



The Effect of a Visually-Based Intervention on Students' Misconceptions Related to Solutions, Solubility, and Saturation in a Core Materials Course

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Abstract

Students' understanding of the concepts of solutions, solubility and saturation has been widely studied, and findings have revealed that students come to a course with misconceptions; most of which have not changed significantly since earlier instruction. One study revealed that, while the majority of students defined solution and solubility concepts correctly, only a small fraction matched these definitions with the correct pictorial representations. Other studies have also shown poor student performance on both pre and post topic test quizzes. The most common misconception from the literature showed that students often mistake a saturated solution for a supersaturated solution. This usually occurs when they are shown a beaker containing a solution with undissolved solute at the bottom. Likewise, a smaller percentage of students also assumes that the same solution is unsaturated because the precipitates have not "mixed" in. The research question posed in this paper is "what is the effect of a visually-based instructional intervention on students' misconceptions related to solutions, solubility and saturation". Data from this 2012 study were compared with that of a 2011 class when the concepts were taught using only phase diagram graphs. The visually-based intervention was a two-part worksheet activity. It was carried out at the beginning of the topic of phase diagrams in an introductory materials science course. In the first part, sugar was added gradually to a beaker containing water until it reached saturation and then retained some undissolved sugar at the bottom. The second part showed a saturated solution that was allowed to evaporate undisturbed. Students worked in teams to discuss the solutions and construct their own meaning of the concepts. A two-part pre and post topic quiz was given before and after phase diagram instruction. The first part showed three beakers, each containing supersaturated, saturated and unsaturated solutions for which students had to choose which one of the three types of solutions each beaker contained. The second part of the quiz asked students to explain their reasoning. Percentages of correct answers were calculated and the scores were normalized using the Hake Gain method. Analysis of pre and post test results showed that students performed better in 2012 than in 2011. The most common misconceptions remained the same. In particular, students still chose the saturated solution as being supersaturated, although the percentage that did was smaller in 2012. After instruction, an average of 25% of the explanations were correct in 2011 compared with 42% in 2012. Post test analysis of students' explanations showed that the reason most incorrect answers were due to a lack of understanding of the role of solubility limit of solutes in solution.

Introduction

Many studies have investigated middle school through college students' conceptions of different aspects of chemistry. Some of these concepts include: conservation of mass and atoms¹⁻³; particulate nature of matter^{4,5}; chemical equilibrium⁶; macroscopic, atomic, and molecular properties^{6,7}; heat and temperature³; liquids and solutions^{2,3}; phase changes^{1,9}; dissolution¹³; solubility and solution^{1, 2, 10-15}; and much more. By eliciting students' thoughts or conceptions about a phenomenon, researchers have been able to gain access to students' understanding. The resulting information has been used to identify "errors" in students' thinking, predict sources of

the “errors”, and develop a framework for designing materials to correct the “wrong” conceptions.

Literature Review

Misconceptions

Students come into class with prior knowledge or conceptions¹⁹. When students’ conception of a phenomenon differed from the correct scientific explanation, they are said to possess “alternative conceptions” or “misconceptions”^{15, 25}. Research shows that students’ misconceptions do not occur in a vacuum. Misconceptions are derived from multiple sources; they could be products of students’ prior knowledge, their interpretations of everyday events, their life experiences, or a result of incorrect teachings^{11, 14, 16}. Teaching-related misconceptions may occur: when concepts are abstract or too difficult to learn; phenomena under study cannot be directly observed; or a macroscopic change occurred from an unobservable microscopic phenomena¹⁷; when there is no connection between microscopic and macroscopic phenomena; or when nothing in the everyday world intuitively leads to an understanding of a phenomena¹⁸. Nonetheless, students’ knowledge does not always consist only of misconceptions. Sometimes, they exist as combinations of misconceptions and correct conceptions, or they may be fragmented and not connected for effective use¹⁷. Research shows that it is often difficult to correct a misconception by just explaining the correct concept. This difficulty tends to be strongest when the misconception has been useful for past learning⁷.

Students’ prior conceptions can act as useful foundational knowledge or can act as barriers to future learning⁷. They become a hindrance to learning when they are misconceptions and hence, must be corrected before learning can take place. Learning occurs when students’ prior conceptions have either been accepted or modified by new information to create a new conception that is accepted by the community of experts. This indicates that learning is an interaction between old and new knowledge^{19, 20}. Duschl & Osborne²¹ explained that new knowledge may go through one of four processes during the learning process. It can be restructured (re-organized), adapted (modified), rejected (not compatible with old knowledge) or discarded (irrelevant to new knowledge). It is when students’ prior knowledge cannot undergo the necessary restructuring / modification with new knowledge to form a correct and acceptable scientific explanation that there is a problem with learning. When this occurs, the new knowledge may be modified or restructured incorrectly; or it may be rejected and discarded completely. Therefore, correct learning can only occur when pathways for repairing misconceptions are employed.

Eliciting Misconceptions and Effecting Conceptual Change

Students communicate or express their misconceptions believing that they are correct²⁵. Using the appropriate means and accompanied by relevant questions or activities, it is possible to elicit misconceptions regarding any phenomena²⁵. Students’ misconceptions have been elicited using different methods such as interviews^{12, 13}, paper and pencil worksheets^{11, 14, 15, 24}, and free writing,²⁵ and free drawing²³. In most studies, researchers use a combination of these methods to gain in-depth access into how students are thinking about the concepts under investigation.

It is established that when students construct their own interpretations of the natural world, that sometimes these interpretations are incorrect and are difficult to change by instruction¹⁰. Research shows that, to change students' conception of a phenomenon, instructors must attend to certain factors related to students' prior knowledge and the process of executing instructions. First, instructors must be aware that students come into class with prior conceptions that may be: in the process of development,; may be incorrect,; or may be a mixture of correct and incorrect conceptions¹⁷. Second, instructors must know that, when some concepts are abstract, they pose special challenges for students to learn. Third, instructors must also know that incorrect conceptions cannot be changed by simply stating or calling students' attention to them. Lastly, instructional efforts must focus on identifying and uprooting these misconceptions so students can develop expert understanding of foundational engineering sciences^{15, 17}. One of the ways of “uprooting” misconceptions is to design instructional material or an activity that will cause cognitive dissonance (also termed cognitive disequilibrium or conflicts) so students can observe the fallibility of their prior conceptions and may become “open” to learn the correct conceptions^{9, 15}. During implementation of such an intervention, it is important to guide students to recognize patterns resulting from the interactions that are under study so they can construct or reconstruct their conceptions into correct scientific explanations^{17, 26}.

Students Misconception of Solution Types

Students understanding of solution types have been extensively studied using different methods. Many of the methods used pre and post topic quizzes to investigate change in students' misconceptions after traditional classroom instruction. Mulford and Robinson¹⁵ investigated students understanding of the effect of evaporation on sugar-water solution using a two-tier paper and pencil worksheet with a multiple choice question followed by an explanation section. Results from the study showed a slight change in students' misconceptions after traditional instruction. Their post test results indicated one-third (34%) of the students chose the correct answer that concentration stays the same. However, a majority (61%) thought incorrectly that it would increase. Also, analysis of students' post test written explanations showed that only a quarter (26%) believed that more salt formed at the bottom. About half (48%) believed the concentration remained the same in less water; while the others believed salt did not evaporate but remained in the water. Mulford and Robinson¹⁵ attributed the observed slight change in students' conceptions to be due to their lack of understanding of the concentration behavior of a saturated solution and the fact that behavior of solutions was not taught as part of the syllabus that semester.

Pinarbasi and Carpolati¹⁴ also used a similar two-tier paper and pencil multiple choice and explanation worksheet to investigate students' conceptions of three types of solutions, supersaturated, saturated, and unsaturated solutions. The paper and pencil task required students to match the correct definitions or name to schematic drawings of the three beakers containing solutions of differing concentrations and to also write an explanation for the answer chosen. Following the post test, sets of informal and formal interviews were conducted to confirm trends in students' conceptions. They also found little change in students' conceptions after traditional instruction. Their results showed that 78% of test takers chose the option that listed the supersaturated solution as the saturated solution and vice versa. Of the 17% who chose the

correct order of definitions for the solutions, only 4% were able to use this knowledge to match the definitions with correct schematic presentations. Their interview transcripts also revealed that students' believed a solution is supersaturated if it has undissolved solute; which could mean that students believed the undissolved solute is part of the solution. They concluded that students had a problem understanding the difference between saturated and supersaturated solutions, and that this misconception could be resolved through an understanding of how saturated and supersaturated solutions are prepared.

In a similar fashion, Krause²⁴ developed, as part of the Materials Concept Inventory or MCI, a pencil and paper multiple-choice quiz to elicit students' misconceptions, as related to understanding of three solution types. This worksheet was administered as pre and post tests before and after instruction in phase diagrams. Students had to pick the correct definition for each solution type and write an explanation for their chosen answer. Results showed a small change in students' conception even after instruction in phase diagrams. Test results showed that 63%, (58%, post), 43% (58%, post), and 77% (92%, post) chose the correct answers for supersaturated, saturated, and unsaturated solutions respectively. About 57% of the students had an incorrect answer for the saturated solution and over half of them thought the saturated solution was supersaturated because solute had fallen out. However, the only observed incorrect answer for the supersaturated solution was that for the saturated solution; which could mean that students may have attributed the presence of solute as an indication of supersaturation. Krause²⁴ concluded that instruction in phase diagrams alone was not sufficient to change students' misconceptions of the concept of solubility and the definitions of the three solution types.

Krause²⁴ also discussed students' misconceptions in terms such as misunderstanding of the concept of solubility, misunderstanding of solubility limit concept and wrong definitions. These categories provided insight into some of the causes of students' misunderstandings and were used to inform the development of an intervention aimed to target the misconceptions. The purpose of this study has been to investigate the effectiveness of the intervention/ instructional material developed to target students' misconceptions relating to knowledge of supersaturated, saturated and unsaturated solutions. The intervention was developed to cause cognitive dissonance and progressively lead students to develop the correct definitions for these solutions. The effect of this intervention will be examined by comparing changes in students' conceptions in the year 2011, when the intervention was not used, and the year it was used 2012. The aim of this study has been to determine if the intervention was adequate for changing students' misconceptions and also to suggest future improvements that may increase its effectiveness.

Method

Description of the Intervention

The intervention is a worksheet developed to enhance students understanding of supersaturated, saturated and unsaturated solutions through engagement in discussions about the process of how the different solutions were prepared. The assumption made here is that, when students understand how these solutions were prepared, they will be able to correctly define whether they are unsaturated, saturated or supersaturated. The pre-post test about solutions and solubility is shown in the Appendix as Figure 1 while the worksheets are shown as Figures 2 and 3. The

worksheet consisted of schematic diagrams of two beakers each filled with water. Teaspoons of sugar were gradually added into the beakers until both reached saturation. An extra teaspoon of sugar was added to beaker A so that excess solute could settle at the bottom while beaker B was left to evaporate; producing a supersaturated solution. Beaker B was left to evaporate until half of its solvent remained; after which a string attached to a supporting rod was lowered into the supersaturated solution so the excess solute in the solution could nucleate and crystallize on the string. At each step of this process, students were required to choose the most appropriate term that best fit the definition that described the type of solution in a given beaker and then write an associated explanation for their choice.

Participants

The participants in this study were the students enrolled in a section of an introductory material science class entitled "Structure and Properties of Materials." The one prerequisite is one class in College Chemistry. The course is required by students in Industrial, Mechanical, and Materials Engineering programs. Normally it is taken in freshman or sophomore year, but since about half of the engineering students are transfers, so there are also many juniors and seniors in the class. The class demography was as follows. The 38 students included: Aerospace Engineering (3 sophomores and 1 senior); Bioengineering (2 seniors); Chemical Engineering (4 juniors and 2 seniors); Industrial Engineering (3 juniors and 1 senior); Mechanical Engineering (8 sophomores, 7 juniors, 4 seniors, and 1 graduate student); 1 sophomore business major, and 1 junior Spanish major. All the students were taking the class for the first time.

Context

The intervention under investigation was administered after the students had taken a concept quiz on supersaturated, saturated and unsaturated solutions to assess prior knowledge as shown in Figure 1 in the Appendix. The questions on the concept quiz were developed in a prior study²⁴ using the guidelines provided by Hestenes^{28, 29} for the Force Concept Inventory. This concept quiz was administered as pre and post tests to capture change in students' conceptions during each of the two semesters under study. In the first semester (2011), the concept quiz was administered before and after instruction in phase diagrams. However in the second semester (2012), the intervention was implemented immediately after the pretest and before instruction. The same quiz was given again after the five-class unit on phase diagrams was completed. During the implementation of the intervention, students worked in teams to discuss their answers to the questions. At the same time, the instructor and teaching assistant walked around the room to probe students about their responses to the questions on the worksheet. This was followed by three weeks of instruction in phase diagrams where students had repeated opportunities to use the knowledge gained from understanding the concepts of supersaturated, saturated and unsaturated solutions to solve phase diagram related problems.

Result and Discussion

Before comparing the two years results from one class held in 2011 without the activity and one class held in 2012 with the activity, a simple t-test was conducted to show that the changes that were observed in students' conceptions were significant and due to the effect of instruction.

Students scores on the post tests averaged 1.96 out of 3 ($N = 28$, $SD = 1.07$) and 2.36 out of 3 ($N = 26$, $SD = 1.09$) for 2011 (no activity) and 2012 (activity) administrations respectively. The t-test concluded that the post test results were statistically significant at $t(27) = 9.70$, $p = 0.00$ and $t(25) = 10.85$, $p = 0.00$ in 2011 and 2012 respectively. This mean that students did not response randomly to the questions and the effect of the treatment(s) were statistically significant. Results from the two semesters under study are presented in Tables 1, 2, 3, and 4. A normalized form of the result, Hake Gain ³⁰, was calculated for both years. as well as for Krause ²⁴. Other studies in this paper did not calculate Hake Gain; hence were not included in this comparison. These results for 2012 and 2011 classes will be compared with each other and with those of prior similar studies.

Exit post tests scores for both visual matching and written explanations were higher in 2012 than 2011 (Tables 1 and 2). On the schematic matching (*Visual*) section, Hake Gain values for 2012 were .65, .48 and .35 while those of 2011 were .14, .26, and .37 for unsaturated, saturated and supersaturated solutions respectively. Krause's²⁴ prior study also showed Hake Gain values of .65, .26, and .14 for the three solutions respectively. The above numbers showed the same Hake Gain value for both Krause's²⁴ study and 2012 results for the unsaturated solution; this may be an indication that students' performance remains the same for this particular question, irrespective of the type of accompanying instruction. Nonetheless, students' performance was moderately higher in 2012 than in Krause's²⁴ for the other two solutions. Likewise, results also showed that the 2012 study was a significant improvement over Pinabasi and Canpolat⁴ where only 17% of test takers correctly identified the saturated and supersaturated solutions. When post test written explanations were compared for both 2012 and 2011 data (Tables 1 and 2), the 2012 results showed higher values of about .22, .10, and .17 Hake Gain over those of 2011 for unsaturated, saturated, and supersaturated solutions, respectively. Overall, it appeared that the 2012 intervention was an improvement over lectures in phase diagrams alone.

Table 1: Categorization of Correct Answers and Explanations for 2011 Study (N=28) in Percentage

	Unsaturated			Saturated			Supersaturated		
	Pre	Post	Hake Gain	Pre	Post	Hake Gain	Pre	Post	Hake Gain
<i>Correct Visual Matching</i>	79%	82%	.14	32%	50%	.26	32%	57%	.37
<i>Correct Written Explanations</i>	25%	25%	0	18%	36%	.22	7%	14%	.08
Categories of Writing Explanations									
<i>Correct Written Explanations, CWE</i>	25%	25%	0	18%	36%	.22	7%	14%	.08
<i>Partially Correct Explanations, PCE</i>	54%	54%	-	67%	46%	-	50%	39%	-
<i>Incorrect Explanations, IE</i>	21%	21%	-	14%	18%	-	43%	47%	-

*Visual: Matching of schematic representation with definition

Table 2: Categorization of Correct Answers and Explanations 2012 Study (N= 26) in Percentage

	Unsaturated			Saturated			Supersaturated		
	Pre	Post	Hake Gain	Pre	Post	Hake Gain	Pre	Post	Hake Gain
<i>Correct Visual Matching</i>	77%	92%	.65	42%	70%	.48	46%	65%	.35
<i>Correct Written Explanations</i>	31%	46%	.22	27%	50%	.32	8%	31%	.25
Categories of Writing Explanations									
<i>Correct Writing Explanations, CWE</i>	31%	46%	.22	27%	50%	.22	8%	31%	.25
<i>Partially Correct Explanations, PCE</i>	35%	31%	-	50%	31%	-	35%	38%	-
<i>Incorrect Explanation, IE</i>	35%	23%	-	23%	19%	-	58%	31%	-

Visual: Matching of schematic representation with definition

*Written: Students written explanations or reasons

Performance on individual questions will be discussed next. In 2011, Table 1 showed that of the 82% who correctly matched the unsaturated solution’s schematic diagram with its definition (*CE, Table 3*), only one third (25%) were able to explain it correctly (*VCCE, Table 3*). However in 2012, half of test takers (46% of 92%) were able to perform the same task. Nevertheless, the significant difference between the *CE* and *VCCE* percentages was also observed by Pinabasi and Canpolat¹⁴. Of the 78% that correctly identified the unsaturated solution, only 6% were able to explain it correctly. Therefore, it is a possibility that the schematic representation for this solution could have intuitively led the students to its correct definition. Krause’s investigation of students’ conceptions of the same solutions did not explore students’ ability to both correctly match and explain the phenomena relating to these three solutions simultaneously; hence that study was not relevant to this case. An important trend was observed when reported results for the unsaturated solution’s question were compared over multiple studies. Hake Gain values for Krause²⁴, 2012 and 2011 studies were compared, and results showed that they were the same for Krause²⁴ and the 2012 study (65); but much lower for the 2011 study (14). However when the actual post test results were considered, they turned out to be fairly comparable at 92%, 82%, and 92% for Krause²⁴, 2011, and 2012 studies respectively. Likewise, the Pinabasi and Canpolat¹⁴ study showed that 78% of students correctly perform a similar task. These data showed that students’ performances on this question are somewhat comparable. This implies that irrespective of the type of instruction implemented, students’ performance for this question tends to remain fairly close. Finally, the most common misconception for unsaturated solution seems to vary with each year’s studies (Table 4). However, due to high students’ performance on the visual section for this question; further analysis of its misconceptions was not conducted.

Table 3: Percentage Distribution of Combined Students' Answers and Explanations

Categories	2011 (N = 28)						2012 (N = 26)					
	*Unsat.		*Sat.		*Supersat.		*Unsat.		*Sat.		*Supersat.	
	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post
VCCE*	21%	21%	7%	25%	7%	14%	31%	46%	12%	35%	8%	31%
VCIE*	57%	61%	25%	25%	25%	43%	46%	46%	31%	35%	38%	35%
IVCE*	4%	4%	11%	11%	0%	0%	0%	0%	15%	15%	0%	0%
IVIE*	18%	14%	57%	39%	68%	43%	23%	8%	42%	15%	54%	35%

*VVCE: Visually Correct Explanation VCIE: Visually Correct Incorrect Explanation IVCE: Incorrect Visual Correct Explanation IVIE: Incorrect Visual and Incorrect Explanation.

As reported earlier, performance on the visual section for saturated solution's question was higher in 2012 (70%) than in 2011 (50%). Pinabasi and Canpolati¹⁴ found that only 17% of their test takers selected the correct order of names for similar schematic representations of the solutions while Krause³⁵ had 59% correct on the same question. These numbers support the fact that the intervention was a moderate improvement over lecturing. Table 3 showed that half of the students who correctly matched the solution also wrote correct explanations for it. However, the exact percentage differs with the 2012 post test showing a 15% increase over 25% observed in 2011. The 2012 number was higher than the prior study¹⁴ where less than 10% of students could have been categorized as VCCE. Consistent with past studies, results from both years' administrations showed that the most common misconception for a saturated solution was a supersaturated solution at 31% and 36% for 2012 and 2011 respectively^{14, 24}. Although no one thought a saturated solution was unsaturated in 2012 (Table 4), a small 19% did in 2011. These results indicate that the most difficult challenge that students had was distinguishing between saturated and supersaturated solutions. Analysis of students' explanations shows this problem may be due to their lack of understanding of the role solubility limit plays during dissolution.

Table 4: Schematic Visual Matching Answers in Percentages

Questions	2011 (N = 28)						2012 (N = 26)					
	Unsaturated		Saturated		Supersaturated		Unsaturated		Saturated		Supersaturated	
	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post
*Beaker A	7	11	32	50	61	39	8	8	42	70	50	27
*Beaker B	79	82	14	14	7	4	77	92	19	0	4	8
*Beaker C	14	7	54	36	32	57	15	0	38	30	46	65

*Beaker A = Saturated Solution Beaker B = Unsaturated Solution Beaker C = Supersaturated Solution

Students' performance on the supersaturated solution question was also higher in 2012 by a smaller 8% compared with 2011. This small change is suspected to have been caused by the focus of instruction. During instruction, significant attention was paid to the difference between the concentration of the saturated solution and those of the other two solutions. This extensive elaboration may have caused some students to focus more on concentration difference at the expense of the role of solubility limit on dissolution. This assumption seemed valid given that 23% of the PCE were a direct concentration comparison between supersaturated and saturated solution. The *VCCE* percent for this question was also reasonable high at half (31% of 65%) of all test takers with *VC*. This number showed a good improvement over 2011 study where only 14% performed the task correctly and likewise over Pinabasi and Canpolati¹⁴ study where a smaller 6% correctly did a similar task. The most common misconception for supersaturated solution was saturated (table 4) at 27% and 39% in 2012 and 2011 respectively. The 27% observed in 2012 was also a slight decrease from Krause's²⁴³⁵ 38%.

Finally, Tables 1 and 2 showed that more students had *PCE* in 2011 than in 2012. Smaller *PCE* values on the post test in 2012 showed that more students progressed from partial understanding to correct understanding than in 2011. Also, Table 3 showed lower *IVIE* percentages for 2012 and a comparable *VCIE* values for both years. Both of these values imply that more students progressed towards *VCIE* and *VCCE* in 2012 than 2011. However, small or no percentage change for *IVCE* category may be an indication that students' ability to write correct definitions for the solutions may be related to their ability to identify it.

Conclusions

This study investigated the effectiveness of a new two part worksheet developed to create cognitive dissonance in students' misconceptions of unsaturated, saturation and supersaturation solutions; with the ultimate goal of leading students to develop the correct conception of these phenomena. Comparison of post test results of the year without the intervention and the year with the intervention was implemented and showed a moderate increase in the percentage of students who were able to match the solutions to their correct definitions. Analysis of students' written explanations also showed that more students progressed to adequate understanding of these concepts in 2012 than in 2011; the year without the worksheet. Also, a significant increase was observed in the percentage of students who were able to correctly identify and define the phenomena. Traditional t-test showed that these improvements were statistically significant and were not due to randomness. Lastly, data also showed that future improvement of the worksheet and instructional efforts should not focus only on how saturated and supersaturated solutions were prepared; but also on the role of solubility limit in determining the differences in the concentrations of the three solutions.

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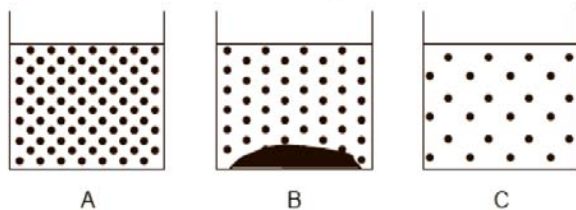
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30. R.R. Hake, (1998). "Interactive-engagement vs. traditional methods: A six-thousand-student survey of mechanics test data for introductory physics courses," *American Journal of Physics*. 66, 64-74

Appendix

Date _____ Solutions and Phase Diagrams Post Topic Concept Quiz 250 Class ID# _____

There are different concentrations of sugar in solution in beakers A, B, and C. One of the solutions is *saturated*. Another of the solutions is *unsaturated*. A third solution is *supersaturated*.

(Increased concentrations are illustrated by the density of the dots in the diagrams. The dots represent the dissolved molecules. The undissolved sugar in beaker B is shown as a darkened area.)



In the questions below, please circle the correct answer and then *give an explanation*.

1. **Solution A** is (**Saturated**, **Unsaturated**, **Supersaturated**).

Explain the reasoning you used for your answer.

2. **Solution B** is (**Saturated**, **Unsaturated**, **Supersaturated**).

Explain the reasoning you used for your answer.

3. **Solution C** is (**Saturated**, **Unsaturated**, **Supersaturated**).

Explain the reasoning you used for your answer.

Figure 1. Pre and Post Two-Tiered Test on Solutions and Phase Diagrams.

Activity – Is it Saturated, Unsaturated, or Supersaturated?

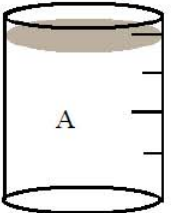
Carefully read ENTIRE page and descriptions, then go back and label solutions as requested

You begin with two identical beakers A and B, each full of pure water.

You add 1 teaspoon of pure sugar to each and stir, see that all of the sugar dissolves quickly

Part A1

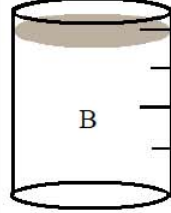
Solution A is:
a) Saturated
b) Unsaturated
c) Supersaturated



You now have two beakers, each full of water with 1 teaspoon of sugar dissolved

Part B1

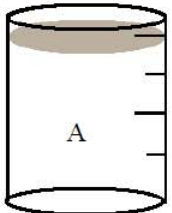
Solution B is:
a) Saturated
b) Unsaturated
c) Supersaturated



You add 1 more teaspoon of pure sugar to each and stir, and see that all of the sugar dissolves again.

Part A2

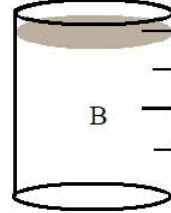
Solution A is:
a) Saturated
b) Unsaturated
c) Supersaturated



You now have two beakers, each full of water with 2 teaspoons of sugar dissolved

Part B2

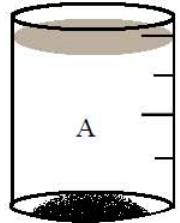
Solution B is:
a) Saturated
b) Unsaturated
c) Supersaturated



For beaker A, you add 1 more teaspoon of sugar and, even after stirring, there is exactly 1 teaspoon of sugar on the bottom of the beaker.

Part A3

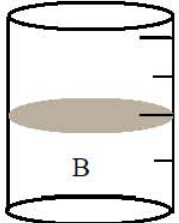
Solution A is:
a) Saturated
b) Unsaturated
c) Supersaturated



For beaker B, you let it sit uncovered for a few days to evaporate exactly $\frac{1}{2}$ of the water, leaving a half-full beaker of liquid that contains 2 teaspoons of sugar in solution.

Part B3

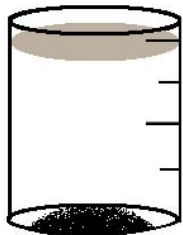
Solution B is:
a) Saturated
b) Unsaturated
c) Supersaturated



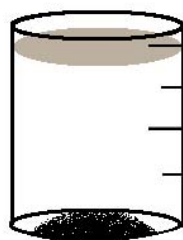
CONTINUES ON REVERSE →

Figure 2. Worksheet Page 1 on Process Activity for Determining Saturated, Unsaturated or Supersaturated Solution

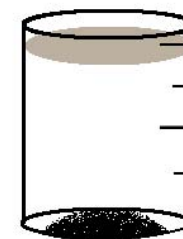
Use the following three graphics of this solution to show what is happening to the sugar in the system



Beaker A at ten minutes

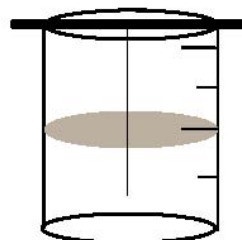


Beaker A at 30 minutes



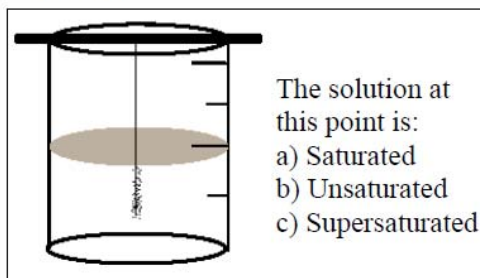
Beaker A at one hour

Now, you take beaker B and hang a string inside it.



After a few hours, you see small sugar crystals forming on the string, about 1/10 of a teaspoon's worth of sugar. The beaker is still 1/2 full of liquid.

Part B4



You cover the solution to avoid evaporation, and let it sit for a week. Large crystals form, and you determine that there is exactly 1 teaspoon worth of crystals on the string.

Part B5

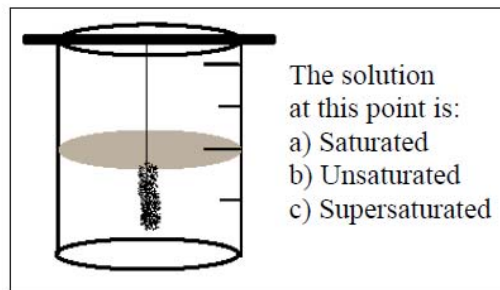


Figure 3. Worksheet Page 2 on Process Activity for Determining Saturated, Unsaturated or Supersaturated Solution