JOURNAL OF BALTIC SCIENCE EDUCATION
ISSN 1648-3898

INTRODUCING SELF-REGULATED LEARNING INTO EARLY PHYSICS TEACHING IN SERBIA: DESIGN, INITIAL IMPLEMENTATION AND EVALUATION OF A MULTI-STAGE SEQUENCE OF HOMEWORK AND CLASSWORK

Jelena Radovanović,
Josip Sliško

Abstract. *Applied research, carried out to examine the possibility of improving students' understanding of heat phenomena through multi-stage homework and teacher-supported classwork assignments, is described. These assignments, designed within the theoretical framework of self-regulated learning, enable students to overcome errors and doubts from the individual problem solving stage by peer interaction and teacher feedback and to reflect on individual and group learning experiences. They also promote the development of students' self-efficacy, critical consideration of information and error detection, making individual and group learning processes more visible to students and teacher. This applied research was conducted in an intact grade VII primary school physics class in Serbia. Analysis shows significant progress in students' understanding of the anomalous behavior of water and their ability to interpret a non-linear graph. The level of self-reflection outcomes depends mostly on the quality of teacher-supported group classwork. It is noted that students should improve expressive and critical thinking abilities.*

Key words: *graph reading in school physics, home physics experiments, inquiry-based homework, self-regulated physics learning, textbook error detection.*

Jelena Radovanović
Primary school „Slobodan Sekulic", Užice, Serbia
Josip Sliško
Autonomous University of Puebla, Puebla, Mexico

Introduction

Modern, knowledge-oriented societies bring with them the need for lifelong learning. The ever increasing pace of scientific and technological progress makes concrete memorized facts and procedures quickly obsolete in many areas of human professional and personal activities. It is, therefore, critically important to realign educational systems in such a way as to provide long-term benefits to learners by teaching them deeper underlying concepts, instead of shallow final outcomes of those concepts, to bolster creativity, critical thinking and expressive abilities (OECD/CERI, 2008). Effectively, students should be taught fundamental principles of scientific reasoning, so that they can continue learning individually or in collaboration, throughout their active lives, long after they have graduated from their formal education. Self-regulated learning, with its focus on learner-oriented reflective thinking and performances in problem solving, is regarded as one of the most important skills needed for lifelong learning (Ifenthaler, 2012).

External evaluation of education quality in Serbia (PISA and TIMSS), as well as the national testing results, have shown that the Serbian educational system has yet to adopt and implement modern understanding of student learning activities (Marinković, 2010). One of the investigations, TIMSS-FT 2007, has shown that science teachers in Serbia make insufficient use of teaching methods that encourage activation of higher and more complex cognitive processes, creativity, forming relations, application of knowledge to novel situations, individuality, initiative, freedom of choice and expression by the students. While most of the science teachers believe that homework assignments contribute to the deeper understanding of subject matter, such learning activities are not provided as frequently as in the case of mathematics (Djerić, Studen & Luković, 2007).

ISSN 1648–3898

Considering the problems listed above, an attempt was made to design a physics learning sequence which would include homework and classwork assignments in several complementary stages, whose objectives were to encourage primary-school students' individuality and help them develop the skills of presentation and argumentation while increasing the quality of both peer and student-teacher classroom interactions.

To inform the reader about the specific context in which this intervention and feasibility research was carried out, it is necessary to point out that there are two pre-university educational levels in Serbia. The first level corresponds to "primary school" ("osnovna kola" in Serbian), and it goes from grades I to VIII. The second level is called "middle school" ("srednja kola", in Serbian) and it stretches from grades IX to XII. Physics, as an obligatory, self-standing academic subject, is taught in primary school in grades VI, VII and VIII. At the middle school level, the curricular presence of physics varies depending on the school type, but it is commonly taught in grades IX and X. So, physics teaching in Serbian "primary school" can be considered as an example of "early physics teaching". In comparison, in some educational systems, one paradigmatic case is the USA; physics as a self-standing school subject may appear rather late (grade XII), after biology and chemistry courses. Such a conceptually unnatural order of highschool science courses provoked a strong curricular reform movement known as "physics first" (Lederman, 2001).

The basic idea behind the mentioned multi-staged homework and classwork learning activity is to introduce the practice of self-regulated learning (Low & Jin, 2012; Zimmerman & Schunk, 2013) into primary school physics teaching and learning.

The research goal of this feasibility study was to examine scientifically the possibility of improving seventh grade primary school (13 years of age) students' understanding of the water anomaly through multi-stage individual homework and teacher-supported group classwork assignments, designed according to the theoretical framework of self-regulated learning.

The basic learning goals planned for students were improvement of knowledge on the water anomaly phenomenon, and development of a better understanding of graphical representation in physics through interpretation of a non-linear plot of water volume versus temperature. Additionally, students' activities were directed towards development of life-long learning skills, such as critical consideration of information and error detection, along with students' argumentation skills and self-efficacy.

Besides the theoretical framework on which multi-stage homework and classwork was based and the information on how it was implemented, the paper presents qualitative analysis of students' achievements on two tasks related to the water anomaly. The focus of the analysis was on general educational skills and important elements of self-regulated learning, such as the ability to express doubts and concerns, and skills related to asking for and receiving feedback information when interacting with peers and teachers.

Theoretical Framework of this Applied Research: Self-Regulated Learning

As stated, the goal of this applied research was to introduce a multi-stage self-regulated learning sequence into early physics teaching in Serbian primary school and to evaluate its implementation feasibility. So, a brief review of the theoretical framework of self-regulated learning would be appropriate.

Regarding metacognitive aspects of learning, self-regulated learners plan, set goals, organize, self-monitor, and self-evaluate gained results at various points during the learning process. They are also very motivated, showing high self-efficacy, self-attribution and intrinsic task interest. In addition, self-regulated learners know and accept that learning results are better with more effort and persistence and within an adequate learning environment (Zimmerman, 1990). The success of self-regulated learning depends on students' abilities to activate and use in the best way metacognitive, motivational and behavioral resources and strategies.

According to Zimmerman (2002), the self-regulated learning process consists of three different phases:

a) Forethought or planning phase;
b) Performance phase;
c) Self-reflection phase.

Although self-reflection should be part of any purposeful performance process, here Zimmerman uses the term "self-reflection phase", as will be clarified later, in a very specific sense.

In the *Planning phase*, students activate all necessary knowledge and skills to understand the given problem and make a plan about how to solve it.

In the *Performance phase*, they monitor how they perform, whether some unexpected or unclear details appear, and verify the validity of their partial and final solution.

The *Self-reflection phase* is the most important part of self-regulated learning. In it, students are supposed to look back and critically evaluate their whole performance to find out what was learned and what was not. In the last case, they try to determine what might be the possible causes of their unsuccessful learning. In order to assist students in their self-reflective performance, students should be provided with adequate and timely feedback at every stage of the learning sequence.

Even if an activity, like keeping a mandatory learning journal, can, in principle, promote self-regulated learning, it does not do so without further teacher intervention. To make things worse, it might lead to decreased motivation (Fabriz, Dignath-van Ewijk, Poarch & Büttner, 2013).

Feedback is therefore important not only because it motivates students but also because it helps them verify their progress towards the more advanced level of knowledge, self-explaining what they are missing while reinforcing well-adopted scientific knowledge and fostering their self-regulation. Research into the educational aspects of feedback points out that it is preferable to analyze the process of receiving, rather than the process of giving feedback (Mayer & Alexander, 2011).

However, in an environment that is encumbered by almost exclusive use of classical lecture-based teaching, it was necessary to devote some attention to this part of the process and determine if students possess even the simple ability of asking for feedback and a desire to use it. It would benefit the students if they were able and willing to ask questions, such as "What did I do well (or wrong)?", "What other task-solving strategies can be used?" or "How can I better monitor my progress?", not only to provide them with additional information directly, but also to make the whole learning process more transparent, both to them and to the teacher.

This information, in turn, helps the teacher to set clear and appropriate learning goals. All of those questions can also be asked, and feedback received, not only from the teacher, but also from their peers, although peers' perceptions of shared self-regulated experiences may differ (Jones, Alexander & Estell, 2010). Peer feedback has additional benefits of fostering an atmosphere of collaboration in the classroom and helping students take ownership of their work and progress. On an individual level, peer feedback provides an opportunity to improve self-regulation by exposing each student to conflicting opinions, and by encouraging reflective and self-probing questions.

Methodology of Research

The Design of the Multi-Stage Learning Sequence

Students' self-regulated learning in the classroom can be promoted directly or indirectly (Kistner, Rakoczy, Otto, Dignath-van Ewijk, Büttner & Klieme, 2010). In the first case, the teachers should directly teach strategies of self-regulated learning. In the second case, teachers should design such learning sequences that are likely to lead students to practice the main elements of self-regulated learning. Due to curriculum restrictions (no time for teaching learning strategies explicitly) and the character of this research study (initial implementation and feasibility exploration and evaluation), an indirect approach was chosen to promote students' self-regulated learning by extending and redesigning classical homework activities.

Homework and classwork assignments were organized in several stages, providing students, in every single one and even more so in all of them together, with multiple opportunities to:

a) activate resources and strategies necessary for active learning (cognitive, metacognitive, motivational and behavioral), and
b) practice all phases of self-regulated learning (planning, personal and group performance and self-reflection).

The stages of the multi-stage sequence aimed at promoting self-regulated learning were the following:

First stage: "individual homework"

Similar to a classical homework, students are supposed to solve the given problem individually at home. In the new homework design, they are additionally asked to make a detailed account of all doubts and difficulties they perceived in understanding problem and solution.

Second stage: "group work in classroom or classwork"

In diverse groups, students examine collectively their individual solutions and discuss unclear points. One of the students makes a report on group activities and asks the teacher questions regarding any doubts that remain unresolved after the group discussion.

Third stage: "self-reflection homework"

ISSN 1648–3898

Based on the group discussion and feedback given by the teacher, students prepare the final version of their problem solutions and answers to questions which were parts of the homework assignment. These include a detailed account of their mistakes made during the first, individual stage and the way they made progress in every problematic part of the homework and teacher-supported classwork assignment.

The way in which activities are organized within this learning sequence is in accordance with the directions of the national curriculum framework for approaching learning and competence development, currently under development in Serbia (Razvionica, 2013). The document recommends encouraging interactions between teachers and students, as well as peer to peer interactions among students themselves, but with deeper meaning and value, rather than simply refreshing teaching routines. Interactions are necessary for meaningful participation of students in their own learning processes, because in that way students are gradually directed towards acquiring skills needed for life-long learning. This is an opportunity to take a step towards modern school and out-school learning that encourages the development of creative and responsible younger generations.

The Sample and Specific Individual and Group Tasks

This is an initial exploration of the possibility of introducing multi-stage homework and classwork, encouraging students to practice self-regulated learning (for example, to discover suppositional and reasoning mistakes by interacting with other students and the teacher). It was conducted on the intact sample of a single seventh grade physics class, taught by one of the researchers (J. R.) at a primary school in Užice (Serbia). An intact class of 19 students (13 years of age) took part in the activity, which was carried out on the topic of "Heat phenomena". Students were previously informed about the research aspect of the activity and agreed that their performances might be anonymously reported in a scientific journal.

After the unit on "Behavior of objects undergoing heating and cooling" was taught to the class, the students were firstly given the homework assignment consisting of three parts. It was emphasized that they should do the homework individually and pay attention to the final part – a description of all the unclear points they had encountered while solving the problem – since the next period would have them involved in activities which could help with resolving those doubts.

The **first task** required the students to perform a simple home experiment. Under the conditions of limited capabilities for performing experiments at school, home experiments with simple elements are a good way to increase students' interest in science (Breckenridge & Zweuifel 1993; Kipnis 1996; Roberts 1997; Logan & Skamp 2008; Newby & Winterbottom 2011).

They were told to pour water into a cylindrical cup, then mark the water level and measure its height (h_1). The cup was then to be placed into a freezer, resting on a flat surface. After the water was completely frozen, the level of ice in the cup had to be marked and measured (h_2). Students were encouraged to take photographs or make sketches of their experiments. After the experiment, the students were asked to (a) calculate the ratio between the levels of ice (h_2) and water (h_1), and (b) interpret the calculated ratio and explain the phenomenon observed during the experiment.

The **second task** of the homework required the students to carefully examine the diagram of super-cooled water's behavior during heating.

A plot showing the relationship between the volume of water and its temperature, as it was presented in their textbooks. The textbook made the following statement: "We can see that the volume of water at 0° C is the same as at 8° C." The students were asked to note if they thought this statement was correct or not, and justify their answer.

In the end, the students were asked to give detailed accounts of all the unclear points they encountered while doing the homework.

Full text of the homework assignment can be found in Appendix 1.

After the first part, in which the students made individual attempts to perform the tasks and to solve related problems, it was time for them to work in groups in the classroom (classwork). Five inhomogeneous groups were formed, taking care to balance them according to students' achievement levels in physics. Four groups had four members and one of the groups had only three students.

Students were given a worksheet during the class, containing pointers and questions for the group activity. It was emphasized that any unclear points remaining after the group discussion should be noted in their reports so that the teacher could respond to those doubts. The worksheet briefly described the homework assignment and asked the students to answer several questions, as a group.

Regarding the **first task**, students were asked if they had properly determined the ratio between the levels of ice (h_2) and water (h_1), whether the determined ratio was approximately the same for all the members of their group and should it be the same or not, what explanation could their group give for the observed phenomenon, and what individual home experiments from their group had the best presentation and interpretation.

In relation to the **second task** the students were told to compare the plots on in textbooks, make notes of any differences between individual textbook copies, and determine at which temperatures water would have the same volume, according to the plots. Students were asked to explain if the following sentence from their textbooks was correct or not: "We can see that the volume of water at 0°C is the same as at 8°C."

In most of the textbooks used by the students (Krneta & Stevanovic, 2010) the sentence is in accordance with the plot shown next to it (Figure 1, left). However, there is an error on the temperature axis on the plot in the 2009 edition of the textbook (Krneta & Stevanovic, 2009), in which the label value of 6°C is left out, leaving only the labels for -2, 0, 2, 4, 8, 10, 12, 14 and 16°C (Figure 1, right). Due to this typographical error, volumes corresponding to the temperature points of 0°C and 8°C aren't equal. As it turned out, only two students used this version of the textbook. Regardless of that, reading the plot turned out to be a daunting task for majority of the students.

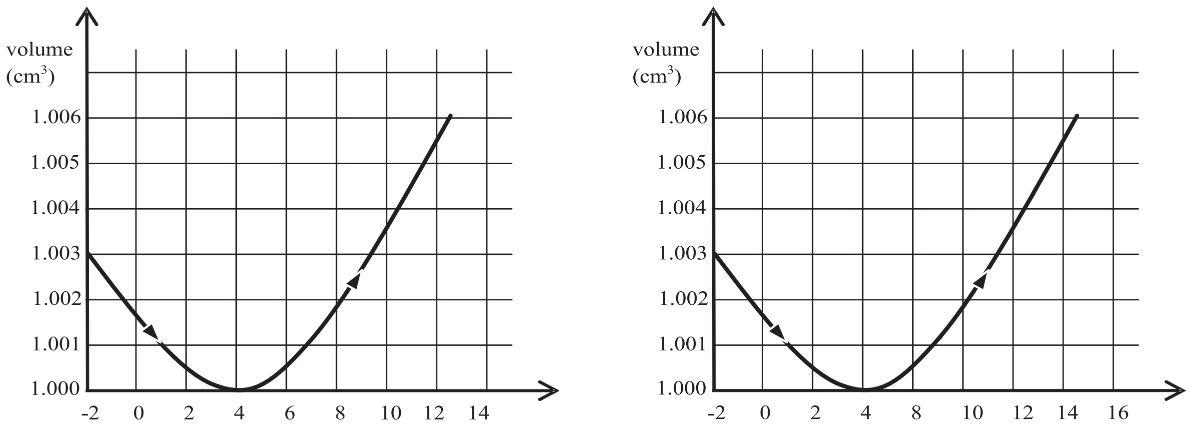

Figure 1: The correct (left) and the incorrect (right) water volume plots.

As a final note, the plot shows a significantly smaller change in volume of water (between 3/1000 and 6/1000), compared to what students witnessed during the experiment in which the volume of ice increased for about 100/1000. In addition, even at -2 °C, the water is not frozen. However, neither during individual nor group stage, did students mention any doubt related to this property of the plot.

Full text of the worksheet can be found in Appendix 2.

As mentioned before, students worked on two heat-related tasks during all individual and group activities. The first task is designed to make students perform a simple experiment and then answer questions related to it. This will test not only student's skills in performing the experiment using provided instructions, but also his or her ability to make relevant conclusions based on measurement results. The second task requires the students to interpret the plot showing the relation between the volume of water and its temperature, thus testing their knowledge of mathematical tools used in physics.

According to the Serbian educational standards in mandatory education for the subject of physics (Anicin, Verbić, Krnata, Marić, Nikolić, Stanković & Tošović, 2010), the requirements of the first part are in accordance with the standards:

FI.2.5.5. – Student knows that the volume of a body depends on its temperature.

FI.2.7.3. – Student can conduct an experiment, given instructions.

FI.3.7.1. – Student can reach relevant conclusions based on measured results.

The second task is mainly related to the educational standard:

FI.2.6.3. – Student can use and interpret plots of physical values.

The FI.2.5.5, FI.2.7.3 and FI.2.6.3 are a part of the middle-level standards which should be met by at least 50 % of the students, while FI.3.7.1 is in an advanced level, expected to be reached by 25 % of the students.

 ISSN 1648–3898

Results of Research

Results of research show that applying self-regulated learning methods through designed multi-stage homework and teacher-supported classwork can lead to significant progress in students' understanding of the water anomaly phenomenon. In addition to that, the research has confirmed that students whose education is predominantly based on classic lectures tend to lack experience in expressing their doubts and in asking a teacher for additional information. Continuous encouragement directed towards the development of those skills should be planned. In this section students' achievements during all three stages of the learning sequence will be presented and qualitatively examined. The data is primarily related to the degree to which the physics teaching goals were reached: understanding of the water anomaly phenomenon and of mathematical foundations of physics - interpreting the water volume versus temperature plot. In addition to that, important elements of self-regulated learning behavior were monitored: the ability to express doubts and concerns, and students' skills related to asking for and receiving feedback while interacting with peers and teacher.

Individual Homework Stage

All 19 students turned in their individual assignments on time.

18 out of 19 students performed the experiment correctly and presented the procedure using sketches or photographs. Only one of the students stated that the levels of water and ice were the same. He drew a sketch of cups with water and ice at the same level, but without any additional comments.

Three students properly calculated the ratio between the levels of ice and water during the individual stage. The rest of the students, instead of the quotient, calculated the difference between h_2 and h_1.

As for the explanations given during this phase, 11 students stated that the experiment demonstrated the phenomenon called "water anomaly", but without any further details. Six students properly named the phenomenon, with additional specification that "the water is a liquid whose volume increases as its temperature falls". Two students failed to recognize the water anomaly, and said only that they witnessed "a heat phenomenon".

Only two of the students stated that they had concerns related to the first task.

The second task deals with interpreting the graphical plot of water volume versus temperature (Figure 1) and explaining if their textbook sentence "We can see that the volume of water at 0° C is the same as at 8° C" is correct or not.

Both students that had the faulty plot in their textbooks noted the omission during the first stage.

As for the 17 other students, who had the proper plot, 14 said that the claim was correct, and three said that it was wrong. Half of the students failed to elaborate their claims, and only three of the remaining students explained that "helper lines" should have been added to the plot in order to compare volumes at the given temperature points. Only one student made the proper connection between the observed experiment and the water anomaly. Explanations included two examples of improper generalizations and one case of alternative conceptions related to density of solids and liquids, which will be examined in more detail in the discussion section.

This task was difficult for most of the students: 78% of them stated that they had concerns. Most of the unclear points were related to students' inability to elaborate a justification of the answer.

Group Work Stage (Classwork)

Students' reports revealed that three of the groups had constructive discussions, resulting in progress shown by their respective members. Students from these groups provided good descriptions of mistakes they made when determining the ratio between the levels of ice and water, concluded that the ratio should be the same in all experiments, and properly explained the observed phenomenon. One problematic point was the question of whether the calculated ratio is or should be the same for all students, and why. Students from one of the groups stated that the ratio between the levels was the same because all of the house freezers keep approximately the same temperature. Students from the other two groups noted that the ratio was the same, but offered no explanation. Still, none of these groups asked for the teacher's help with this unclear point, even though that possibility was offered more than once. Namely, the activity was framed as teacher-supported group classwork.

Looking at the reports of the remaining two groups, one can conclude that they had little success in the group work stage, and that they also failed to use the option of getting supporting help from the teacher. The fourth group submitted a report containing only a few sentences, without even offering a common explanation for the experiment. The fifth group's reporting member didn't submit a report.

The situation from the first task, in which three groups made significant progress and the remaining two groups did not, was encountered again when the second task was considered. The three groups, which were involved in a lively discussion related to plot interpretation during the class, also asked questions related to that topic in their reports. Two of those groups simply asked the teacher for an explanation on how to read the plot, and whether the statement was correct, while one group was somewhat more detailed in describing their doubts and asking for help. In contrast, the fourth group's report said just: "We had doubts in the second task, on whether all the plots were the same, but we later realized that they were." Students from the fifth group didn't submit their report.

Self-Reflection Homework Stage

Having received answers to the questions stated in their reports, the students turned in the final versions of their homework assignment.

All final versions of the homework assignment contained the properly calculated value of the ratio between the levels of ice and water. There was general improvement in understanding and explanation of the observed phenomenon. This stage saw 6 more students stating that the experiment demonstrates the increase in water volume due to reduction of its temperature. Being so, the total number of correct answers increased from 6 to 12. Two of the students that failed to even mention the term "water anomaly" in their original versions did so at this point, leaving 5 students with only the proper name of the effect, but still with no detailed explanations (Figure 2).

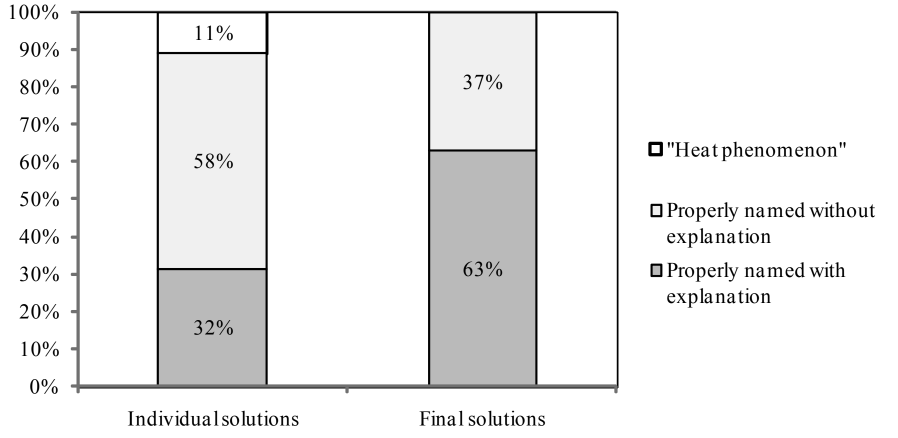

Figure 2: First task - naming the phenomenon observed during the experiment in individual and final solutions.

All of the students now agreed that the textbook sentence on the equality of water volume at 0˚C and 8˚C was correct. The two students with the faulty plot in their textbooks again stated what the problem was and referred to the correct plot, which they had considered together with the rest of their group. They had, together with another 11 students, given good explanations as to why the statement on volume equality was correct. Those explanations included statements that the plot shows an increase in volume as the temperature was reduced below 4 degrees, but also as the temperature was increased above 4 degrees. After the group activity, these students realized that they needed to draw additional helper lines at 0˚C and 8˚C to be able to compare the volumes properly. The remaining 6 students wrote that the sentence was correct: four offered no explanations and two only mentioning the water anomaly (Figure 3).

ISSN 1648–3898

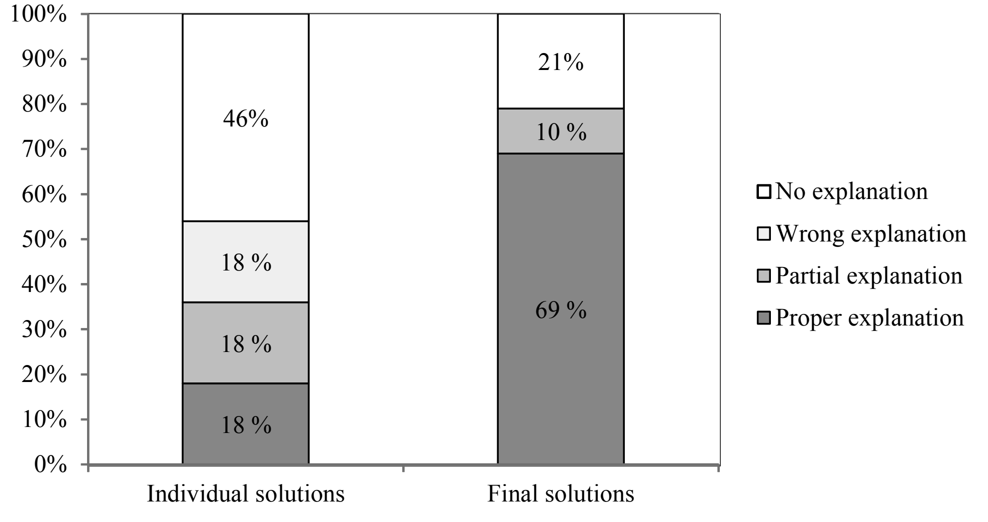

Figure 3: Second task - evaluating the sentence on equality of water volume at 0°C and 8°C in individual and final solutions.

Limitations

Since the research was conducted towards the end of academic term, conditions were lacking for a comparison between the sample group and a possible control group, not subjected to the described learning sequence. In addition to that, the research was conducted on a sample of 19 students. Future research should include a larger sample and introduce a control group.

Discussion

Individual Homework Stage

As mentioned in the results section, all of the students submitted their individual homework assignments, on time and without copying, which was a good starting point for this kind of activity. One can also notice a positive correlation between the achieved level of digital culture and students' motivation to prepare quality presentations of their homework assignments.

Several assignments with detailed descriptions and a series of sketches and photographs stood out, clearly demonstrating the devotion with which those students approached the task. For example, one student stated:

"I have poured water into an approximately cylindrical cup, with flat bottom and relief patterns, but only on the outside, and used a felt-tip pen to carefully mark the level. I proceeded to measure the level of the water, taking care to hold the ruler straight upward. Then I have placed the cup into a freezer, onto a flat surface. The level of ice is greater than the level of water. I have marked it carefully and measured it."

Another student also paid a lot of attention to the correctness of the measurement procedure, and provided a sketch of what could be expected if the cup was not placed horizontally, commenting on an unasked, hypothetical situation: the cup, in which water is freezing, is placed on a tilted surface. By this comment, the student justified his claim in the text that the cup with freezing water must be in the correct position in order to get a usable ice level for the height measurement. This was clear from the comment below the drawing, which said: "(The ice level would be horizontal) if the cup would have been at the horizontal surface." This is a very nice example of spontaneous self-explanation behavior, which is very important in building sound understanding (Chi, De Leeuw, Chiu & LaVancher, 1994).

Only 15% of the students were able to properly calculate the ratio between the levels of ice and water during the individual stage. One of the correct calculations was described like this: "Since the water level in the cup was 6 cm, and ice level is 6.5 cm, I conclude that the ratio between levels of ice and water $h_2{:}h_1$ = 6.5 cm: 6 cm = 1.083. We could say that this ratio is approximately 1.1."

Most of the students calculated the difference between h_2 and h_1, instead of the quotient. This error is similar to mistakes students make in solving word problems using an incorrect arithmetic operation because they failed to understand problem properly (Cummins, Kintsch, Reusser & Weimer, 1988).

Apparently, most of the students never even considered whether the procedure was correct, with only one of the papers stating a concern: "I have calculated the ratio between the levels of ice and water, but I don't know if I have done it correctly". This suggests that many students lack the ability to critically evaluate their solutions. This claim is supported by the fact that only one out of every three students was able to identify the observed phenomenon in the individual stage, and yet we encountered only a single concern: "I am not sure how to explain the phenomenon witnessed in this experiment." Although the students were expressly required to explain what they have observed in the experiment, 68% of them have failed to do so, and, at the same time, never stated that they had encountered unclear points in this task.

The second task was "reading" of the graphical plot. Students were asked to evaluate whether the textbook statement was correct or not and to justify their answers, which required them to consider the plot carefully. As mentioned before, one of the textbook editions has an error in the plot. Exploring students' skills for textbook error detection might be an interesting line of research in physics learning.

In the involved sample, only two of the students had the textbook with the error in the plot. They have both noticed the error, and made the following observations:

"The plot is missing number 6, which means it is wrong. I don't know if one could tell for sure if the sentence is correct."

"The claim is not correct because the plot is not in order – it doesn't have all the numbers for temperature."

As for the 17 other students who had the proper plot, 14 said that the claim was correct, and three that it was wrong.

Only one of the three students who stated that the claim was incorrect provided an explanation: "The statement is incorrect because the plot first shows the volume decrease at low temperatures, which is not true, because the volume increases as the temperature goes down; then it shows the increase in volume at high temperatures which again is not correct. Water is different than other liquids – when the temperature decreases, its volume increases, and when the temperature increases its volume goes down, which is called the water anomaly."

This is a really important comment, because it gives us not only insight into how non-linear plots of changes in a physical quantity can be interpreted by students, but also into students' ability to "expand" definitions of some physical phenomena.

During the follow-up interview with the student, much better insight into her thinking was obtained: As for the plot itself, she thought that the section of the plot to the left of the minimum depicted a reduction in volume because "it goes down, and the arrow on the plot also points down", while the section to the right of the minimum "shows the increase in volume because the arrow points upwards and the line itself is climbing up". Since the water anomaly is explained in the textbook as "the effect of water expanding while cooling at temperatures between +4°C to 0°C", the student said that she "thought it is logical that the unusual behavior of water exists even when it is being warmed, and that, unlike other liquids', its volume would then decrease."

This is an example of a student's improper generalization of a fact or a textbook statement. This behavior is frequently present in mathematics learning, even at the university level (Stylianides, Stylianides & Philippou, 2004).

Of the 14 students who said that the claim regarding equal volumes of water at 0°C and 8°C was correct, three argued that "if one draws lines on the plot, one can see that it is the same volume at both temperatures". One of these students added: "This happens because water expands at both lower and higher temperatures than 4°C." Three students said that the claim was correct because of the water anomaly, since its volume would increase even when it was cooled down, and 6 students offered no explanation.

Two students picked the correct answer, but with the wrong explanation. One of them said: "The statement is correct because water expands at lower, and contracts at higher temperatures." This statement reflects a similar thought pattern of an improper generalization, as in the previously described case.

The second student obviously considered density instead of volume, and claimed: "The lower the temperature, the higher the density. As the temperature increases, the density decreases." One can find out what happened by looking at his stated doubts: "I didn't know how to elaborate on the 2nd task, but then I remembered that when one holds an ice cube in his hand, which is, of course, at higher temperature, the ice melts, and its density decreases." This is another example of a known alternative conception related to density: solid bodies always have higher density than liquids (Muralidhar, 1988).

ISSN 1648–3898

Most of the students (78%) stated that they have concerns related to the second task, but they usually pointed out their inability to elaborate their answers, without providing any more details. This is one of the more precise comments on the individual stage tasks: "Homework was interesting, especially the first part with the experiment. I have some doubts regarding the second part of the assignment. I really don't know how to interpret the plot. It doesn't look like the plots we had when we were learning about motion. It is strange."

Group Classwork Stage

Three groups of students made significant progress during this stage. As mentioned before, these students worked together to notice the error in the calculation of ratio between levels of ice and water, and then corrected it. The phenomenon that the experiment illustrates was properly named and explained. They also gave rather objective evaluations of the quality of individual assignments. One illustrative example is:

"In our group, Ana (a pseudonym) has given the best presentation of the home experiment. The images are clear and show all the details. She interpreted the experiment well and is the only one in our group that has properly determined the ratio between h_2 and h_1. This is the best-looking homework and it was presented using PowerPoint".

In this stage the students were also asked if the ratio between the levels of ice and water should be the same or different for everyone, and why. Answering this question was a weak point for all three groups during their work on the first task. Only one of the groups offered the answer that the ratio should be the same because everybody has freezers with approximately the same temperature. By saying so, the students made it clear that they failed to grasp that the same ratios express the fact that the relative volume increase in the water – ice transition (volume of ice / volume of water) must be the same for any quantity of water because it is an intrinsic physical property of the water. Instead of such a conclusion, students attributed the sameness to the supposedly same temperature in house freezers, which is an environmental variable. A similar tendency to consider the temperature as a main causal variable in explanation of phase changes was found in other studies (Paik, Kim, Cho & Park, 2004).

In general terms, temperature-based accounts of an experimental fact are another example that students are prone to choose *ad hoc* causal explanations containing known and easily observable variables. For instance, students' explanations of floating and sinking contain mostly obvious features (size, form, weight) as causal variables and rarely use "hidden" buoyant force of water which, with the gravitational force, plays a basic causal role (Gang 1995; Yin, Tomita & Shavelson, 2008).

Although they were informed about the opportunity to ask the teacher any questions related to the task, none of the groups did so, again showing that students, whose education is dominated by the classical lecture-based teaching, lack the habit of analyzing problem solutions and asking for additional information or hints.

In spite of this weak point, the activities undertaken by the three groups can be considered as productive, keeping in mind all the progress that was made on the first and second task, which the majority found difficult during the individual stage.

The students were especially interested in interpreting the plot, leading to lively discussions during the class. Group stage results related to this task can be noticed primarily by examining the final individual students' assignments. Group reports themselves contained much less content than the classroom discussions. This suggests that expressing concerns in written form can be a demanding task for students with limited writing experience. In other words, the students need much more physics-related writing tasks in order to become "competent writers" who are able to take advantage of their written expressions in the process of science learning (Glyn & Muth, 1994). It is known that, especially in the case of older learners, talking and writing are mutually supporting processes in construction of scientific knowledge (Syh-Jong, 2007).

Two groups chose to simply ask the teacher for help with reading the plot, while one of the groups made a more detailed comment:

"Our group has three identical plots and one which is different due to a printing error (it lacks the 6°C label on the temperature scale). We didn't even interpret this plot, but we used the correct ones. However, we are unsure on how to proceed, since the plot is not a straight line. The caption says that it depicts expansion of water, but the line goes down and then backs up again, so we don't know if the water is sometimes expanding and sometimes contracting, and therefore we can't tell if the statement on volumes at 0°C and 8°C can be correct. Although, when we draw helper lines over the plot, the claim seems to be correct."

The teacher (J. R.) has noted that these two groups had difficulties during the group discussion in the classroom.

Attempts were made to repeat the explanations on what should be done and additional hints were given, but the only progress made was with regards to calculating the level ratio, while other elements of the task remained poorly done. Since only a single class period was planned for the group activity, there was no opportunity to shuffle the groups in order to improve efficiency. This also implies that, when planning for future activities, groups should be formed with extra care and that their compositions should possibly be checked before the activity begins, in order to enable successful group work on the given tasks.

Self-Reflection Homework Stage

By comparing the students' answers in the individual and self-reflection homework stages, we can observe that significant progress was made, at the group level, in the overall solution quality and understanding of phenomena related to the water anomaly. It should be noted that the quality of the final, self-reflected version doesn't depend as much on the correctness of the initial version and students' individual ability, as it does on the quality of the group activity.

As for the first task, the percentage of students who properly named and explained the phenomenon observed during the experiment rose from 32% in the individual stage up to 63% in the self-reflection stage. For example, one student, who had only named the phenomenon during the individual stage, provided a significantly more detailed answer during self-reflection:

"The experiment I have conducted represents phenomenon called water anomaly. This is said to be an anomaly because the volume of water increases as the water is cooled down, while other liquids have their volumes reduced. This gives us ice, and since the mass remains the same, and the volume is larger, ice density is smaller than water density."

Only one student was able to properly calculate the ratio between the levels of ice and water in the initial version of homework assignment, whereas in the final version every student did so. Surprisingly, only 4 students stated that it was the group activity stage that helped them comprehend that ratio didn't mean the difference but the quotient between levels h_2 and h_1. An example is:

"When I calculated the ratio between the levels of ice and water, I looked for the difference $h_2 - h_1$. However, during our group talk we realized that the ratio doesn't mean difference but quotient. We should divide these two numbers. We all did that during the past class and corrected our errors."

Significant progress was achieved in the second task as well. Most of the students saw the interpretation of a non-linear plot as a difficult task in the individual stage, with almost 50% of the students unable to give any explanation on the validity of the volume equality claim. In their final versions, approximately 70% of the students gave complete explanations, reflecting their ability to interpret the plot. However, even here we only encountered a small number of students that clearly stated that the better solution was the result of a group effort. For example, one of the students made a drawing of the plot and described:

"During the past class we realized that regardless of the fact that the plot is not a straight line, we should add helper lines, in order to enable us to compare the volumes at given temperatures. I drew a sketch and marked the lines blue so that they can be seen easily. We see that the volumes are approximately equal at 0°C and 8°C."

While it is evident that students learn through group activities and by considering answers to the questions they have asked of their teacher, and that they fix their mistakes using that knowledge, only a few students could clearly express that important learning fact in their self-reflection reports. To make such conclusions more likely in the future, the final self-reflecting task should also contain a small table for self-evaluation, offering them a scale of 1 to 3 on which to grade: the quality of their individual solution, the quality of the final solution, the influence of the group activity and the influence of expert solution provided by teacher on the quality of the final version of the assignment.

Conclusions and Implications

Based on the results of this initial applied research on implementation and feasibility of the self-regulated learning on the example of heat-related phenomena topic taught in the seventh grade of a primary school in Serbia, it is evident that students can make significant progress in their understanding of studied phenomena when going through the three described individual and group stages of self-regulated learning while carrying out the homework assignment. This methodology helps students reach the required Serbian educational standards. While

ISSN 1648–3898

at the individual stage only a few correct solutions were seen, after the second, teacher-supported group stage the quality of the solutions at class level improved significantly, so that the required Serbian educational standards were reached within the suggested percentages.

The quality of the final, self-reflected version of the homework assignments depends not only on the correctness of the initial version and students' individual abilities, but, above all else, on the interaction established among students during the classroom-based and teacher-supported group stage. It is therefore necessary to pay special attention to the group forming process. Students' communication skills, both among peers and with teacher, should be checked in a timely manner, so that the selected problem is tackled in the most efficient way possible.

This applied research has revealed that students, whose education is dominated by classical lecture-based teaching, lack experience and skills needed to express their own opinions, point out doubts and concerns and ask for feedback. This unfortunate situation can be improved only by systematic introduction of self-regulated learning sequences into the everyday school practice. Systematic application of this method of learning would help students to acquire the habit to reorganize their knowledge and skills, and to evaluate their own progress, which are important elements in adopting life-long learning model. Although only a minority of students exhibited spontaneous self-explanation behavior, permanent application of self-regulated learning sequences could lead to significant improvements in that aspect of learning.

Regardless of the fact that some of the students' skills needed more work, it is clear that, through finding the errors and fixing them, the students became far more involved in task problems and questions than they would be in the case of routine homework assignments. To additionally test the quality of learning, future research should include a comparison between two groups of students, doing the same homework assignment in the traditional way and in self-regulated learning methodology designed and carried out in this research, and then administering a knowledge test at the end of the treated conceptual area. This paper lacks such a comparison because the heat phenomena topic was taught at the very end of the school year, and there were no possibilities to involve a control group.

For the teacher, the multi-stage homework and classwork learning activity enhances the visibility of the individual and group learning processes and represents an additional time-saving opportunity for identifying known and unknown alternative conceptions and replacing them with valid scientific ideas and knowledge.

The students involved in this initial research were for the first time ever asked to evaluate the correctness of a textbook statement. Developing critical thinking and error detection skills are some of the key goals of this activity. The students were successful in detecting the printing error in certain copies of the textbook, although, as mentioned before, their abilities to express the observed facts should be further worked on.

Acknowledgements

Participation of the second author in this applied research was possible thanks to his sabbatical research project "*Active physics learning online*" supported by CONACyT Mexico in the period August 2012 – July 2013.

The authors would like to thank Dr. David R. Sokoloff (Professor of Physics at the University of Oregon and past President of American Association of Physics Teachers) and Dr. David Brookes (Professor of Physics at the Florida International University) for their valuable comments and generous help with improving English language in this article.

References

Anicin, I., Verbić, S., Krnata, M., Marić, V., Nikolić, B., Stanković, S., & Tošović, R. (2010). *Obrazovni standardi za kraj obaveznog obrazovanja za nastavni predmet fizika*. [*Educational standards for the end of mandatory education for the subject of physics*]. Beograd: Ministarstvo prosvete Republike Srbije, Zavod za vrednovanje kvaliteta obrazovanja i vaspitanja.

Breckenridge, J., & Zweuifel, F. (1993). *Simple physics experiments with simple materials*. New York: Sterling.

Chi, M. T., De Leeuw, N., Chiu, M. H., & LaVancher, C. (1994). Eliciting self-explanations improves understanding. *Cognitive science*, *18* (3), 439-477.

Cummins, D. D., Kintsch, W., Reusser, K., & Weimer, R. (1988). The role of understanding in solving word problems. *Cognitive psychology*, *20* (4), 405-438.

Djerić, I., Studen, R., & Luković, I. (2007). Realizacija nastave prirodnih nauka u Srbiji u kontekstu rezultata TIMSS-FT 2007. [Implementation of natural sciences teaching in Serbia in the context of TIMSS-FT 2007 results]. *Nastava i vaspitanje, 56*(1), 40-55.

Fabriz, S., Dignath-van Ewijk, C., Poarch, G., & Büttner, G. (2013). Fostering self-monitoring of university students by means of a standardized learning journal - a longitudinal study with process analyses. *European Journal of Psychology of Education*, 1-17.

Gang, S. (1995). Removing preconceptions with a"Learning Cycle." *Physics Teacher, 33* (6), 346-354.

Glynn, S. M., & Muth, K. D. (1994). Reading and writing to learn science: Achieving scientific literacy. *Journal of Research in Science Teaching*, *31* (9), 1057-1073.

Ifenthaler, D. (2012). Determining the effectiveness of prompts for self-regulated learning in problem-solving scenarios. *Educational Technology & Society*, *15* (1), 38–52.

Jones, M. H., Alexander, J. M., & Estell, D. B. (2010). Homophily among peer groups members' perceived self-regulated learning. *The Journal of Experimental Education*, *78* (3), 378-394.

Kipnis, N. (1996). The 'historical-investigative' approach to teaching science. *Science and Education*, 5, 277-292.

Kistner, S., Rakoczy, K., Otto, B., Dignath-van Ewijk, C., Büttner, G., & Klieme, E. (2010). Promotion of self-regulated learning in classrooms: investigating frequency, quality, and consequences for student performance. *Metacognition and learning*, *5* (2), 157-171.

Krneta, M., & Stevanović, K. (2009). *Fizika, udžbenik za sedmi razred osnovne škole*. [*Physics, textbook for seventh grade of primary school*]. Beograd: BIGZ, pp.145.

Krneta, M., & Stevanović, K. (2010). *Fizika, udžbenik za sedmi razred osnovne škole*. [*Physics, textbook for seventh grade of primary school*]. Beograd: BIGZ, pp.145.

Lederman, L. (2001). Revolution in science education: Put physics first! *Physics Today*, *54* (9), 11-12.

Logan, M., & Skamp, K. (2008). Engaging students in science across the primary secondary interface: listening to the students' voice. *Research in Science Education*, *38*, 501–527.

Low, R., & Jin, P. (2012). Self-Regulated Learning. In *Encyclopedia of the Sciences of Learning* (pp. 3015-3018). New York: Springer.

Marinković, S. (2010). Problemi kvaliteta našeg obrazovanja i promene u koncepciji obrazovanja. [Problems with quality of our educational system and changes in the conception of education]. *Nastava i vaspitanje, 59* (1), 5-23.

Mayer, E. R., & Alexander, A. P. (Eds.). (2011). *Handbook of research on learning and instruction*. New York: Routledge.

Muralidhar, S. (1988). Solid water is denser than liquid water: Students' experiences of science lessons in Fiji. *Research in Science Education*, *18* (1), 276-282.

Newby, L., & Winterbottom, M. (2011). Can research homework provide a vehicle for assessment for learning in science lessons? *Educational Review*, *63* (3), 275-290.

OECD/CERI (2008). *21st century learning: Research, innovation and policy directions from recent OECD analyses.* Paris: OECD/CERI.

Paik, S. H., Kim, H. N., Cho, B. K., & Park, J. W. (2004). K-8th grade Korean students' conceptions of 'changes of state' and 'conditions for changes of state'. *International Journal of Science Education*, *26*(2), 207-224.

Razvionica (2013). *Smernice za pristup usmeren na učenje i razvoj kompetencija nacionalnog okvira kurikuluma – Osnova učenja i nastave.* [*Directions for approach directed to learning and comptenteces development of national curriculum framework – Fundation of learning and teaching*]. Beograd: Razvionica

Roberts, R. J. (1997). Teaching about science. *Accountability in research: Policies and quality assurance*, *5* (1-3), 45-50.

Stylianides, A. J., Stylianides, G. J., & Philippou, G. N. (2004). Undergraduate students' understanding of the contraposition equivalence rule in symbolic and verbal contexts. *Educational Studies in Mathematics*, *55* (1-3), 133-162.

Syh-Jong, J. (2007). A study of students' construction of science knowledge: Talk and writing in a collaborative group. *Educational Research*, *49* (1), 65-81.

Yin, Y., Tomita, K. M., & Shavelson, J. R. (2008). Diagnosing and dealing with student misconceptions: Floating and sinking. *Science Scope*, *31* (8), 34 - 39.

Zimmerman, B. J. (1990). Self-regulated learning and academic achievement: An overview. *Educational Psychologist*, *25* (1), 3-17.

Zimmerman, B. J. (2002). Becoming a self-regulated learner: An overview. *Theory into Practice*, *41* (2), 64 -67.

Zimmerman, B. J., & Schunk, D. H. (Eds.). (2013). *Self-regulated learning and academic achievement: Theoretical perspectives.* New York: Routledge.

Appendixes

Appendix 1 - Individual homework

1. This homework has two parts. For the first part, you should do a simple experiment at home:

a) Pour water into a cylindrically-shaped cup up to a certain level and mark it. Then measure the level of water in the cup and note that value (h_1= _______cm).

b) Place the cup with water into a freezer, so that it rests on a flat surface. Once the water is completely frozen, carefully mark and note the level of ice in the cup (h_2= _______cm).

c) Draw sketches, or, if you have the means, take photographs of the experiment and submit them.

Once you have finished the experiment and noted the needed data:

ISSN 1648–3898

1) Calculate the ratio between the levels of ice (h_2) and water (h_1).
2) Explain the calculated ratio and the phenomenon observed during the experiment.
3) What is the proper term for this phenomenon?

2. For the second part of the homework, you will need the physics textbook. On page 145 you can find the plot showing the dependency between the volume and temperature of water. The text states: "We can see that the volume of water at 0° C is the same as at 8° C."

Look at the textbook plot carefully and answer the following question: Is the quoted statement true or false? Give detailed explanation of your answer!

Describe IN DETAIL any issues or unclear points you have encountered while doing the homework!

Appendix 2 - Group work stage (classwork)

1. In the first part of the homework you were supposed to perform this experiment:

a) Pour water into a cylindrically-shaped cup up to a certain level and mark it. Then measure the level of water in the cup and note that value (h_1= _______cm).

b) Place the cup with water into a freezer, so that it rests on a flat surface. Once the water is completely frozen, carefully mark and note the level of ice in the cup (h_2= _______cm).

c) Draw sketches, or, if you have the means, take photographs of the experiment and submit them.

Additionally, you were asked to:

1) Calculate the ratio between the levels of ice (h_2) and water (h_1).
2) Explain the calculated ratio and the phenomenon observed during the experiment.
3) What is the proper term for this phenomenon?

Examine carefully how other members of your group have completed this assignment and compare your answers.

1) Have you properly determined the ratio between the levels of ice (h_2) and water (h_1)?
2) Is the ratio between the levels of ice (h_2) and water (h_1) approximately the same for all the members of your group or not?
3) Should the ratio between the levels of ice (h_2) and water (h_1) be approximately the same for all the members of your group or not? Elaborate on your answer!
4) How do you, as a group, explain the phenomenon observed during the experiment?
5) Which of the individual home experiments has the best presentation and interpretation?

2. In the second part of the homework you were supposed to answer whether the statement "We can see that the volume of water at 0° C is the same as at 8° C" is true or false, based on the textbook plot of the dependency between the volume and temperature of water.

1) Compare the plots on page 145 of your textbooks. Are all of the plots completely identical? Make a note of any differences!
2) At which temperatures will water have the same volume?
3) State any issues or unclear points that remain unresolved after your group consideration.

Received: *February 26, 2014* Accepted: *May 18, 2014*

Jelena Radovanović	MSc, Teacher, Primary School „Slobodan Sekulic", Užice, Serbia. E-mail: lena.radovanovic@gmail.com
Josip Sliško	PhD, Professor-researcher, Faculty of Physical and Mathematical Sciences, Autonomous University of Puebla, Puebla, Mexico. E-mail: jslisko@fcfm.buap.mx josipslisko47@gmail.com