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Fundamental thermal concepts understanding: the first-year chemistry student questionnaire results

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Abstract: The main aim of this study is to show the research results of learning outcomes on thermal physics that have gained a group of first-year chemistry students in the fall semester of the academic 2013-2014 year. In this paper is described the use of a questionnaire to explore chemistry freshmen capacity to which they achieve their understanding of thermal physics concepts they learn within the chemistry and physics courses during the first study year. A used questionnaire contains 20 questions including a question on which the 94 study participants had the task to give their explanations related to a selected question. Research results show that knowledge about thermal equilibrium, the first law of thermodynamics and other relations among physical quantities students did not acquire in a way to present their scientific literacy developed enough at university learning outcomes level. Students need some additional instructions to find their pathways from pre-instructional alternative concepts to learn the scientific concepts through new working sessions enriched with experiments and demonstrations by instructors, teaching assistants as well as a group of students actively involved in learning on thermal physics subject matter.

INTRODUCTION

One of main concepts within the chemistry study curriculum is thermal physics concept as fundamental one that students study within the first-year science courses (General Chemistry and General Physics). David Meltzer (2005) highlighted the importance of fundamental thermal physics concepts to avoid confusion associated with students' difficulties to understanding dependent or independent quantities of state and process (heat, internal energy, entropy, and work). Meltzer has conveyed several reasons why students could express some difficulties caused by a confusion gained in mechanics to understand energy and work concepts, or in using models or approximations in physics. Talking about known Sommerfeld's story and a view of thermodynamics as a difficult subject matter Rodrigo de Abreu and Vasco Guerra (2012) have given the framework of a need to define and to introduce all basic concepts on thermodynamics to be understandable for learners. They presented „a simple and clear model" to introduce thermodynamics, and its scientific concepts of heat, internal energy and work formulated in the frame of laws of thermodynamics. Investigation of students' understanding of thermal physics concepts has been conducted by a group of authors who found evidences of student difficulties „in applying scientific concepts in everyday contexts", according to received the conceptual test answers (Chu et al., 2012).

In this paper, we describe the use of a questionnaire to explore chemistry freshmen capacity to which they achieve their conceptual understanding in thermal physics they learn within the chemistry and physics courses during the first study year semester of the academic 2013-2014 year.

The study objective is concerned with misconceptions in thermal physics and low students' success in a partial *Physics I* examination. In this sense, the specific objective of this study was to discover whether students have integrated previously acquired knowledge with knowledge gained in general chemistry and general physics courses at the university level in the field of thermal physics trying to find a way for changing their misconceptions. An insight in students' thermal physic learning outcomes is important for their further education in chemistry as their field of study at university.

The significance of research findings could initiate findings of better teaching-learning methodology to enable students to take part in an active learning environment focused to change their passive role in the traditional *ex cathedra* learning environment. Among other things, this means that it could launch initiatives to better organize the curriculum in the first year of chemistry study with at least two smaller student groups (less then 60 students in each group) that could attend classes aimed toward achieving better understanding and the necessary scientific literacy.

Literature background

Several widely used questionnaires that cover the scientific concepts, developed by science researchers have been used in different disciplines such as mechanics, astronomy, electromagnetism, optics, thermal physics (Hestenes, Wells, & Swackhamer, 1992; Zeilik et al., 1998; Zeilik, 2002; Sadler et al., 2010; Hieggelke et al., 2001; Prince, Vigeant & Nottis, 2012; Yeo & Zadnik, 2001). A questionnaire developed in Australia by Shelly Yeo and Marjan Zadnik (2001) was evaluated and their research results were presented after its application. Their final research instrument (The Thermal Concept Evaluation/TCE) consists of the 26 questions for reaching students' knowledge related to the "real-life" understanding of phenomena and environmental issues according to the basic learning thermal concepts. Yeo and Zadnik discussed the response choices by students' alternative conceptions and beliefs. The authors evaluated their research instrument by comparison of student scores reached by upper and lower group of students. Yeo and Zadnik presented the average normalized gain (*g* factor) between the pretest and posttest scores in amount of 0.30. The TCE can be used for testing the thermal conceptual understandings at high school and university first-year study level.

Prince, Vigeant, and Nottis (2012) conducted a research to explore undergraduate engineering student misconceptions related to: temperature vs. energy, temperature vs. perceptions of hot and cold, factors that affect the rate vs. amount of heat transfer, and thermal radiation using the Heat and Energy Concept Inventory (HECI). They found from the HECI research data that student misconceptions were resistant to change if standard instructions were implemented. For students' conceptual changes they highlighted a need to introduce an ontology training and implementation of the inquiry-based activities.

Katharyn Nottis with two colleagues (2010) explored student misconceptions about heat transfer that were found „even after students successfully completed relevant coursework". They studied possibilities in students' conceptual changes after inquiry-base activities and application of a concept inventory with ten questions conducted for a group of chemical engineering students. The research results showed the increasing scores after new learning activities that were reached by inquiry-based learning (the simulations).

Heat and temperature were the research subjects conducted by Paul Jasien and Graham Oberem (2002) in the undergraduate and post-baccalaureate student groups. Jasien and Oberem created and implemented a survey related to the heat and temperature applying a multiple choice question form. Their sample was the 30 students at two universities in California. Jasien – Oberem's research results showed that the research participants had „confusion about a number of concepts" and knowledge less then it was expected. Lack of understanding was a main characteristic of the findings among students who took part in the Jasien-Oberem survey, especially for topics such as the thermal equilibrium problems, specific heat, heat capacity, heat transfer and temperature change.

Several resistant misconceptions in thermal physics Pizzolato and collaborators were investigated within a research conducted among engineering students who worked in groups and performing scientific investigations using materials to practice the „collecting, processing and analyzing data" that enabled them to enhance their practical and reasoning skills (Pizzolato et al., 2014). This study is an affirmation of an inquiry-based teaching approach. The research findings showed that students improved their conceptual knowledge, practical and reasoning skills in amount of 55% of reduction of unanswered questions compared with questionnaire results in pre and post answering sequences related to the conceptual questions in thermal physics.

What students need to know?

Students enrolled to study chemistry and aiming to become scientists, engineers or chemistry teachers cross into new intellectual domain after their secondary schooling. Their prior knowledge is considered as a basic one that enables them during the first-year of study to develop deeper and wider scientific concepts in three main fields: general chemistry, general physics, and mathematics. For chemistry freshmen, the most important idea is to be familiar with units of measurements as main concepts defined in the Standard International System (SI). Other essential ideas to develop are concepts of force, energy, work, pressure, temperature, heat, and entropy. Chemistry students should understand the laws of thermodynamics and the nature of interactions between atoms, molecules, and other ensembles of particles.

Chemistry freshmen study several topics on thermal physics within the *General Chemistry* and *General Physics* syllabi that are considered as very important ones for their study field. For chemistry students, the thermodynamics knowledge is fundamental to „understand the behavior of materials under various environmental conditions and to develop process for novel materials" (Balducci et al., 2009, p.305).

Chemistry freshmen need to understand thermal physics concepts in a such a way so eventually they possess knowledge to solve a thermal physics questionnaire, applied under this study, which contains the questions about:

temperature,
internal energy,
heat and specific heat,
phase changes,
system work,
the first low of thermodynamics,
isothermal process,
constant volume (pressure) process, and
adiabatic process.

It is also important that students have to show their factual knowledge about relationships among thermal physics quantities. The temperature and thermal equilibrium concepts are important knowledge content and their understanding of the substance phase changes, and understanding of energy in the form of heat released or absorbed during a change of substance phase is important. It should be noted that chemistry freshmen need to know the meanings of the laws of thermodynamics applied in everyday context. According to the essential thermal physics concepts students need to make a distinction between thermal physics quantities by their nature.

METHODS

Participants

Study participants were the 94 first-year chemistry students at Sarajevo University in Bosnia and Herzegovina. A dominant number of students were females (82% of students under research). The study was carried out in the fall of 2013-14academic year at the end of semester. They were enrolled to study chemistry without a university-entrance examination.

Table 1: Distribution of students by residence.

Residence	Frequency	Percent
Sarajevo Canton	36	38.3
The Federation of BH	53	56.4
The Republic of Srpska	4	4.2
International student	1	1.1

The students were from various regions of Bosnia and Herzegovina attending different secondary schools before their university study. Their distributions by residence and secondary school are presented in Table 1 and Table 2.

Table 2: Distribution of students by secondary school.

Secondary school	Frequency	Percent
High school	67	71.3
Medical secondary school	24	25.5
Technical secondary school	3	3.2

The students under this study had just started their first semester at university, taking six courses, all as required ones: Mathematics I, Physics I, General Chemistry I, Stehiometry, Mineralogy with Crystallography, and Introduction to Chemistry Laboratory. The students completed different secondary school curricula Because attending different secondary schools, these students had studied physics differently, according to the number of study years in physics class (from one to four school years). They completed their secondary education in three types of secondary school: a high school, medical secondary school, and technical secondary school (mechanical and agricultural).

Research instruments

To measure the level of student understanding of subject of thermal physics we used the Thermal Concept Questionnaire (TCQ) as a research instrument. It is a set of 20 questions (see Appendix) aimed to explore student understanding of the basic concepts on thermal physics. The first 12 questions were adapted ones from a research instrument created in Australia known as the Thermal Concept Evaluation (Yeo & Zadnik, 2001). Next two questions are adapted from a survey found in a paper by Jasien and Oberem (2002), and the rest are six questions according to the Murray's quiz (2012) that is an *online* material available for thermal physics knowledge testing.. The TCQ composition consists of five subscales to cover t subjects of (1) heat transfer and temperature changes; (2) boiling; (3) heat conductivity and equilibrium; (4) freezing and melting; (5) the internal energy-heat-work relationships. TCQ was applied once during this diagnostic study of students' conceptual knowledge on thermal physics. As was mentioned, a main TCQ usage is related to evidences relevant for a physics course development, assessment and instructor awareness of student learning difficulties in the introductory physics course (*Physics I*). The *Physics I* syllabus realization is seen by the course instructors as a main difficulty in the teaching-learning process according to thermal physics topics that take only two weeks with only six teaching-learning hours, each 45 minutes long.

Evaluation of the student TCQ achievements, were based on a conducted scoring by authors. Each correct student's TCQ answer was graded with one point (20 points in total) plus six points as maximum of the bonus points for each correct explanation and calculation related to the Q6. The scoring rubric elements for achieving these six points are:

A (6 points): a notion of the thermal equilibrium given textually, the thermal equilibrium equation expressed correctly, correct calculation of required temperature, and correct answer chosen;
B (4 points): the thermal equilibrium equation expressed and chosen answer correctly;
C (1 point): a notion of the thermal equilibrium, and correct answer chosen.
D (1 point): a description of the thermal equilibrium without the equation, and answer chosen correctly.
E (0 points): without or no logical explanation.

RESULTS AND DISCUSSION

A group of the 94 chemistry freshmen among 110 of students taking the *Physic I* class were tested about understanding of basic thermal physics concepts using the TCQ. This questionnaire was realized during the *Physic I* class (45 minutes long) by students who took part in examination voluntarily. All of them gave their names to receive some extra bonus; 0-6 points within the *Physics I* grading scheme. Students' ranking statistics is presented in Figure 1 according to their TCQ correct answers. The TCQ questions and percents of each Q1-Q20 item frequencies are presented in Appendix Table 4.

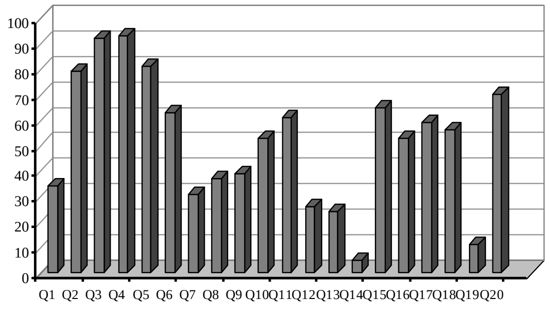

Figure 1: Percents of correct answer frequencies for each TCQ question.

The Table 4 in Appendix and Figure 1 revealed that around 60-90% of students perceived scientific knowledge of a body/system temperature (see the data of Q2-Q6 and Q20 answers). The majority of students (Q14; 95% and Q19; 89%) have no developed concepts and understanding of causal relations for both thermal energy (internal energy) change and heat flow. The data show that a number of students selected the following answers Q1: b; Q14: b, c, d and Q19: c (Table 4 in Appendix). It indicates that chemistry freshmen have no factual knowledge about temperature, heat and internal energy.

Students' results were tested for normality of distribution with Kolmogorov-Smirnov and Shapiro-Wilk tests related to the three variables: (1) TCQ student score; (2) studentgender, and (3) usage of textbooks as learning sources according to the *Physics I* syllabus. The points' distribution by students was not normal; the scores were expressed as median and compared with Mann-Whitney test for different groups. Chemistry freshmen reached the median value of 10 points for both females and males. A significant difference was not found in scores between male and female students (Mann-Whitney U: 621.0, p = 0.74) or between students according to the textbooks used or not (Mann-Whitney U: 761.5, p = 0.65). The minimum score was four points (2 % of students) achieved by the male students, whereas the female students have got a minimum score of three points (only one student). Two female students achieved a maximum score of 17 points (2 % of students), and 15 points was the maximum score accomplished by one male student.

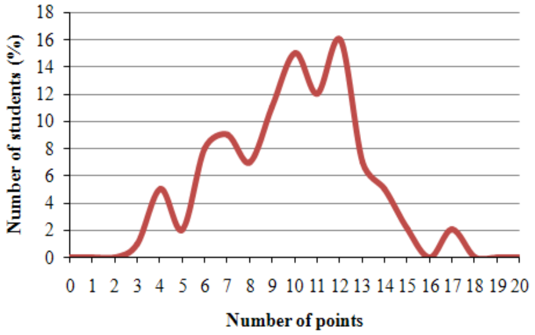

Figure 2: Students' distribution by points achieved.

Students' distribution by number of achieved points according to the Q1-Q20 answers without bonus points is presented in Figure 2. Majority of students (15% and 16% of them) achieved 10 and 12 points, respectively, showing a bimodal statistics. The distribution of the students among the above mentioned groups is shown in Figure 3. The students showed undeveloped scientific concepts but hold some alternative concepts.

Students were classified into three groups according to the number of achieved points as follows:

Group 1: 3 – 10 points
Group 2: 11 – 15 points
Group 3: 16 – 20 points

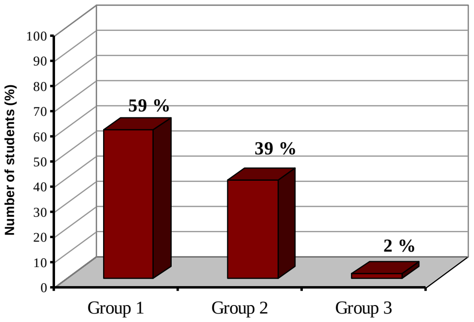

Figure 3: Students' distribution by group category.

There are several examples to show students' alternative conceptions within their incorrect answers.

1. According to the Q1-d 3% of students considered that „*the temperature of an object depends on its size*".
2. The answer Q9-c was chosen by 13% of students who considered that „*different materials hold the same amount of heat*".
3. The Q10-a answer was chosen by 22% of students who had thought that „*temperature can be transferred*".

According to the data seen in Table 4 one can notice that Q14 was the most difficult question (5% of students with correct answers). The same situation is found with the Q19 (only 10% of students gave their correct answers). The highest number of students with correct answers was achieved according to the Q4 and Q5 (more then 80% of students).

Distribution of points by each student (marked by their code number) is presented in Figure 4.

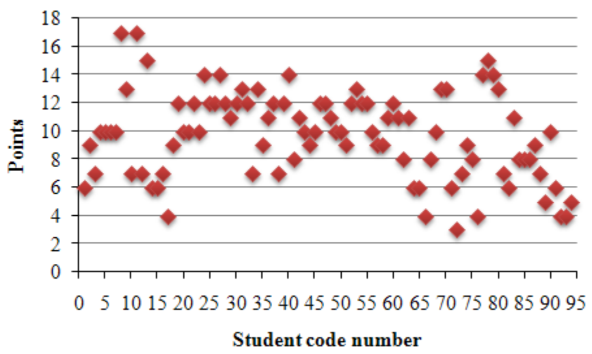

Figure 4: Points' distribution by each student (N = 94).

The passing points in accordance to the university threshold was 11. The TCQ passing score (count > 11 points) have achieved 40% of students. It is important to note that 60% of students showed a low examination score on thermal physics concept understandings and knowledge applications in everyday situations. If one counts the overall results it can be found that study participants have won only 49% of the potential 1,880 points.

Bonus point results

Students could earn from one to the six bonus points giving their explanations to one of the Q6 answer choices. Total number of students who presented their explanations was 47 (50%), but accounted points were found for 33 (36%) of students with bonus scores.

Table 3: Bonus points results.

Category	Bonus points	Number of students (%)
A	6	0
B	5	0
C	1	26 (28%)
D	1	7 (8%)
E	0	14 (15%)

Therefore, according to the aforementioned coding scheme students' bonus point results are presented in Table 3. As can be seen from these data, none of the students gave an answer in the A or B bonus point category. The other half of students had presented their explanations, but other half did not try to give any word or equation to explain their reasons for a chosen answer.

Students' explanations according to the Q6 answer

Students were asked to give their explanations for the chosen the Q6 answer. Mostly student explanations were not precise. Students typically did not express the temperature unit (degree Celsius). They only used digits (40, 30, 10 or 25). The calculations were presented without proper equation or notion about temperature equilibrium. Several examples of students' explanations of the chosen Q6 answers are presented:

Example 1: Q6 *Answer c) and explanation as*

$$Q_1 = Q_2$$

Example 2:

Q6 *Answer c) and explanation by a calculation as*

$$t = \frac{40+40+10}{3} = 30$$

Example 3:

Q6 *Answer b) and explanation by a calculation as*

$$t = \frac{t_1 + t_2}{2} = 25$$

Example 4:

Q6 *Answer c) and explanation by a calculation as*

$$40 - 10 = 30$$

Example 5:

Q6 *Answer c) with following explanation:*

Mixing water at 40 heat transfer starts from warmer to colder water at 10.

Example 6:

Q6 *Answer c) with following explanation:*

Mixing water at 40°C with water at 10°C its internal energy (of hot water) will decrease and of cold water will increase to reach water mixed at 30°C.

From these examples, one can see that the student explanations were not scientifically based or not given by arguments as was expected by university students. In the other hand, if they have used the thermal equilibrium equation in general form, they did not know to articulate meaning of each Q in such equation (see Example 1).

One may ask why 50% of students did not give any argument or a try to provide an explanation. One can find an answer in the teaching/learning approach. Firstly, the study participants attended their classes in a large group of students (approximately 100 students at every class meeting) where they could not participate as active learners in *Physics I* and *General Chemistry I* course because of an inadequate working space (a classroom in the form of an amphitheater). Secondly, in such learning environment they attended only two meetings each 135 minutes long with the *Physics I* instructor to learn about thermal physics concepts mostly instructor-centered. Thirdly, as the most important reason can be found in a fact that about 50% of students who learned the same concepts in secondary school two or three years ago, have still retained many misconceptions.

It is significant to point out that, despite requests by researchers that students should give their answers; they found a total of 3.8% of the unanswered questions in the questionnaire. For these students, it was not possible to determine the existence of misconception and then there is no strategy for conceptual change.

CONCLUSION

The prior and actual thermal physics learning outcomes of chemistry freshmen examined in this study showed the gap in conceptual understanding of thermal physics. The findings show that around 60% of chemistry freshmen have not presented even their factual knowledge. The research participants did not demonstrate the required knowledge outcomes on thermal physics. Students' learning outcomes on thermal physics need to be appropriate for individuals who need to learn more complex subject matter in Physical Chemistry course and other chemistry courses at higher study years.

These study findings show that students under research had difficulties in understanding heat, temperature and phase changes similar to students under mentioned study results. The same confusion as Jasien and Oberem (2002) highlighted were found among these study results about:

(1) the meaning of thermal equilibrium;

(2) the physical basis of heat transfer and temperature change;

(3) the relationship between specific heat, heat capacity, temperature change, work-heat-internal energy relationships, and phase changes.

Students who were choosing the incorrect TCQ answers have showed “the beliefs of naive thinkers“, as Yeo and Zadnik commented in their paper (2001). Following the Yeo and Zadnik instructions, we think that a detailed examination of student alternative concepts can be carried within an extended research. It should be a basic strategy of the *Physics I* syllabus realization using research results related to the thermal physics subject matter, but associated with a need for additional class hours

Hiebert and Lefevre (1986) thought that “knowledge may be a collection of unrelated facts, whereas conceptual knowledge puts the focus on relationships“can be confirmed by data presented in Table 4. One can see there are students’ misconceptions and lack of factual knowledge according to aforementioned learning thermal physics topics. Following ideas proposed by Reinders Duit (1999) a physics instructor need to help students to find their pathways toward the conceptual changes from „pre-instructional conceptions“ to the science concepts that need to be learned. It is important to note that science instructors in the same time need to learn how to develop conceptual change strategies for their students within a new teaching practice different then traditional one (Duit, 1999; Duit & Treagust, 2003; Kalman, Rohar & Wells, 2004).

In conclusion, it is evidently that chemistry freshmen need tto gain better factual knowledge and to overtake a very complex and difficult process to accomplish their conceptual changes of thermal physics understanding. Students need some additional instructions to find their pathways from pre-instructional alternative concepts to learn the scientific concepts through new working sessions enriched with experiments and demonstrations by instructors, teaching assistants as well as students as active learners.

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APPENDIX

THERMAL CONCEPT QUESTIONNAIRE (TCQ)

Table 4: Questions and answer statistics (N =94)

Q1. What is the most likely temperature of ice cubes stored in a refrigerator's freezer compartment?	Percents of frequency
a) –10°C	34
b) 0°C	61
c) 6°C	0
d) It depends on the size of the ice cubes.	3
No answer	2
Q2. The ice cubes Edin left on the counter have almost melted and are lying in a puddle of water. What is the most likely temperature of these smaller ice cubes?	Percents of frequency
a) –10°C	0
b) 0°C	79
c) 6°C	13
d) 10°C	6
No answer	2
Q3. On the stove is a kettle full of water. The water has started to boil rapidly. The most likely, temperature of the water is about:	Percents of frequency
a) 86°C	0
b) 98°C	92
c) 112°C	2
d) none of the above answers could be right.	5
No answer	1
Q4. Five minutes later, the water in the kettle is still boiling. The most likely temperature of the water now is about:	Percents of frequency
a) 86°C	0
b) 98°C	93
c) 112°C	6
d) 120°C	0
No answer	1
Q5. What do you think is the temperature of the steam above the boiling water in the kettle?	Percents of frequency
a) 86°C	11
b) 98 °C	81
c) 112 °C	4
d) 120 °C	1
No answer	3
Q6. Maja takes two cups of water at 40°C and mixes them with one cup of water at 10°C. What is the most likely temperature of the mixture?	Percents of frequency
a) 20°C	1
b) 25°C	28
c) 30°C	63
d) 50°C	2
No answer	6

Give here your explanation for the chosen answer.

Q7. Selim believes he must use boiling water to make a cup of tea. He tells his friends: “I couldn’t make tea if I was camping on a high mountain because water doesn’t boil at high altitudes.” *Who do you agree with?*	Percents of frequency
a) Adi says: “Yes it does, but the boiling water is just not as hot as it is here.”	31
b) Amra says: “That’s not true. Water always boils at the same temperature.”	33
c) Ema says: “The boiling point of the water decreases, but the water itself is still at 100^0C.”	16
d) Tin says: “I agree with Selim. The water never gets to its boiling point.”	17
No answer	3

Q8. Samir takes a can of cola and a plastic bottle of cola from the refrigerator, where they have been overnight. He quickly puts a thermometer in the cola in the can. The temperature is 7^0C. What are the most likely temperatures of the plastic bottle and cola it holds?	Percents of frequency
a) They are both less than 7^0C.	11
b) They are both equal to 7^0C.	37
c) They are both greater than 7^0C.	13
d) The cola is at 7^0C but the bottle is greater than 7^0C.	35
e) It depends on the amount of cola and/or the size of the bottle.	3
No answer	1

Q9. Aida asks one group of friends: “If I put 100 g of ice at 0^0C and 100 g of water at 0^0C into a freezer, which one will eventually lose the greatest amount of heat? *Which of her friends do you most agree with?*	Percents of frequency
a) Emina says: “The 100 g of ice.”	4
b) Lada says: “The 100 g of water.”	39
c) Luka says: “Neither because they both contain the same amount of heat.”	13
d) Nermin says: “There’s no answer, because ice doesn’t contain any heat.”	7
e) Emil says: “There’s no answer, because you can’t get water at 0^0C.	24
No answer	13

Q10. After cooking some eggs in the boiling water, Meliha cools the eggs by putting them into a bowl of cold water. Which of the following explains the cooling process?	Percents of frequency
a) Temperature is transferred from the eggs to the water.	22
b) Cold moves from the water into the eggs.	18
c) Hot objects naturally cool down.	5
d) Energy is transferred from the eggs to the water.	53
No answer	2

Q11. Why do we wear sweaters in cold weather?	Percents of frequency
a) To keep cold out.	1
b) To generate heat.	5
c) To reduce heat loss.	61
d) All three of the above reasons are correct.	21
No answer	12

Q12. Damir is reading a multiple-choice question from a textbook: “Sweating cools you down because the sweat covering your skin:	Percents of frequency
a) wets the surface, and wet surfaces draw more heat out than dry surfaces.”	4
b) drains heat from the pores and spreads it out over the surface of the skin.”	28
c) is the same temperature as your skin but is evaporating and so is carrying heat away.”	41
d) is slightly cooler than your skin because of evaporation and so heat is transferred from your skin to the sweat.”	26
No answer	1

Q13. As a material freezes, it	Percents of frequency
a) decreases in temperature and transfers heat to the environment	52
b) increases in temperature and absorbs heat from the environment	0
c) remains at the same temperature and transfers heat to the environment	24
d) remains at the same temperature and absorbs heat from the environment	6
e) none of the above	16

No answer	1

Q14. If body A (temperature 30^0C, mass 2g, specific heat 4 J/g^{0}C) and body B (temperature 30^0C, mass 25 g, specific heat 2 J/g^{0}C) are placed in contact	Percents of frequency
a) heat energy will naturally flow from B to A since B has the larger mass.	6
b) heat energy will naturally flow from A to B since A has the larger specific heat.	24
c) heat energy will naturally flow from B to A since the product of the mass and specific heat is larger for B.	22
d) heat will naturally flow from A to B since A has more heat per gram than B;	34
e) no heat energy will flow.	5
No answer	7

Q15. During an isothermal process then a gas internal energy change is:	Percents of frequency
a) positive	10
b) negative	12
c) zero	65
d) undecided	11
No answer	2

Q16. If the gas expands in an isothermal process, then heat is	Percents of frequency
a) positive	53
b) negative	22
c) zero	7
d) undecided	12
No answer	6

Q17. If the gas is compressed in, then the work done by the gas is	Percents of frequency
a) positive	21
b) negative	59
c) zero	7
d) undecided	10
No answer	3

Q18. If the volume of the gas decreases (P is constant), then the work done by the gas is	Percents of frequency
a) positive	19
b) negative	56
c) zero	11
d) undecided	11
No answer	3

Q19. During an adiabatic expansion of a gas its change in internal energy is	Percents of frequency
a) positive	14
b) negative	11
c) zero	59
d) undecided	15
No answer	1

Q20. If the temperature of the gas increases then its change in internal energy is	Percents of frequency
a) positive	70
b) negative	19
c) zero	4
d) undecided	5
No answer	2

Summary/Sažetak

Glavni cilj u ovom radu je da se pokažu rezultati istraživanja ishoda učenja o kalorici i termodinamici koje su stekli studenti prve godine studija hemije u zimskom semestru akademske 2013./2014. godine. U ovom radu je opisano korištenje upitnika za istraživanje kapaciteta studenata prve godine studija hemije o njihovom razumijevanju osnovnih koncepata iz kalorike i termodinamike, koje su stekli u okviru predmeta opće hemije i opće fizike. Korišten je istraživački instrument koji sadrži 20 pitanja na koja su 94 studenta davali odgovore, uključujući i jedno pitanje na koje su imali zadatak da daju objašnjenje za odabrani odgovor. Rezultati istraživanja pokazuju da studenti nisu stekli odgovarajuće znanje o toplinskoj ravnoteži, prvom principu termodinamike i drugim odnosima među fizičkim veličinama iz kalorike i termodinamike, pokazujući nedovoljno razvijenu naučnu pismenost za univerzitetski nivo ishoda učenja. Studentima su potrebne dodatne instrukcije kako bi našli načine da prevladaju prethodne alternativne koncepte ka usvajanju naučnih koncepata, kroz aktivnosti obogaćene eksperimentima i demonstracijama od strane nastavnika, asistenata kao i grupe studenata aktivno involviranih u savladavanje gradiva iz kalorike i termodinamike.