabled creative and collaborative work. It allowed all the knowledge building activities such as revise, critique, build on, reference, organize, and rise above. As commented by Sterelny (2005), these knowledge building activities not only cooperatively gathered ideas from the

[15] Previously, the product was called Computer Supported Intentional Learning Environments (CSILE). In 1995, the software was redesigned and called Knowledge Forum (KF). See Scardamalia & Bereiter, 2006. KF website (http://www.knowledgeforum.com/Kforum/products.htm)

community, but also collaboratively contribute towards the advancement of community knowledge.

Bakhtin (1981) had compared the dialogic with the monologic works. He found that when a person carried on a continual dialogue with other authors, his novel had fresh aspects in the words and his work had broader sense. Driver et al. (2000) had applied the dialogic setting in classroom teaching and found that students learn more in dialogic work because it helped them to 'construct and reconstruct' their knowledge. The building up of knowledge by dialogic work could be achieved in the KB environment.

3. METHODOLOGY

3.1 Samples and Instrumentation

The students from the two of the participating schools (Schools B and Y) were of average standard in Singapore. In each school, two Secondary 3 (Grade 9) classes – one treatment class and one control class – were selected on the basis of the equivalence in their PSLE T-scores[16]. The t-tests of the PSLE T-scores between the treatment-control classes are: School B = -0.330, and School Y = -0.473. Both are not significant. The classes consisted of boys and girls with races of Chinese (majority), Malays and Indians. The common language of communication is English. The class sizes from the two schools are shown in Table 1.

School B	Treatment class	32
	Control class	28
School Y	Treatment class	41

[16] PSLE (Primary School Leaving Examination) is the national examination in Singapore taken by all Primary 6 (Grade 6) pupils. The T-score is the total score of the four subjects, English, Mother Tough, Mathematics and Science.

	Control class	42

Table 1. Class Sizes of Schools B and Y

The students had no previous experience in KB and KF. The teachers of the classes were experienced teachers (more than 8 years teaching). The teacher of the treatment class from School B was trained in KB and KF, but not the teacher of the control class. For school Y, teachers in both classes were trained in KB and KF.

Content analysis was performed on students' online posts. A post-test was carried out using the same rubric as the pre-test. The tests were set based on higher cognitive order which require students to design experiments. The treatment class emphasized on the use of KB and had a more structured discussion using KF. Surveys on self-directed learning (SDL) and collaborative learning (CoL) were conducted before the KB intervention and after the post-test.

3.2 Enculturation Phrase

In school B, students from the treatment class were enculturated in a knowledge building setting for three months (April, July and August 2014). Since the students came from different Secondary 2 classes (Grade 8) and they needed time to build relationship with each other, so the training did not start in the first school term (January to March). The training was stopped in May and June, when it was the examination period and term break respectively. During the enculturation, they were trained on the KB skills, through the KF, such as, problematization, building on ideas with evidence support and summarizing interrelated ideas with rise-above. The training was infused in the teaching of chemistry. The topics used for the KB training included, separation methods and qualitative analysis.

For school Y, the students underwent about six hours of enculturation within and outside of curriculum time. A non-science related discussion on "how to improve my chemistry results" and an experiment on energy changes were used to allow the students to be accustom with the KB approach and the use of KF.

The KB learning cycle employed in the training consisted of five steps: setting the context, problematization, experimentation, consolidation and reflection.

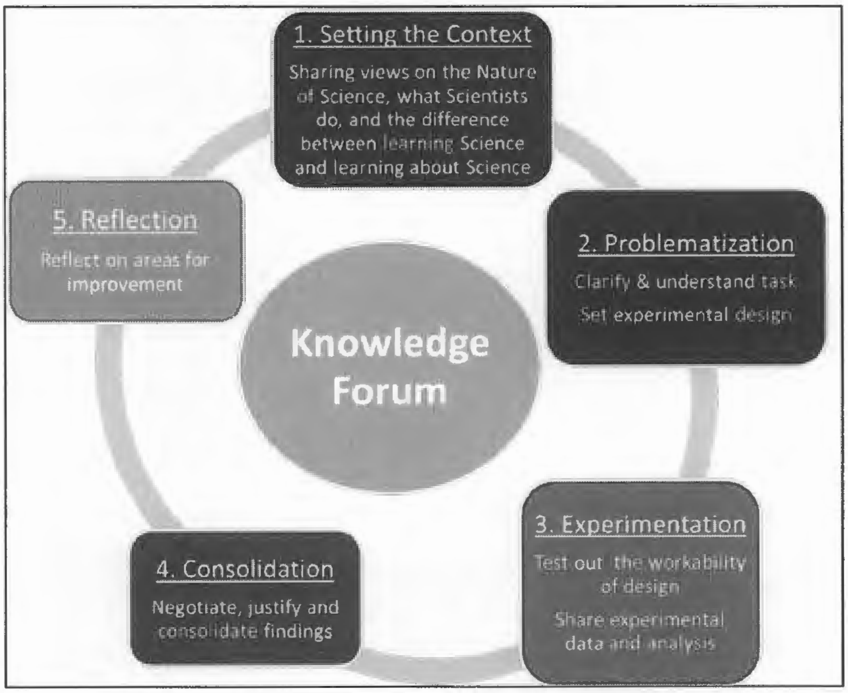


Fig. 1 KB learning cycle

In the **Setting the Context** phase, students took the role of scientists. They shared their views on the nature of science, the scientific approach in solving problems, and the difference between learning science and learning about science. In the **problematization** phase, students brainstormed their ideas and sought clarification to understand the task. In the **experimentation** phase, students suggested possible approaches to solve the problem. They improved the suggestions by asking clarification questions, providing more supporting evidence, posting more new information and connecting related ideas to make a rise above. In the **consolidation** phase, the group knowledge was built through negotiation and justification of their findings. In the **reflection** phase, the group reflected on their theories and applications, and shared their findings with other groups.

Most of the training sessions were conducted in the schools' computer laboratories. Only a few training sessions required students to work at home on their own computers. Since the students were working on chemistry-related tasks away from the chemistry laboratories, computer animations related to the tasks (virtual-lab) were made as supplemented information.

4. RESULTS AND ANALYSIS

4.1 KB Skills Development

During the enculturation, it was observed that the students' online interactions changed from the informal internet chatting style to the KB construction format. At the end of enculturation, they built-on peer's ideas constructively by asking questions, providing new information, discussing based on evidence, and generating new ideas without teachers' help.

The students were divided into groups consisting of 4 – 6 students during the KB enculturation. All the groups were given the same task to work on. Students were also encouraged to build on their classmates' ideas from other groups.

From the analysis of the students' discussions from two of the participating schools, the KB interactions depended greatly on the tasks. Examples of the interactions of the KB groups on reading and building on are shown in Fig. 2 and 3.

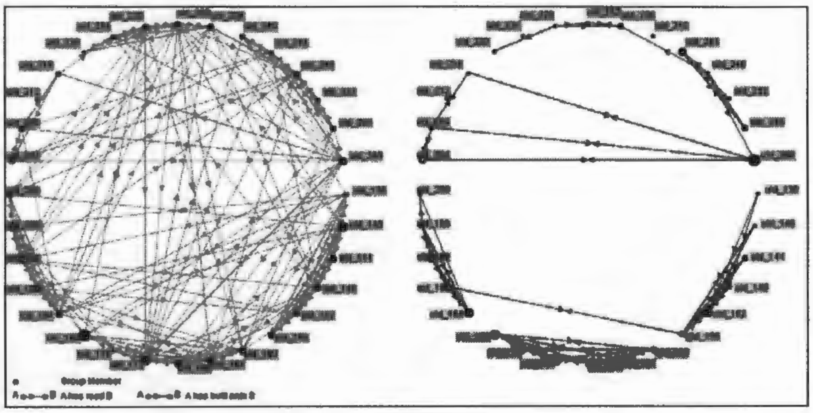


Fig. 2 Network of reading and building-on posts (School B)

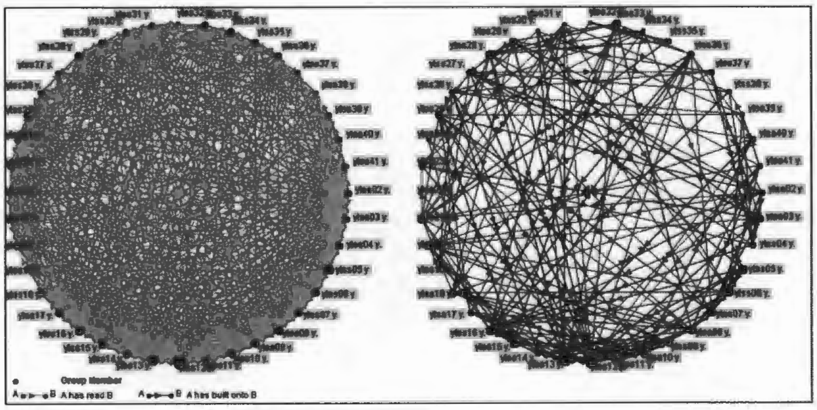


Fig. 3 Network of reading and building-on posts (School Y)

Great differences were observed in the interactions of the students in School B and Y. Intense reading and building activities within groups were observed in both schools, but the inter-group reading and building activities were different.

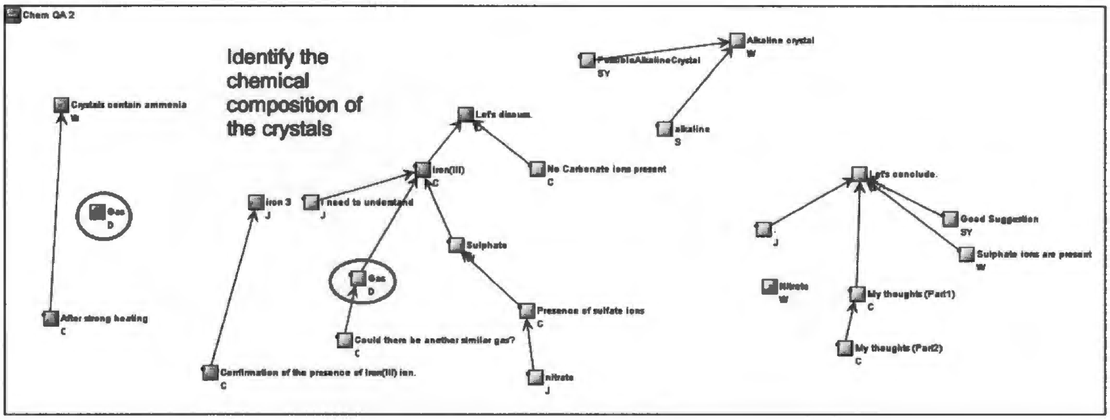
The inter-group activities from the students in School B were few, although time was allowed for the students to view the discussions of the other groups. It was because the tasks given to students were related to qualitative analysis, which had well defined ways of solving the problems and the answers were specific. The specific tasks limited the development of diverged ideas. The students found that the discussions and conclusions from the other groups were similar to theirs. There was no need for them to build-on the postings of the other groups.

The task for the students in School Y was an open question: "Design a heat pad with the chemicals provided". The answers from each group might not be the same. Students were interested to view the suggestions and discussions from the other groups and built-on (asked questions and gave feedback) the postings.

From the results of students' interactions, we found that KB discussions worked better for opened tasks. This observation agrees with one of the twelve KB principles – Real and Authentic Problems. When the students' curiosity and interest were intrigued, they would naturally be more eager to find out more and participate more actively in the KF discussions.

4.2 Development of Ideas

KB provided the opportunities for students to develop ideas. By posting ideas online, students had the chance to consolidate their knowledge and theories. When they were questioned by others and asked to give supporting evidence, their knowledge was further deepened. An example for students in School B discussing on the qualitative analysis was shown in Fig. 4.



<u>Fig. 4 Development of Ideas (School B)</u>

Since KF documented ideas and allowed students to read their peers' ideas, students of lower ability had the opportunity to incorporate the posted ideas as scaffolds and built up their own knowledge. In Fig. 4, it is found that student D, a low ability and shy student, did not participate much in the discussion. He had posted up an idea but it was out of the discussion culture. Other students did not build on his posting. After he had read other's postings, he improved his posting and was able to join the discussion. He could develop ideas to solve the problems in the task after the KB discussion, and complete the worksheet.

4.3 Diversity of Ideas

The student-centred KB activity encouraged creativity and diversity of ideas. The students of School Y were working on the same chemistry task: "Design a heat pad with the chemicals provided". Both the treatment and control classes were allowed to access the internet and the virtual-lab when completing the task. This open task allowed diversity of ideas. Group discussions were conducted in the two classes and individual reports were collected. The results of the treatment and control classes were shown in Table 2.

Treatment Class Four different correct designs	
1	Silver nitrate with magnesium Reason: Reaction produced the highest temperature increase.
2	Copper(II) nitrate with magnesium Reason: Silver nitrate is very expensive. Copper(II) nitrate is cheaper
3	Lead(II) nitrate with magnesium Reason: Give a reasonable increase in temperature and the reagents are cheap.
4	Mix several pairs of reagents (expensive pair mixed with cheaper pair) Reason: Give sufficient heat to last for 1hr.
Control Class Two different correct designs	
1	Silver nitrate with magnesium Reason: Reaction produced the highest temperature increase.
2	Copper(II) nitrate with magnesium Reason: Silver nitrate is very expensive. Copper(II) nitrate is cheaper

Table 2. Various Designs from the Classes (School Y)

From the results, four different workable designs were proposed from the treatment class with KB discussion and two from the control class. The KB groups had more feasible ideas and deeper discussions. They did not just consider the costs and the highest temperature. They also considered the required temperature and the time of lasting. The diversity effect of KB dynamic, mentioned by Woodruff & Meyer (1997) was observed.

4.4 Pre- and Post- tests

A pre-test was conducted in School B, just after the students learnt the topic on "separation of mixtures". The students had 30 minutes to work on a Chemistry task: "To separate a mixture of aluminium, green tea and sugar". In both the treatment and control classes, 15 minutes of traditional group discussions were conducted before the written report.

During the pre-test discussion, it was observed that the discussion was shallow. Students only brainstormed ideas but lacked the depth. Some students had difficulty to develop good plans. The average score of the control class was better than that of the treatment class.

Towards the end of the KB enculturation, the students of the two classes had finished the topics on qualitative analysis. A post-test was conducted. Students were asked to design tests on the purple crystals (found by a team of explorers in a cave) to identify the chemical compositions. The descriptions of the crystals had enough hints for the students to identify the three ions presented. Students from the treatment class were allowed to use KF to discuss for 30 minutes. They were supplemented with virtual laboratory animations, which were visually repeated the tests described in the worksheet. The students in the control class were allowed to have discussion too, but without KF and animations.

It was found that all the students were able to finish the written report in 30 minutes. From the student-interview, some students from the control class could not understand all the hints from the written descriptions, but all the students from the treatment class understood the hints with the help of the animations. Many students from the control class did not deduce the composition of the crystals correctly, but most of the students from the treatment class were able to deduce the composition of the crystals through KB discussion. The results of the pre- and post-tests were shown in Tables 3 and 4.

	Classes	Mean (Total mark =21)	SD	t-test on results (2-tail equal variances)
Pre-test	Treatment	9.86	1.07	0.027 (results significant)
	Control	10.63	1.39	
Post-test	Treatment	14.41	2.77	3.54×10^{-6} (results significant)
	Control	10.26	3.13	

Table 3. The results of the pre- and post-tests: Comparing individual tests (School B)

Class	Tests	Mean (Total mark =21)	SD	t-test (2-tail equal variances)
Treatment	Pre-test	9.86	1.07	5.32×10^{-11} (results significant)
	Post-test	14.41	2.77	
Control	Pre-test	10.63	1.39	0.584 (results not significant)
	Post-test	10.26	3.13	

Table 4. The results of the pre- and post-tests: Comparing the improvements (School B)

Both of the pre- and post-tests had similar rubrics, with same categories and total marks. In the pre-test, the control class performed better than the treatment class, but in the post-test, the treatment class performed better than the control class (Table 3). The differences in the results were significant. Regarding on the improvement, significant improvement was shown in the treatment class, but insignificant in the control class.

The results showed that KB discussion with the supplement of virtual-lab animation helped the students to understand the task better. The KB discussion also deepened the knowledge of the students on the task, so the results of the students were good and the improvement was significant. On the other hand, the students of the control class, with discussion in traditional way, maintained their standards and had no significant improvement.

4.5 Perception Survey on Collaborative Learning (CoL) & Self-Directed Learning (SDL)

Surveys on SDL and CoL were conducted on the treatment and the control classes in both schools. The same survey was conducted before the KB enculturation and after the post-test. The eight survey questions were adopted with permission from the 'learning practice scale' from Goh, Chai and Tsai (2012). The questions were set in a 7-point scale.

4.5.1 Results of Self Directed Learning (SDL) Survey

Self-directed learning (SDL) involves initiating personally challenging activities, and developing personal knowledge and skills to pursue the challenges successfully. (Gibbons, 2002)

SDL Survey	Class	Mean (Total mark =28)	SD	t-test (2-tail equal variances)
Pre-Survey	Treatment	4.93	1.26	0.509 (results not significant)
	Control	5.09	1.18	
Post-Survey	Treatment	5.04	1.15	0.041 (results significant)
	Control	4.39	1.23	

Table 5. Results of SDL survey in School B

Comparing the results from the classes in School B, there was no significant difference in the results of the pre-survey. It showed that the students in the two classes had similar SDL attitude in their studies before the KB intervention. After the KB enculturation, the students showed better SDL attitude than the control, and the difference was significant. That is, the students in the KB class were more eager to look for information relating with the topics which they learnt from the Internet.

SDL Survey	Class	Mean (Total mark =28)	SD	t-test (2-tail equal variances)
Pre-Survey	Treatment	5.19	1.16	0.095 (results not significant)
	Control	4.75	1.16	
Post-Survey	Treatment	5.53	1.22	0.052 (results not significant)
	Control	4.94	1.46	

Table 6. Results of SDL survey in School Y

School Y showed insignificant difference in the pre-survey and almost significant difference in the post-survey ($p=0.052$). The KB class had better results than the control, but the difference was not significant enough.

4.5.2 Results of Collaborative Learning (CoL) Survey

Collaborative learning (CoL) is where students work in pairs or groups to solve a problem or to achieve a common learning objective. (Barkley et al., 2005)

CoL Survey	Class	Mean (Total mark =28)	SD	t-test (2-tail equal variances)
Pre-Survey	Treatment	4.14	1.39	0.793 (results not significant)
	Control	4.04	1.57	
Post-Survey	Treatment	4.07	1.48	0.017 (results significant)
	Control	3.17	1.31	

Table 7. Results of CoL survey in School B

CoL Survey	Class	Mean (Total mark =28)	SD	t-test (2-tail equal variances)
Pre-Survey	Treatment	3.98	1.54	0.315 (results not significant)
	Control	3.62	1.67	
Post-Survey	Treatment	5.19	1.02	0.000 (results significant)
	Control	3.91	1.52	

Table 8. Results of CoL survey in School Y

Comparing the results from the classes in School B, there was no significant difference in the results of the pre-survey, but showed significant difference in the post-survey. The results from the classes in School Y were similar, insignificant difference in the pre-survey, but significant in the post-survey. It showed that the collaborative skills in group communication, discussion and development were improved significantly by the KB culture in both schools. The KB learning cycle adopted in this project encouraged the students to collaborate and learn from each other. The ground rules for online discussions also helped students to frame their learning and online interactions with each other. These factors had contributed to the significant differences in the perception survey for the treatment classes in both schools.

5. CONCLUSION

The results of the students from the two schools showed that teachers who adopted the KB approach had positive effects on the development of students' understanding on scientific knowledge and improved their ability to plan scientific investigations. KB facilitated the interaction among the students especially in the opened tasks discussions. KB encouraged quiet students to participate in the discussions and scaffold low ability students. Through the 'construct and reconstruct' processes, students were able to develop and build on each other's ideas and deepened the understanding.

From the perception surveys, the collaborative skills were developed successfully during KB training, but the self-directed learning habit was only cultivated in one of the schools. Insignificant results in the other school might be due to shorter enculturation period.

Lastly, the animations used in the tasks also acted as a good visual aid to support the students. Although same information was given in words in the worksheets, students found that the animations indeed helped them to understand the problems more.

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