Appendices

Appendix A. Reading List

1) Driver, R., Guesne, E., & Tiberghien, A. (1985). *Children's ideas in science. (Chapter 1: Children's ideas and learning of science).* Philedelphia: Open University Press.

2) Garnett, P. J., Garnett, P. J., & Hackling, M.W. (1995). Students' alternative conceptions in chemistry: A review of research and implications for teaching and learning. *Studies in Science Education, 25*, 69-95.

3) Kruse, R. A., & Roehrig, G. H. (2005). A comparison study: Assessing teachers' conceptions with the chemistry concepts inventory, *Journal of Chemical Education*, *82*(8), 1246-1251.

4) Liew, C. W. (1995). A predict-observe-explain teaching sequence for learning about students' understanding of heat and expansion of liquids, *Australian Science Teachers Journal, 41*(1), 68-72.

5) Posner, G. J., Strike, K. A., Hewson, P. W., & Gertzog, W. A. (1982). Accommodation of scientific conception: Toward a theory of conceptual change. *Science Education, 66, 211*-227.

6) Stepans, J. (1996). *Targeting students' misconceptions: Physical science concepts using the conceptual change model*. Idea Factory: Florida, USA.

7) Taber, K. (2002) *Chemical misconceptions: Prevention, diagnosis and Cure, Vol: 1. Theoretical background*. Royal Society of Chemistry: London, UK.

8) Tasker, R., & Dalton, R. (2006). Research into practice: visualization of the molecular world using animations. *Chemistry Education: Research and Practice, 7*(2), 141-159.

9) White, R., & Gunstone, R. (1992). *Probing Understanding*, *(Chapter 3: Prediction-Observation-Explanation).* London: Falmer Press.

10) Zirbel, E. L. (2007). Teaching to promote deep understanding and instigate conceptual change. *Bulletin of the American Astronomical Society*, 38, 1220.

Appendix B. Some pre/post question examples prepared by participants

Pre/posttest question prepared by S11:

The reaction,

$Fe_3O_{4\,(s)} + 4\,H_{2\,(g)} \rightleftharpoons 3\,Fe_{(s)} + 4\,H_2O_{(g)}$

occurring at constant temperature in a closed container, is a reversible reaction.

In a reversible reaction like the above, when does the reverse reaction start?

a. When the forward reaction is completed

b. When the forward reaction is started and some products are formed

c. When the reactants are completely consumed

d. When the products are completely consumed

I chose (a) / (b) / (c) / (d), because, ____

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Pre/posttest question prepared by S16:

Let's suppose that the following reaction reaches chemical equilibrium in the 10th minute. When 13 minutes have passed after the reaction has started, which sentences below are true and which are false? Explain your choice briefly.

$$2\ XY_{2\ (g)} + Y_{2\ (g)} \rightleftharpoons 2\ XY_{3\ (g)}$$

a) None of XY_2 molecules turn into XY_3 molecules anymore (T) (F)

b) None of XY_3 molecules turn into XY_2 and Y_2 molecules anymore (T) (F)

c) Both forward and reverse reactions still continue (T) (F)

d) There are only the products in the container (T) (F)

e) There are both products and reactants in the container (T) (F)

f) The rate of forward reaction is equal to the rate of reverse reaction (T) (F)

Pre/posttest questions prepared by S20:

1) 0.05 M HBr and 0.01 M H_2S are two different acid solutions with different concentrations. 0.05 M HBr is a stronger acid than 0.01 M H_2S. If you change the concentration of H_2S solution to 0.25 M, how does the strength of H_2S change? Will 0.25 M H_2S be stronger or weaker than 0.05 M HBr? Explain your answer.

2) Order the following acid solutions according to their acid strength (from weak to strong). Explain why you ordered them in that way.

0.05 M HCl

0.1 M CH_3COOH

0.25 M HCl

0.01 M CH_3COOH

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Appendix C. Exemplary quotations selected from self-reflection reports written by the participants

Characteristics of misconceptions mentioned by participants		
Category of the response	**Exemplary participant quotations**	**ID**
Misc. are very resistant to change	*"It is really difficult to correct a misconception even though it is easy for students to form it. I realize this after I checked posttests of students. I got shocked when I see that some of them still have the misconception even though I focused only that misconception in the classroom"*	S20
Misc. are very hard to eliminate and require special effort	*"They are very difficult to change. If we want to change them, we have to work hard on that, for instance, we should confuse their beliefs with some events that they can observe and then reconstruct a more scientific idea"*	S1
Teachers need to use special strategies to eliminate misconceptions	*"When students construct wrong or alternative ideas about a subject, they can be diagnosed and eliminated only with alternative instructional methods instead of traditional methods".*	S13
They influence further learning negatively	*"If you can't reveal their misconceptions and their reasons, they will form new misconceptions while learning new subjects/issues"*	S7
Several different misconceptions may exist	*"After I administered my pretest, I saw that each student has a unique misconception"*	S3
Misc. are deeply rooted	*"I have learnt from this experience that misconceptions are deeply rooted. Previous learnings can cause misconceptions. If students learned a concept in a wrong way, this affects their further learning unless their roots are not treated by the instructor"*	S12
Misc. make sense for the students	*"They make sense for the students. They present a plausible explanation about the phenomena and for this reason students don't need to change them. The most important thing that I learned about misconceptions is that students strongly believe that their ideas are correct".*	S8
Misc. are hidden	*"Misconceptions might stay forever, if they are not noticed. They are not generally come to light if teachers do not spend effort to diagnose them"*	S17
Misc. are like a snowball, getting bigger and bigger if not corrected	*"I think that misconceptions are like a snow ball, if they are not corrected, they are going to be bigger and bigger"*	S19

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Problems perceived by the participants as a reason for an ineffective lesson		
Category of the response	**Exemplary quotations from reflective reports**	**ID**
Inadequate explanations/elaborations were provided by me	*"At the end of the lesson, I thought that I didn't have a good explanation part. I didn't ask the students the difference between their prediction and observation, so they couldn't be aware of their misconceptions. If this plan is applied to more interested students with a well-prepared explanation part , I believe that it can work better"* & *"… Furthermore I haven't planned to make them engaged with the animation and try it for several different conditions, so this made something unclear in their minds, I think".*	S11 & S18
Most of the students were not familiar with the prerequisite knowledge and/or skills needed to grasp the content at hand	*"Many students were not knowledgeable about fundamental things related to this topic. For instance they couldn't represent atomic or molecular elements, they couldn't differ between elements and compounds"*	S9
There was not enough time to cover what I had planned	*"At the beginning of the lesson, I realized that students have other misconceptions related to my topic besides the ones that I planned for my lesson, so I felt that I should start the topic of equilibrium reactions from the beginning. As a result, I experienced timing problem"*	S16
Classroom management was a problem for me	*"I faced classroom management and organization problems. That was because students were not used to do laboratory activities. Using balloons in the experiment took their attention, but they tended to play with them. This made the lesson a little bit unorganized and chaotic"*	S4
Most of the students didn't hold the misconception assigned to me before the lesson	*"I think my lesson plan was appropriate for elimination of the misconception, but students in this classroom didn't have such a misconception, so my lesson was not so much effective"*	S5
The quality of the animations used by me was not good enough	*"One of my simulations was problematic. It was not working correctly in some parts, so this affected students' understanding negatively"*	S15
The use of a real demonstration would have been better than use of an animation	*"I couldn't have appropriate laboratory conditions, real experimentation might be more effective to teach that gases have weight".*	S6
It wasn't a good lesson plan	*"My lesson plan was not clear and students didn't understand what was going on. Explanations are not good because the prediction part is already weak".*	S21
The misconceptions assigned to me was hard to eliminate	*"I think that electrochemistry is one of the most difficult concepts in chemistry, there are lots of students who have some difficulties to understand this topic, so misconception that I worked on was really hard in terms of diagnosis and remediation"*	S22
Students are not motivated enough for the lesson	*"Being the last lesson hour of the day affected their motivation, making the lesson at earlier class hours could have been better"*	S5

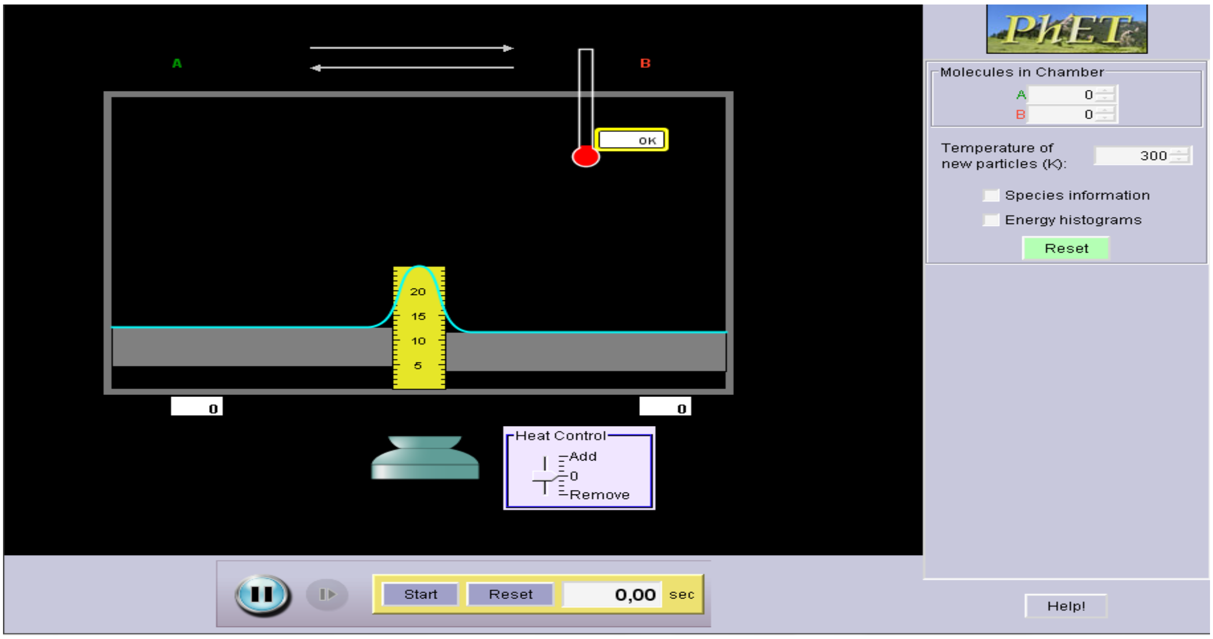
Appendix D. Sample lesson flow designed by S16 to eliminate Misconception 8 (Chemical equilibrium is a static process)

Prediction Phase:

The "Reversible Reactions" simulation (which is freely accessible via internet) (http://phet.colorado.edu/simulations/sims.php?sim=Reversible_Reactions) will be opened.

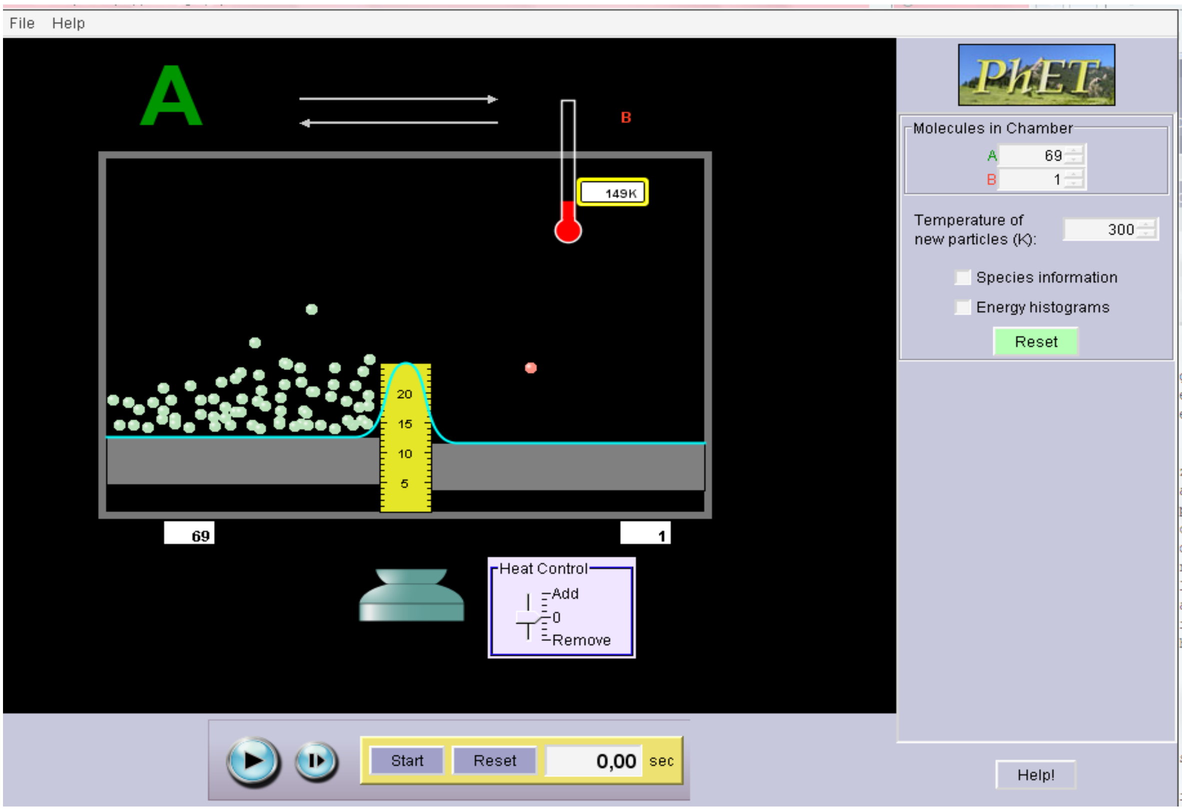
At first, on the screen simulating the equilibrium reaction A $\rightleftharpoons$ B, no molecule is pumped into the container. The potential energy levels are set to be the same on this screen (See Screen 1). The following question will be asked, and the students are asked to write their answers individually on the handout given:

- What will happen if I pump some type A molecules into the medium? Explain your prediction.



Screen 1

When they finish writing their answers, the simulation will be started by pumping some type A molecules into the medium. They will see that type A molecules go to the other side as type B molecules, as seen in Screen 2 (forward reaction).



Screen 2

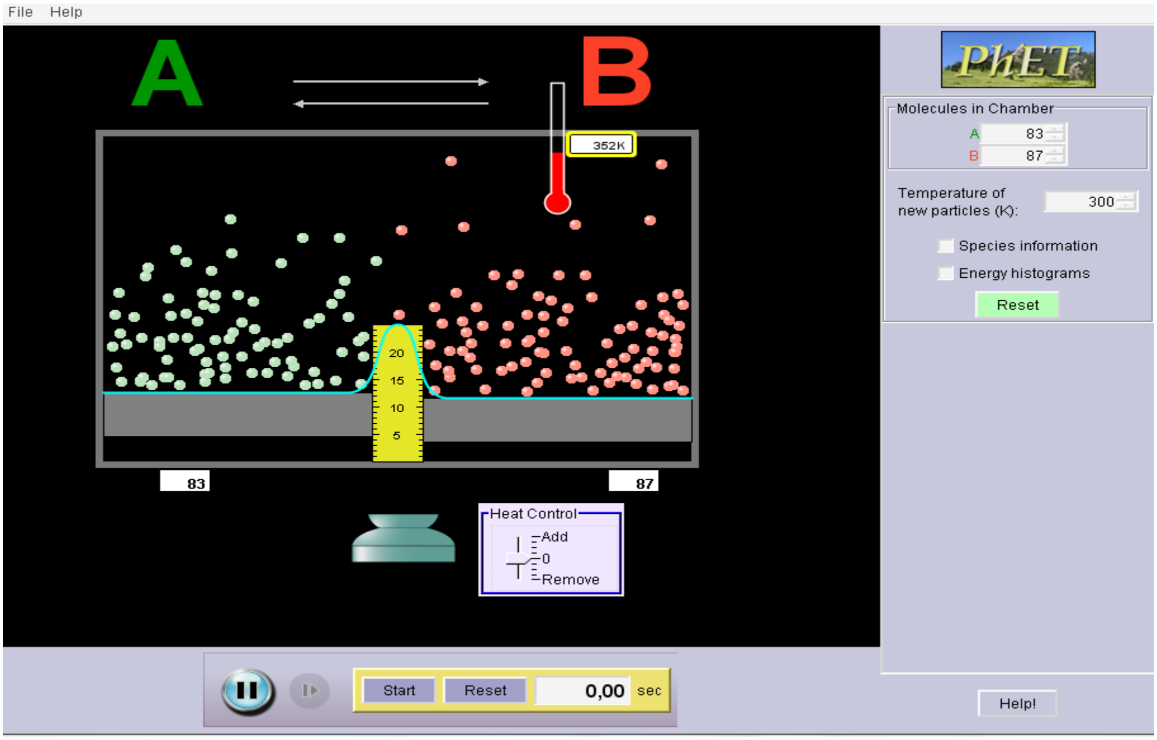
Next, the simulation will be paused, as seen on Screen 2, and students will be invited to answer the Part 2 questions on the handout:

- What will happen next?
- Will all type A molecules turn into type B molecules?
- Will the reaction stop after a certain amount of time?
- How do we classify this process (static or dynamic)?

Students are asked to answer the questions first individually, and then to share their answers with one of their classmates. Lastly, a whole class discussion will be held so that students can hear each other's predictions.

Observation Phase:

Next, the teacher will continue to show the simulation from the paused point, and students will have a chance to observe what will happen next.



Screen 3

In the simulation, when type A molecules are pumped into the medium, they start to go to the other side as type B molecules (forward reaction). At the same time, Type B molecules also turn into type A molecules (reverse reaction) and this process continues indefinitely. After some time, the reaction reaches the equilibrium position in which the number of both type A and type B molecules come to constant values and stop changing. Students can see that the reaction still goes on after the equilibrium position.

After watching this simulation, the teacher again asks students to answer the same Part 2 questions in the handout.

Explanation Phase:

Students will be asked to compare their initial ideas with the current ones and think about the following questions:

- Although the reaction seems to be dynamic at the molecular level, what do we see at the macroscopic level?
- While we perceive that the reaction has stopped at the macroscopic level, do the equilibrium reactions stop in reality?

Then the following questions will be discussed:

- Why are the equilibrium reactions like that?
- Why do we call them equilibrium reactions?
- What is equal and what is not equal at chemical equilibrium?

The teacher tries to arrive at the point that "reactions do not stop at the equilibrium position, so chemical equilibrium is not static as it is seen in macro world".

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Handout

Part 1

What will happen if I pump some type A molecules into the medium? Explain your prediction.

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Part 2

Explain all your answers for the following questions.

What will happen next?

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Will all type A molecules turn into the type B molecules?

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Will the reaction stop after a certain amount of time?

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How do we classify this process (static or dynamic)?

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