Proceeding

The 4th International Seminar on Science Education

Bandung, 30 October 2010

“Curriculum Development of Science Education in 21st Century”

Science Education Program
School of Postgraduate Studies
Indonesia University of Education

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"Curriculum Development of Science Education in 21st Century"

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Science Education Program
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Foreword of Chair of Science Education Program

The fourth International Seminar of Science Education is conducted to fulfill annual agenda of the School of Graduate Studies, Indonesia University of Education.

The seminar theme “Curriculum Development of Science Education in the 21st Century” is chosen emerge from many problems of science education in Indonesia. One of them is the overstuffed condition of science curriculum that affected from rapid development of information in this era. Besides, there are challenges of Indonesian people in facing against global competition. To win the competition they have to think critically. Therefore many massages have to cover by science curriculum caused it overloaded and difficult to be implemented.

We are not able to overcome the problem ourselves. We need input of information and experience from many researchers all over the world. Therefore this seminar hoped to be an exchange experience to solve the problem and lead to the discovery of science curriculum to enhance Indonesian science education quality.

I would like to express my special gratitude to Prof Dr Bruce Waldrip from Monash University, Australia; Prof Dr Russell Tytler from Deakin University, Australia; and Dr. Benny H.W.Yung from The University of Hongkong; who are specially come here to be key note speakers. Thank you for sharing the result of your latest result with us.

Finally I would like to thank to the committee who have been working hard to prepare the seminar and publish the proceedings. Last but not least thank you for all speakers and participants of your contribution today.

Bandung, 31 October 2010
Chair of Science Education Program
School of Postgraduate Studies
Indonesia University of Education,

Prof.Dr.Liliasari,M.Pd

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The ways the physics teachers solve a multifaceted real-world problem relates to the behavior of gas

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Abstract

This paper examines the ways in which the physics teachers solve a multifaceted real-world problem that relates to the behavior of gas. The participants consist of 30 physics teachers of senior high schools in East Java. Most of them have had 20 years or more experiences in teaching physics. They discussed the problem in a group of 3-4 teachers. This study shows that no teacher succeeded to solve the problem. In solving such problem, most teachers relied on the surface feature of the problem and employed a common sense argumentation: no teacher used diagram or equations, no teacher referred to Newton laws of motion or state equation $PV = nRT$. Therefore, it is critical that Physics Education Program should provide their prospective physics teacher the opportunities to acquire a deeper content knowledge and enough experiences in solving multifaceted real-world problems.

Keywords: physics teacher, gas, multifaceted real-world problem

Introduction

Indonesian ordinances concerning on teachers (UU RI No 14, year 2005 and Permendiknas RI no 16 year 2005) require that Indonesian teacher should be able to demonstrate the four kinds of competences, i.e.: professional, pedagogical, social, and personal competence. Professional competence refers to a deeper and broader understanding of subject matter in the field of their licensure. Pedagogical competence refers to a deeper insight of general pedagogical knowledge including how student learn, how schools work, and how teaching and learning processes should be well planed, implemented, and evaluated. Social competence refers to the ways in which teacher able to develop well social relationship with students and other school communities. Personal competence refers to the well integrity and personality the teacher should behave.

Relating to professional and pedagogical competences, there is now a broad agreement in the physics education research community that physics teacher should be able to demonstrate the three pillars knowledge, i.e. content knowledge, pedagogical knowledge, and pedagogical-content knowledge (Etkina 2005, 2010; Loughran et al. 2006; Wenning 2007; Jimoyiannis 2010). Content knowledge refers to the knowledge of subject matter they will teach. Pedagogical knowledge refers to the general knowledge of how people learn and how schools work. Pedagogical-content knowledge (PCK) refers to the special knowledge for teaching a particular topic to particular student in a particular condition. Figure 1 describes the relationship among the three pillars.

PCK is the most important knowledge that teacher should develop continuously. It is not only the knowledge that distinguishes the knowledge of physics teachers from that of physicist (Pellathy 2009), but also the knowledge that colors the way the teacher teach; PCK is something of "knowledge in action". However, in order to able to develop a comprehensive PCK, teacher should have broader insight and deep understanding of knowledge related to subject matter (content knowledge).

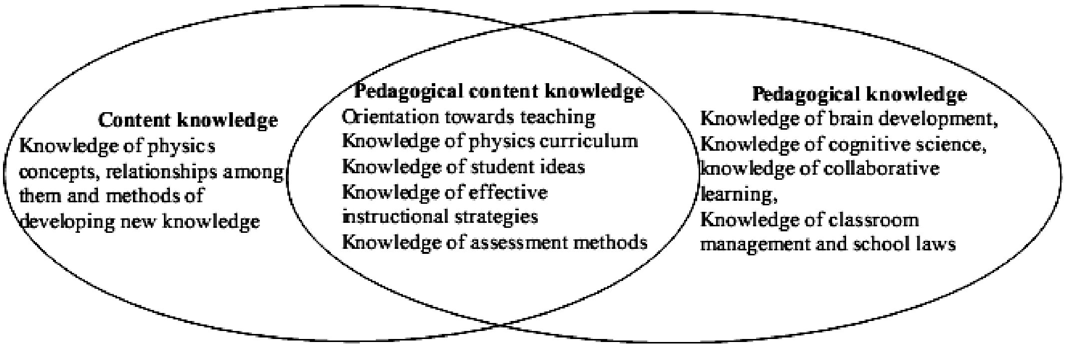


Figure 1. The Structure of Physics Teacher Knowledge (Etkina 2005, 2010)

Deep content knowledge is a necessary condition for the development of PCK. If a teacher themselves does not understand the nuances of a concept, the deep relationships between this particular concept and other concepts, and the ways through which this concept was constructed by the physics community, then translating these nuances into student understanding is impossible (Etkina 2010). Physics teacher should have strong organized conceptual knowledge, not only within a particular branch of physics (e.g. mechanics, electrodynamics, etc), but also across branches of physics (e.g. mechanics and thermodynamics, etc). In addition, teachers must understand the processes used to establish new knowledge and determine the validity of claims (Eylon and Bagno 2006)

For deepening their content knowledge, teacher should practices themselves to solve physical problems in the manner of expert, instead of novice. (See Table 1 for more information). Strategy problem solving such as plug-and-chug strategy (Walsh et al. 2007), which is usually used by students and novices, do not give significant contribution to conceptual development.

The expertise of teacher in solving problem mirrors their deepness content knowledge. This paper examines the ways the physics teacher solve a multifaceted real-world problem.

The problem is about the real world phenomenon related to the behavior of gas. The problem contains similar scientific principle used in "*bekam*" technique in the field of alternative medicine. (See section Method for more detail information of the problem). To successfully solve the problem, teacher should have a deep and organized conceptual understanding about the mechanics (Newton's law of motion), the state equation of ideal gas ($PV = nRT$), thermodynamics processes, and the behavior of gas. Since there are many phenomena occurred in the problem, teacher should also be able to select the appropriate surface features of the problem. That is why author call the problem a multifaceted real-world problem, after Ogilvie (2009) developed the similar problem but more complexes.

The problem also requires the use of multiple representations, at least pictorial, verbal, and mathematical representation. Instructors and researchers in physics education research have long argued that students can benefit from solving problems that require the use of multiple representations together (Khol et al. 2007). Multiple representations ability is a key for learning physics and often required for understanding the scientific concepts and for problem solving (Nieminen et al. 2010). The problem is also about prediction. Prediction is a nature of physics: physicist develops model and theory to describe and explain observed physical phenomena and to predict the outcomes of new phenomena (Etkina et al. 2005).

The science content of the problem is closely relevant to the Content Standard of National Standard of Education (Permendiknas RI no 22, Year 2006). According to the standard, junior high school students should be able to study the pressure of gas and its application in their daily life; and the senior high school students should be able to describe the nature of monatomic ideal gas and analyze the change of the state of ideal gas. Thus, despite the complexity of the problem, author argues that teacher necessary be able to solve such problem. Moreover, Indonesian teachers should have much experience in solving such problems.

Table 1. Comparison of expert and novice problem-solving strategies (Malone, 2008)

Expert behaviors	**Novice behaviors**
Typically use a working forward strategy except on more difficult problems	Typically use a working backward strategy
Performs an initial qualitative analysis of the problem situation	Usually manipulates equations discovered via equation hunting
Constructs diagrams during solution process	Rarely constructs or uses diagrams
Spends time planning approach sometimes via models of the physical situation	Rarely plans approach simply dives in
Uses fewer equations to solve the problem	Uses more equations to solve problem
Usually solve problems in less time	Usually takes more time to solve the problems
Refers to the physical principles underlying the problem	Refers to the numeric elements of the problem
Concepts more coherent and linked together	Concepts not coherent and lack applicability conditions for special cases
Fewer errors—concepts usually deployed correctly	More errors—concepts usually deployed Incorrectly
Can use more than one representation to solve problems—which usually allows them to deviate to other solution paths when stuck	Usually only utilize a numeric representation to solve problems—once they become stuck rarely can free themselves
Check and evaluate solution by a variety of methods i.e., more flexible	Superficially check solution if at all
Rarely refer to problem statement or text	Frequently refer to problem statement and examples in textbook

Method

Setting and context. The setting of the study was a training session of in-service training for the prospective professional teacher (PLPG) held in September 2010 by UM (State University of Malang, Indonesia). Author acted as the instructor. Subject of study consists of 30 high school physics teachers, the participants of the training. They had 10 to 24 years of experience in teaching physics. Most of them (26 of 30) have at least 20 years experience. They came from seven districts around East Java Province.

The training session started with introducing a problem presented in power point contains video of real phenomena. The presentation consists of four segments as described in Figure 2. The first three segments describe the problem. The last segment describes the answer and be presented after discussion. Having understood the problem, participants discussed the problem in the group of 3-4 persons. Instructor asked all groups to write their argument or rationale in choosing an option. To the group that failed to achieve agreement, instructor allowed the group to choose more than one options, e.g. “A or B”; but the group must explain their confusion.

The group discussion needed about 20 minutes along. During the time, instructor moved around the groups to observe the way the participants discuss and to record the argumentation occurring in discussion. The next session was group presentation. The situation during this class discussion was very similar to that of group discussion. Then, instructor showed the correct answer by continuing the presentation had been paused in advance (see Segment 4 in Figure 2).

The rest activities were the explanations of the phenomenon. Throughout a series of question and answer interactions, and the use of multiple representations (instructor used process diagrams, mathematical, and verbal representation), participants realized that the problem is an application of state equation of ideal gas: $PV = nRT$. This training session ended with participants reflecting on what they had learned from the problem.

Focus of Study. The focus of the study is the ways the participants solve the problem. There are two questions proposed in the study. 1) How many participants succeed to solve the problem? 2) How did they develop their argumentation to solve the problem?

Segment 1

Exposing a small rubber balloon situated on the mouth of Erlenmeyer flask. Balloon is easy to move and leaves the Erlenmeyer flask.

Segment 2

Exposing the air in the Erlenmeyer flask is burned using match until the fire off.

Segment 3

Exposing the problem statement:

Upon the fire off, balloon is situated on the mouth of Erlenmeyer flask. What will happen to the balloon?

- ***A: balloon moves upward, leaves Erlenmeyer***
- ***B: balloon moves into the Erlenmeyer***
- ***C: balloon is still in its condition as before, there is no effect on the balloon***
- ***D: balloon explodes***

Segment 4

Exposing the right answer: balloon moves into Erlenmeyer flask.

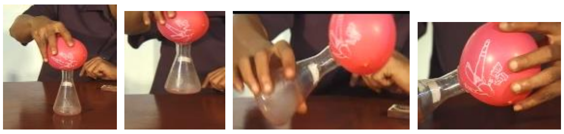
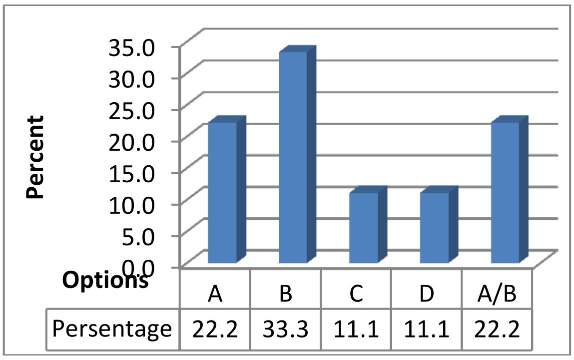


Figure 2. The storyboard to present the problem

Results and Discussion

Participants' answer

Figure 3 and Table 2 shows the group's answers and their argumentations respectively. There are three groups getting the right answer (option B). However, if we confront their answers to their reasoning, we judge that this correctness is likely occurs by accident. Therefore, it can be concluded that there was no participant successfully solved the problem.



Options	A	B	C	D	A/B
Persentage	22.2	33.3	11.1	11.1	22.2

Figure 3. Fraction of groups choosing each option. A/B indicates that the groups failed to choose A or B. The right option is B.

Let us examine the argumentations of the three groups. Author will use the terms in argumentation such as claim, warrant, data, and backing introduced by Toulmin (Osborne 2005). Group I argued that balloon moves into the Erlenmeyer caused by the wind (flowing air) from colder region (inside balloon) to hotter region (inside Erlenmeyer). It means that, according to the Group I, there is a wind from balloon to Erlenmeyer. This claim, of course, is very different from what really happens; no such a wind occurs. Balloon as a whole (rubber and air therein) moves slowly into the Erlenmeyer. Group II used a claim that balloon is denser than the air inside Erlenmeyer. The claim is true and sensible, but this is also true before the air inside Erlenmeyer was burning. The fact that balloon tends to fall to the earth is the evidence for the latter claim. It is clear that this group was inconsistent in using data and employing warrant to develop a claim. Now, we turn to Group III. Although this group succeeded to develop more comprehensive argument than the other two groups did, their final claim is scientifically still unclear and insensible. The group used the claim that the volume of air inside Erlenmeyer decreases so that the outer-air must flows into the Erlenmeyer. This claim, of course, is very different from what really happens; no such a flowing air occurs. Existing balloon in the mouth of Erlenmeyer prevents this possibility.

The ways the participants solved the problem

Besides written report, author also gathered data through observation. Author found that no participant proposed diagram or equation during discussion. They all relied on verbal argumentations that frequently common sense. There was also no participant who referred to state equation of ideal gas, $PV = nRT$, or referred to Newton laws of motion to discuss the possibility of balloon's motions.

Let us back to the groups' argumentation listed in Table 2. Most groups had successfully constructed the claim that fire increases the temperature of air inside Erlenmeyer (Group VI did not mention the claim explicitly). It is the claim closely related to the surface feature of the phenomena. The next claims were very diverse (see Figure 4).

Table 2. The reasoning of the participants in deciding their answer

Group	Option	Reasoning
I	B (right answer)	Because of the fire, temperature inside Erlenmeyer increases exceeding the temperature of air inside balloon. Since air flows from colder to hotter region, then balloon moves into the Erlenmeyer.
II	B (right answer)	Fire increases the temperature of air inside Erlenmeyer. The air's density then decreases and become lighter than balloon's density. As the result, balloon moves downward into the Erlenmeyer.
III	B (right answer)	The fire increases both the temperature and pressure of air inside Erlenmeyer. This high pressure pushes some air particles away from Erlenmeyer. Upon the fire off and the balloon on the mouth of the Erlenmeyer, the pressure and temperature of the air inside Erlenmeyer decreases to get equilibrium with pressure and temperature of outer air. During this process, the volume of air inside Erlenmeyer decreases so that the outer-air must flows into the Erlenmeyer. As the result, balloon moves into the Erlenmeyer.
IV	A	Fire increases the temperature of air inside Erlenmeyer. There are two possible effects on the air inside Erlenmeyer. (1) Its pressure increases such that it is able to push balloon up. (2) Its volume expanses exceed the volume of Erlenmeyer so that a part of air particles flow to outer Erlenmeyer. These moving particles push balloon up.
V	A	Because of the fire, the temperature of air inside Erlenmeyer is greater than that of air outside Erlenmeyer. As a result, there must be a heat transfer, through convection, from inside to outside Erlenmeyer. Because the convection is in upward direction, then the balloon will move upward too.
VI	C	There is no significant effect on the balloon. Air inside Erlenmeyer unable lift balloon from Erlenmeyer nor pull balloon into the Erlenmeyer.
VII	D	Air inside Erlenmeyer has so high temperature that it pushes strongly the balloon. Since balloon has own pressure caused by the air therein, the pressure inside balloon become so high that balloon explodes.
VIII	A	Hot air in the Erlenmeyer has so high pressure that able to lift balloon.
	B	**First argument**: The fire increases the temperature of air inside Erlenmeyer so that its density decreases. The outer air then flows into Erlenmeyer while pulls balloon into the Erlenmeyer. **Second argument:** Upon the fire off, the temperature of air inside Erlenmeyer is decreasing. When this temperature is lower than the balloon's temperature, there will heat-flow (through convection) from air inside balloon to the air inside Erlenmeyer. Because of the nature of convection, balloon is also moving into the Erlenmeyer.
IX	A	Temperature of air in the Erlenmeyer increase, so does the pressure. Such high pressure then lifts balloon out of Erlenmeyer.
	B	The density of air inside Erlenmeyer is lighter than that of air inside balloon. Then, balloon moves into the Erlenmeyer.

Note: author has renamed the groups for just a technical purpose.

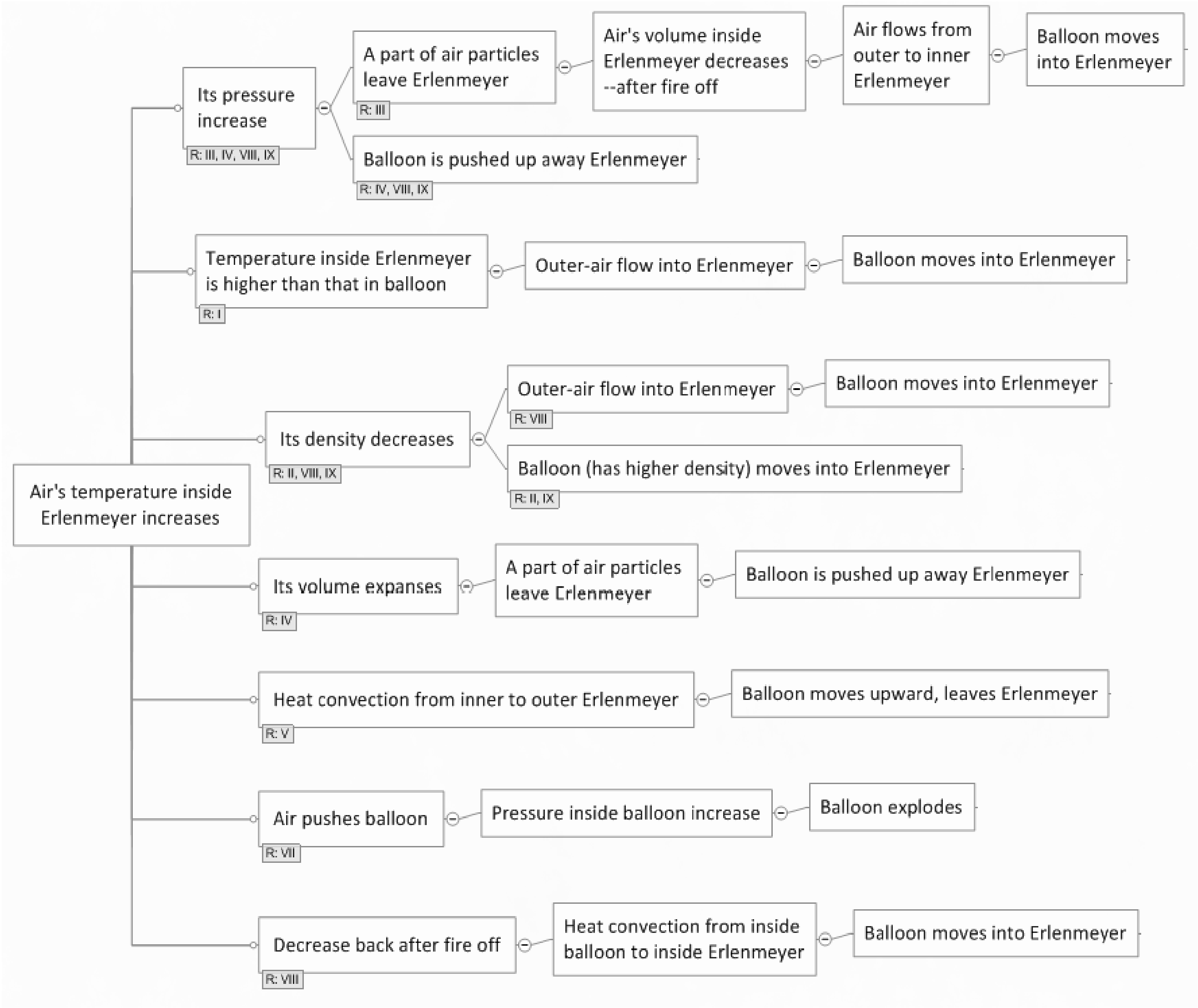


Figure 4. The variations of participants' reasoning in solving the problem. The Roman number below the box indicates the name of group.

Based on the patterns shown in Figure 4, author introduces some models likely used by participants in solving the problem. (1) The Sea-Continental Wind model: wind flows from lower to higher temperature (Group I). (2) The Heat Convection model: moving particles accompany heat transfer (Group V and VIII). (3) The Collision model: internal force increases during collision (Group VII). (4) The Steam-Engine model: high-pressure air exerts high force (Group III, IV, VIII, and IX). (5) The Particle's Motion in Fluid model: the denser particle tends to move downward (Group II, VIII, and IX). There was no group employed the model of ideal gas.

Conclusion and Recommendation

Conclusions

1. There was no participant successfully solved the problem.
2. There was no participant proposed diagram or equation during discussion. They all relied on verbal argumentations that were frequently common sense. In discussing the possibilities of balloon's motion, there was also no participant who referred to state equation of ideal gas, $PV = nRT$, or referred to Newton laws of motion.

3. There were five models used by participants in solving the problem: (1) the Sea-Continental Wind model, (2) the Heat Convection model, (3) the Collision model, (4) The Steam-Engine model, and (5) the Particle's Motion in Fluid model. No group employed the model of ideal gas.

Recommendation

Teachers (participants) in this study have had long-time experiences. Unfortunately, this study shows that they failed to solve a problem that they should be able to solve. According to participants' reflection, explored at the end of the training, this situation is due to the lack of teacher's experience in solving such multifaceted real-world problem. Teachers also rarely construct such problem for their students. Therefore, it is critical that Physics Education Program should provide their prospective physics teacher the opportunities to acquire a deep content knowledge and many experiences in solving and constructing such multi-faceted real-world problems.

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