Exploring Indonesian preservice physics teachers' development of physics identity and physics teacher identity

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Appendices

APPENDIX A

Overview of the studies reviewed

Authors	Journal	Purpose	Context	Methods	Findings
In what ways does the use of MR in instruction support students' learning?					
Sutopo and Waldrip (2014)	International Journal of Science and Mathema-tics Education	To explore whether a representational approach could impact the scores that measure students' understanding of mechanics and their ability to reason	Introductory physics course in preserve physics teacher education; Indonesia	Mixed method –embedded experimental design; pre- and post-test; n=24 students	The students' reasoning and conceptual understanding were improved after learning with multiple representations approach
Podolefsky and Finkelstein (2006)	Physical Review Special Topics - Physics Education Research 2	To investigate the mechanism of using analogies and obtain information whether the representations from these analogies have a crucial role in students' reasoning and promotion of certain analogical mapping	Undergraduate physics course about electromagnetic waves; USA	Quantitative method; large – scale study of physics course; n=602	There was a correlation between students' representation choice and their reasoning ability
Susac, Bubic, Martinjak, Planinic, and Palmovic (2017)	Physical Review Physics Education Research 13	To investigate the influence of graphical representation of data on student understanding and interpreting of measurement results	Introductory physics course about measurement; Croatia	Quantitative method; a paper and pencil test, aye tracking measurement; n=101	The graphical representation can reduce the load of working memory and provide a prediction that data presented in graphical representation helps students to understand concept of measurement
Rosengrant, Van Heuvelen, and Etkina (2009)	Physical Review Special Topics - Physics Education Research 5	To investigate why students, use the representations (free-body diagrams) and whether those who use them are more successful	Physics – based algebra course about mechanics; USA	Mixed-method; multiple-choice exam and interview; n=500	The students used free – body diagram not only for solving the physics problems but also for evaluating their work and they get higher achievement that the students who did not draw free – body diagrams
Maries and Singh (2018)	Physical Review Physics Education Research 14	To investigate in which two different interventions related to the use of diagrams which were implemented during recitation quizzes in a large enrollment algebra-based introductory physics course	Algebra – based introductory physics course; USA	Quantitative and qualitative method; physics problems quiz and think-aloud interview; n=134	The students who provided diagram representations spent less time in understanding and analyzing physics problems. The use of diagram representations in not too complex physics problems may have a detrimental effect

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Susac, Bubic, Planinic, Movre, and Palmovic (2019)	Physical Review Physics Education Research 15	To explore the role of supportive diagrams using eye tracking	Introductory physics course about energy; Croatia	Quantitative and qualitative method; problem solving physics question and eye tracking measurement; n=60	The supportive diagrams provided a positive effect on students' correctness in answering physics problems
McPadden and Brewe (2017)	Physical Review Physics Education Research 13	To examine the number and variety of representations, the impact of the second semester on students' representation choices, and how students' familiarity with the Modeling Instruction class	Algebra–based introductory physics course; USA	Quantitative method; card-short survey in pre- and post-semester; n=58	There was significant different on students' achievement between a group of students who already employed modeling instruction in the previous semester and a group of students who were new with this kind of method
Korff and Rebello (2012)	Physical Review Special Topics - Physics Education Research 8	To describe how Amber learned with a sequence of seven lessons which facilitate learning of integration in physics context	Introductory physics course about mechanics; USA	Qualitative method-a case study; n=1	The use of multiple representations can enhance students' conceptual understanding of physics
Klein, Viiri, Mozaffari, Dengel, and Kuhn (2018)	Physical Review Physics Education Research 14	To investigate the effectiveness of two strategies involving representations in enhancing students' conceptual understanding	Introductory undergraduate physics course on electromagnetism; Germany	Quantitative and qualitative method; pre- and post- test, interview, and eye tracking measurement; n=41	Two strategies which involved the use of representations (i.e., derivative strategy and integral strategy) have their own characteristics to complete each other and provide a positive impact on students' understanding of physics concept
What kinds of representations do students use?					
Kuo, Hull, Gupta, and Elby, (2013)	Science Education	To describe the case that problem-solving expertise should include an opportunistically blending of conceptual and formal mathematical reasoning *even while* manipulating equations	A calculus – based introductory physics course about kinematics; USA	Case study; interview with physics problems; n=13	The use of representations such as blending conceptual and symbolic reasoning in the problem – solving process has a potential to support students' learning physics

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Authors	Journal	Purpose	Context	Methods	Findings
Chiou and Anderson (2010)	Science Education	To probe 30 undergraduate physics students' mental models and their predictions about heat conduction	Advanced undergraduate physics course; Taiwan	Constant comparative method; interview; n=30	The students' ontological beliefs could lead to conceptualizations of phenomena that refer to students' mental models
Fredlund, Airey, and Linder (2012)	European Journal of Physics	To draw on a number of sources in the literature that explore the role of representations in interactive engagement in physics	Undergraduate physics course on refraction; Sweden	Qualitative method – case study; a group student consisted three students	The students used several representations such as ray diagrams, wave front, mathematics symbols, speech, and gesture during interactive engagement learning process
Ibrahim and Rebello (2013)	Physical Review Special Topics - Physics Education Research 9	To explore the categories of mental representations that students work with during problem solving of different representational task formats	A calculus – based physics course; USA	Qualitative method; problem-solving task and interview; n=19	Most students used propositional mental representation when they dealing with physics problems
What difficulties do students face in using MR?					
Bollen, van Kampen, Baily, Kelly and De Cock (2017)	Physical Review Physics Education Research 13	To describe a study of student difficulties regarding interpreting, constructing, and switching between representations of vector fields, using both qualitative and quantitative methods	Introductory physics courses in Belgium, Ireland, Germany	Qualitative method; semi-structured interview; n=196	The students lacked representational fluency when interpreting and constructing field line diagrams because the difficulties in understanding magnitude and direction of vector field
Maries, Lin, and Singh (2017)	Physical Review Physics Education Research 13	To investigate student difficulties in translating between mathematical and graphical representations for a problem in electrostatics and find the effect of increasing levels of scaffolding on students' representational consistency	A calculus – based introductory physics course about Gauss's law; USA	Qualitative method; problem-solving physics task and think-aloud interview; n=65 (problem-solving); n=7 (interview)	The scaffolding can impact positively n students' performance when translating mathematical to graphical representation

Authors	Journal	Purpose	Context	Methods	Findings
What is the relation between the use of MR and students' problem-solving ability?					
Kohl and Finkelstein (2005)	Physical Review Physics Education Research 1	To examine student performance on homework problems given in four different representational formats (mathematical, pictorial, graphical, verbal), and to examine students' assessment of representations	Introductory physics course; USA	Quantitative method; problem-solving physics quizzes and homework; n= 600	There were statistically significant performance differences between different representations of nearly isomorphic statements of quiz and homework problems
Kohl and Finkelstein (2006)	Physical Review Physics Education Research 2	To investigate in more detail how and when student problem-solving performance varies with problem representation, verbal, mathematical, graphical, or pictorial.	Introductory physics course; USA	Qualitative method; problem-solving physics task and interview; n=16	The form of representations in presenting physics problems influence students' problem – solving skills
Meltzer (2005)	American Journal Physics 73	To analyze the students' problem-solving performance on similar problems posed in diverse representations	Algebra – based general physics course; USA	Quantitative method-comparison between two representations; pre- and post-test and quizzes	There was significant difference of students' achievement in the coulomb quiz which used diagram and graphical representation, but there is no significant difference among different representation in general.
De Cock (2012)	Physical Review Special Topics - Physics Education Research 8	To examine student success on three variants of a test item given in different representational formats (verbal, pictorial, and graphical), with an isomorphic problem statement	Undergraduate physics course in a pharmaceutical science program; Belgium	Quantitative method-a large-enrollment class; n=200	The representational format impacted the students' problem – solving skills which implies that the specific, micro – level features of representation can lead students to use a particular problem – solving strategy

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Authors	Journal	Purpose	Context	Methods	Findings
Susac, Bubic, Kazotti, Planinic, and Palmovic (2018)	Physical Review Physics Education Research 14	To study physics and non-physics (psychology) students' understanding of graphs	Prospective physics teachers and psychology students; Kinematics and finance; USA	Quantitative and qualitative method; n=90	The physics students (graph expert) had much higher scores than psychology students (non-expert) in solving physics problems; physic students solved equally well quantitative and qualitative problems, but psychology students solved qualitative problems better than quantitative problems
What is the added value of technology integration in teaching with MR?					
Kohnle and Passante (2017)	Physical Review Physics Education Research 13	To describe work characterizing students' spontaneous use of representations before and after working with combined simulation and tutorial on first-order energy corrections in the context of quantum-mechanical time-independent perturbation theory	Undergraduate physics course; USA	Quantitative method; pre-, mid-, and post-test; n=116	The number of the representational formats used by the students and their consistency increased following the instruction which combined the tutorial and simulation
Zacharia and Jong (2014)	Cognition and Instruction	To investigate whether introducing virtual laboratories (which refers to virtual manipulatives) within an existing inquiry curriculum that is geared toward the use of physical laboratories (which refers to physical manipulatives)	An introductory physics course; teacher education program; Cyprus	Quantitative and qualitative method; conceptual knowledge test, video, interview; n=194	The students in the physical manipulative group had more difficulties in setting up a complex circuit than the students who used virtual manipulatives
Magana, Serrano, and Robello (2019)	Journal of Computer Assisted Learning	To provide guidelines on how visuohaptic simulations can be implemented effectively	A physics class for elementary education; USA	A pre- and post-test quasi experimental design; conceptual knowledge test; n=170	Haptic force feedback has the potential to enrich learning when compared with visual only environments; Haptic and visual modalities interact better when sequenced one after another rather than presented simultaneously

Authors	Journal	Purpose	Context	Methods	Findings
Hill, Sharma, and Johnston (2015)	European Journal of Physics	To develop, implement, and evaluate research-based online learning resources in the form of pre-lecture online learning module (OLMs)	A first-year undergraduate physics course; Australia	Quantitative method; pre- and post-test; n=400	The use of concept-based OLMs and representation-based OLMs enhanced students' learning achievement in terms of both conceptual understanding and representational fluency

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APPENDIX B

The syllabus of the introductory physics course: Fundamental of Physics II

I. Course description

Module Designation	**Fundamentals of Physics II**	
Module Level, if Applicable	Undergraduate	
Language	Bahasa Indonesia	
Relation to Curriculum	Ba Physics Education, Compulsory, 2nd semester	
Type of teaching, Contact Hours	Lecture, 200/week	
Workload	Lectures: 4 x 50 = 200 minutes	
	Exercises and Assignments: 4 x 60 = 240 minutes/week	
	Private study: 4 x 60 = 240 minutes/week	
Credit Points	4 credit (sks) (6.35 ECTS)	
Requirements According to the Examination Regulations	(1) Student has an attendance rate of minimal 80% with no valid reasons for the absence; and (2) Student has an attendance rate of minimal 65% with valid reasons for the absence	
	Assessment methods: (1) Mid Exam; (2) Final Exam; (3) Daily Test; (4) Weekly Assignment; and (5) Project	
Module Objectives/ intended Learning Outcomes (LO)	LO3	To master theoretical concepts and basic principles of classical and modern physics and their application in relevant problems
	LO4	To be skilful in mathematics and computation to solve physics problems.
	No.	Module objectives:
	1	Students master the body of knowledge of physics about vibration, mechanical wave, and sound; and able to scientifically explain natural phenomena and technological products in everyday life related to vibrations and wave.
	2	Students master the body of knowledge of thermodynamics and able to scientifically explain natural phenomena and technological products in everyday life related to thermodynamics.
	3	Students master the body of knowledge of electrical phenomena and able to scientifically explain the natural phenomena and technological products in everyday life related to static electricity and direct current circuit.

Content	Oscillations: 1. Simple harmonic motion, 2. Energy in simple harmonic motion, 3. An angular simple harmonic oscillator, 4. Pendulums, circular motion, 5. Damped simple harmonic motion, 6. Forced oscillations and resonance. Wave I: 1. Transverse wave, 2. Wave speed on a stretched string, 3. Energy and power of a wave traveling along a string, 4. The wave equation, 5. Interference of waves, 6. Phasors, 7. Standing wave and resonance. Wave II: 1. Speed of sound, 2. Traveling sound waves, 3. Interference, 4. Intensity and sound level, 5. Sources of musical sound, 6. Beats, 7. The doppler effect, 8. Supersonic speeds, shock waves. Temperature: 1. Temperature and the Zeroth Law of Thermodynamics, 2. Thermometers and the Celsius Temperature Scale, 3. The Constant-Volume Gas Thermometer and the Absolute Temperature Scale, 4. Thermal Expansion of Solids and Liquids, 5. Macroscopic Description of an Ideal Gas. The First Law of Thermodynamics: 1. Heat and Internal Energy, 2. Specific Heat and Calorimetry, 3. Latent Heat, 4. Work and Heat in Thermodynamic Processes, 5. The First Law of Thermodynamics, 6. Some Applications of the First Law of Thermodynamics, 7. Energy Transfer Mechanisms in Thermal Processes. The Kinetic Theory of Gases: 1. Molecular Model of an Ideal Gas, 2. Molar Specific Heat of an Ideal Gas, 3. The Equipartition of Energy, 4. Adiabatic Processes for an Ideal Gas, 5. Distribution of Molecular Speeds. Heat Engines, Entropy, and the Second Law of Thermodynamics: 1. Heat Engines and the Second Law of Thermodynamics, 2. Heat Pumps and Refrigerators, 3. Reversible and Irreversible Processes, 4. The Carnot Engine, 5. Gasoline and Diesel Engines, 6. Entropy, 6. Changes in Entropy for Thermodynamic Systems Entropy and the Second Law.Electricity: 1. Electric Fields, 2. Gauss's Law, 3. Electric Potential, 4. Capacitance and Dielectrics, 5. Current and Resistance, 6. Direct Current Circuits.
Reading lists	Serway, R. A., & Jewet, J. W. 2004. Physics for Scientist and Engineers, 6th edition. California: Thomson Books/Cole..
	Halliday, D., & Resnick, R. 2014. Fundamental of Physics, Tenth Edition. New York: Wiley.
	Knight, R. D. 2013. Physics for Scientist and Engineer a Strategic Approach, Third Edition. United State of

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II. The objectives for the topics of thermodynamics

Sub-topics	Objectives
Temperature and thermal expansion	· Students are able to understand and explain the concept of "absolute zero" · Students are able to understand and solve the problem related to different temperature scales · Students are able to understand and explain the concept of thermal expansion following length, area and volume
Macroscopic description of the ideal gas	· Students are able to understand the relation between volume (V), pressure (P), and temperature (T) in ideal gas phenomena.
Heat	· Students are able to nderstand the concept of heat · Students are able to understand and explain the heat used to change the state of matter · Students are able to explain the mechanism of heat transfer.
The first law of thermodynamics	· Students are able to understand the energy transfers known as work and heat · Students are able to understand and explain the application of the first law of thermodynamics and its correlation with the thermodynamics process · Students are able to understand and explain the thermodynamics processes and the representation in the PV-diagram
Heat engine and the second law of thermo-dynamics	· Students are able to understand the concept of the second law of thermodynamics · Students are able to understand and explain the application of the second law of thermodynamics in heat engine

III. Instructional activities

General steps	Instructor's activities	Students' activities
Identifying the variable of the problems	- Introducing the topic - Presenting physics problems using some representations [*the instructor uses some representations such as problems in pictorial and diagram representations, or the live and pre-recorded demonstrations]* - Asking students about physics variables related to the problems	- Paying attention to the instructor's explanation - When the instructor uses live demonstrations, the students are involved in these activities. - Responding to questions proposed by the instructor
Creating representation	- Asking students to create different representations from the presented problems - Moving around the classroom to provide individual assistance	- Creating some representations based on the guidance from the instructor - Working individually on problems presented by the instructor
Discussing response with peers or group work	- Asking students to discuss with their peers in a group of 3-4 students - Facilitating students' working groups and encouraging students to ask when they are stuck or have difficulties	- Working in a group and discussing their work
Whole-class discussion	- Asking students to explain the solution of the problems in front of the class - Facilitating the discussion process of the students - Asking students to evaluate their work in the form of conceptual explanation from representations that have been used	- Presenting the work in front of the class Discussing all groups' answers

APPENDIX C

Physics identity questionnaire (adapted from Hazari, et.al., 2010)

Performance scale: Please indicate how often the following occurred during your physics class

Activities	None	Very rarely	Once/ month	2-3/ month	Once/ week	2-3 times/ week	Every class
You taught your classmates							
Did hands-on or lab work							
Small group work was held							
You asked questions							
You answered questions or made comment							

Interest scale: Please rate your general interest in the following

	Not interested at all					Extremely interested
Physics topics: thermodynamics	1	2	3	4	5	6
Conducting your own experiments	1	2	3	4	5	6
Understanding natural phenomena	1	2	3	4	5	6
Understanding everyday-life science	1	2	3	4	5	6
Explaining things with facts	1	2	3	4	5	6
Using mathematics	1	2	3	4	5	6
Telling others about science concepts	1	2	3	4	5	6
Making scientific observations	1	2	3	4	5	6
Wanting to know more science	1	2	3	4	5	6
Graduating from college with honors	1	2	3	4	5	6

Recognition scale: Do the following people see you as a physic person?

	No, not at all					Yes, very much
Yourself	1	2	3	4	5	6
Parents/ relatives/ friends	1	2	3	4	5	6
Your teacher	1	2	3	4	5	6

APPENDIX D

Conceptual understanding test (adapted from Wattanakasiwich et al., 2013)

Thermodynamic Concept Survey

Directions: For each question, please indicate your answer by circling a choice.

1. Cup A contains 100 grams of water at 0°C but cup B contains 200 grams of water at 50°C. The contents of the two cups are mixed together in an insulated container (no heat transfer occurs). When it reaches thermal equilibrium, what is the final temperature of the water in the container?
   A) Between 0°C and 25°C
   B) 25°C
   C) Between 25°C and 50°C
   D) 50°C
   E) Higher than 50°C

2. Jim believes he must use boiling water to make a cup of tea. He tells his friends that, "I couldn't make tea if I was camping on a high mountain because water doesn't boil at high altitudes." Which statement do you strongly agree with?
   A) Joys says, "Yes it does, because the water boils below 100°C because the pressure decreases."
   B) Tay says, "Jim is incorrect because water always boils at the same temperature."
   C) Lou says, "The boiling point of the water decreases, but the water itself is still at 100°C."
   D) Mai says, "I agree with Jim. The water never gets to its boiling point."

3. Cup A contains 100 grams of water and cup B contains twice as much water. The water in both cups was initially at room temperature. Then the water in cup A was heated to 75°C and the water in cup B was heated to 50°C. When the water in both cups cooled down to room temperature, which cup had more heat transferred from it?

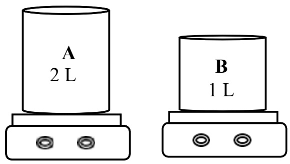
   A) Cup A had more heat transferred out.
   B) Cup B had more heat transferred out.
   C) Both cups had the same amount of heat transferred.
   D) Not enough information is given to determine the answer.

A

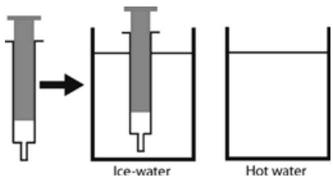
4. If 100 grams of ice at 0°C and 100 grams of water at 0°C are put into a freezer, which has a temperature below 0°C. After waiting until their temperature equals to the freezer temperature, which one will eventually lose the greatest amount of heat?
   A) The 100 grams of ice.
   B) The 100 grams of water.
   C) They both lose the same amount of heat because their initial temperatures are the same.
   D) There is no answer because ice does not contain any heat.
   E) There is no answer because you cannot get water at a temperature of 0°C.

5. Kim picks up two rulers, a metal one and a wooden one. He announces that the metal one feels colder than the wooden one. What is your preferred explanation for this situation to Kim?
   A) Metal conducts heat faster than wood.
   B) Wood is naturally a warmer substance than metal.
   C) Metals are better heat radiators than wood.
   D) Cold flows more readily from a metal.

6. Cup A contains 2 litres of water and cup B contains 1 litre of water. The water in both cups was initially at room temperature. Then both cups are placed on a hot plate and heated until the water in the cup is boiling (100°C). Which statement is correct?
   A) Water in both cups has the same heat transfer.
   B) Water in cup A has more heat transfer.
   C) Water in cup B has more heat transfer.



Please use the following information to answer questions 7-9.



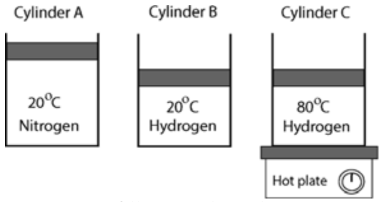
A syringe that contains an ideal gas and has a frictionless piston of mass M is moved from a beaker of cold water to a beaker of hot water. Answer the following questions and consider that the syringe reaches thermal equilibrium with hot water.

7. How does the gas temperature change?
   A) Increase B) Decrease C) No change

8. How does the gas pressure change?
   A) Increase B) Decrease C) No change

9. How does the gas volume change?
   A) Increase B) Decrease C) No change

Please use the following information to answer questions 10-11.



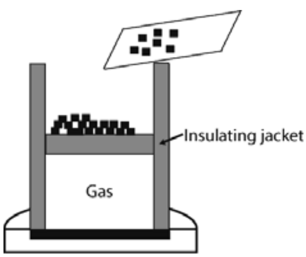
Three identical cylinders are filled with unknown quantities of ideal gases. The cylinders are closed with identical frictionless pistons of mass M. Cylinder A and B are in thermal equilibrium with the room at 20°C, and cylinder C is kept at a temperature of 80°C. The piston of each cylinder is in mechanical equilibrium with the environment.

A

10. How does the pressure of nitrogen gas in cylinder A compare with the pressure of hydrogen gas in cylinder B?
    A) Greater B) Less than C) Same

11. How does the pressure of hydrogen gas in cylinder B compare with the pressure of hydrogen gas in cylinder C?
    A) Greater B) Less than C) Same

Please use the following information to answer questions 12-14.
An ideal gas is contained in a cylinder with a tightly-fitting piston so that no gas escapes. Several small masses are on the piston. (Neglect friction between the piston and the cylinder walls.) The cylinder is placed in an insulating jacket. A large number of masses are quickly added to the piston.



12. How does the temperature of the gas change?
    A) Increase B) Decrease C) Remains unchanged

13. How does the pressure of the gas change?
    A) Increase B) Decrease C) Remains unchanged

14. How does the volume of the gas change?
    A) Increase B) Decrease C) Remains unchanged

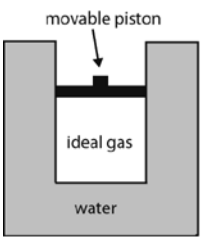
Please use the following information to answer questions 15-17.
A cylindrical pump contains one mole of an ideal gas. The piston fits tightly so that no gas escapes, and friction is negligible between the piston and the cylinder walls. The piston is quickly pressed inward so the volume of gas reduces instantly.

15. How does the temperature of the gas change?
    A) Increase B) Decrease C) Remains unchanged

16. How does the total work done by the system (gas) change?
    A) Increase B) Decrease C) Remains unchanged

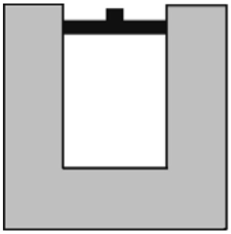
17. How does the internal energy of the gas change?
    A) Increase B) Decrease C) Remains unchanged

Please use the following information to answer questions 18-23.
A fixed quantity of ideal gas is contained within a metal cylinder that is sealed with a movable, frictionless, insulating piston. (The piston can move up or down without the slightest resistance from friction, but no gas can enter or leave the cylinder. The piston is heavy, but there can be no heat transfer to or from the piston itself.) The cylinder is surrounded by a large container of water with high walls as shown.



Time *A*
Entire system at room temperature

Step 1. Start of Process # 1: The water container is gradually heated, and the piston very slowly moves upward. At time B the heating of the water stops, and the piston stops moving when it is in the position shown in the diagram below:

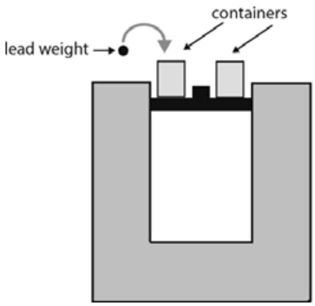


Time *B*

Piston in new position.

Temperature of system has changed.

Step 2. Now, empty containers are placed on top of the piston as shown. Small lead weights are gradually placed in the containers, one by one, and the piston is observed to move down slowly. While this happens, the temperature of the water is nearly unchanged, and the gas temperature remains practically constant. (That is, it remains at the temperature it reached at time B, after the water had been heated up.)

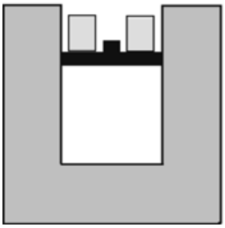


weights being added

Piston moves down slowly.

Temperature remains same as at time B.

Step 3. At time C we stop adding lead weights to the container and the piston stops moving. (The weights that were added until now are still in the containers.) The piston is now found to be at exactly the same position it was at time A.



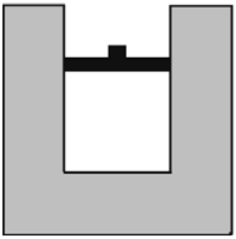
Time *C*

Weights in containers.

Piston in same position as at time *A*.

Temperature same as at time *B*.

Step 4. Now, the piston is locked into place so it cannot move; the weights are removed from the piston. The system is left to sit in the room for many hours, and eventually the entire system cools back down to the same room temperature it had at time A. When this finally happens, it is time D.



Time *D*

Piston in same position as at time *A*.

Temperature same as at time *A*.

Step 5. Now let us begin Process # 2. The piston is unlocked so it is again free to move. We start from the same initial situation as shown at time A and D (i.e., same temperature and position of the piston). Just as before, the water is heated and we watch as the piston rises. However, this time, heat transfers to the water for a longer period of time. As a result, the piston ends up higher than it was at time B in Process # 1. The piston then continues from step 2 to step 4 and the final state when the weights are removed occurs at time E.

18. During the process that occurs from time A to time B, which following statement about work is true?
    A) Positive work is done on gas by the environment.
    B) Positive work is done by the gas on the environment.
    C) No net work is done on or by the gas.

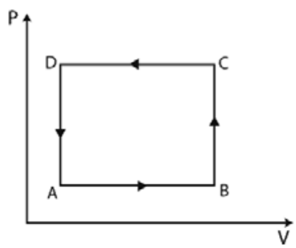
19. During the process that occurs from time A to time B, the gas absorbs x Joules of energy from the water. What happens to the total kinetic energy of all of the gas molecules?
    A) Increases by more than x Joules.
    B) Increases by x Joules.
    C) Increases, but less than x Joules.
    D) Remains unchanged.
    E) Decreases by less than x Joules.
    F) Decreases by x Joules.
    G) Decreases by more x Joules.

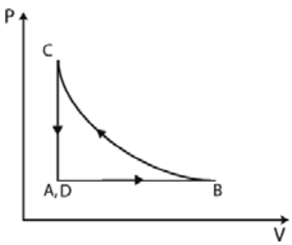
20. During the process that occurs from time B to time C, what happens to the total kinetic energy of all gas molecules?
    A) Increase B) Decrease C) Remains unchanged

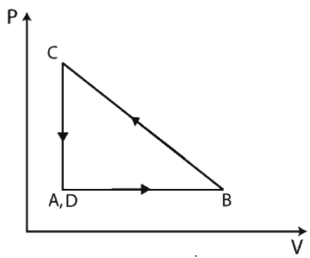
21. During the process that occurs from time B to time C, is there any net heat transferred between the gas and the water?
    A) There is the net heat transferred from gas to water.
    B) There is the net heat transferred from water to gas.
    C) There is no heat transferred.

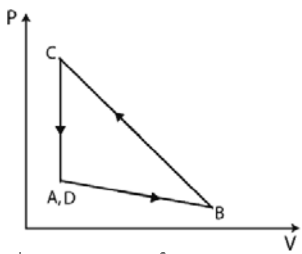
22. During the process that occurs from time C to time D, y Joules of heat transfer occurs from the gas to the water. What happens to the total kinetic energy of all of the gas molecules?
    A) Increases by more than y Joules.
    B) Increases by y Joules.
    C) Increases, but by less than y Joules.
    D) Remains unchanged.
    E) Decreases by less than y Joules.
    F) Decreases by y Joules.
    G) Decreases by more than y Joules.

23. Which P-V diagram best describes the process that occurs from time A to time D?

A)


B)


C)


D)


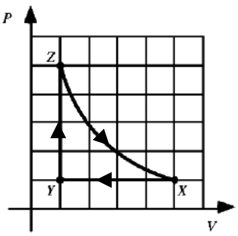
For questions 24-26, please consider the process that occurs from time A to time D, and then to time E.

24. What is the net work done by the gas on the environment during that process?
    A) Equal to zero. B) Less than zero. C) Greater than zero.

25. What is the heat transfer from water to gas during the process?
    A) Equal to zero. B) Less than zero. C) Greater than zero.

26. Consider the total kinetic energy of all the gas molecules at time A, D, and E; call those KE_A, KE_D, and KE_E. Rank these in order of magnitude of total kinetic energy of the gas molecules at these times.
    A) $KE_A > KE_D > KE_E$ C) $KE_A = KE_D = KE_E$
    B) $KE_A < KE_D < KE_E$ D) $KE_A = KE_D < KE_E$

Please use the following information to answer questions 27-29.
A student performs an experiment with an ideal gas that is contained in a cylinder with a piston. The P-V diagram below shows the values of pressure and volume of the gas throughout the experiment, starting at point X, continuing to points Y and Z, and returning to point X. Process Z → X is isothermal.



27. What is the total work done by the gas in the entire cycle (X → Y → Z → X)?
    A) Positive B) Negative C) Zero

28. What is the total heat transfer for the entire cycle (X → Y → Z → X)?
    A) Positive B) Negative C) Zero

29. What is the change of internal energy of the gas in the entire cycle (X → Y → Z → X)?
    A) Positive B) Negative C) Zero

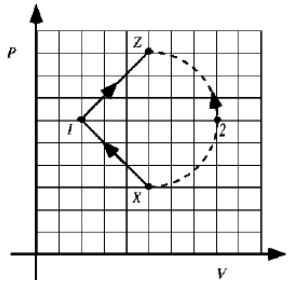
Please use the following information to answer questions 32-34.
This P-V diagram represents a system consisting of a fixed amount of ideal gas that can undergo two different processes in going from state A to state B through Process #1 and Process #2.

30. Work done by the system in Process # 1 is ….. than Process # 2.
    A) greater than B) less than C) equal to

31. The change in internal energy of all molecules in the system for Process #1 is …. than Process # 2.
    A) greater than B) less than C) equal to

32. Heat transferred into the system in Process # 1 is …. than Process # 2.
   A) greater than   B) less than   C) equal to

33. A student performs an experiment with an ideal gas that is confined to a cylinder with a piston. The P-V diagram below shows the values of pressure and volume of the gas throughout the experiment, starting at point X and ending at point Z. Compare the absolute value of the work done during process X → 2 → Z (a dash line) and process X → 1 → Z (a bold line). Which statement is correct?



   A) X → 2 → Z is greater than X → 1 → Z.
   B) X → 2 → Z is less than X → 1 → Z.
   C) X → 2 → Z is equal to X → → Z.

A

APPENDIX E

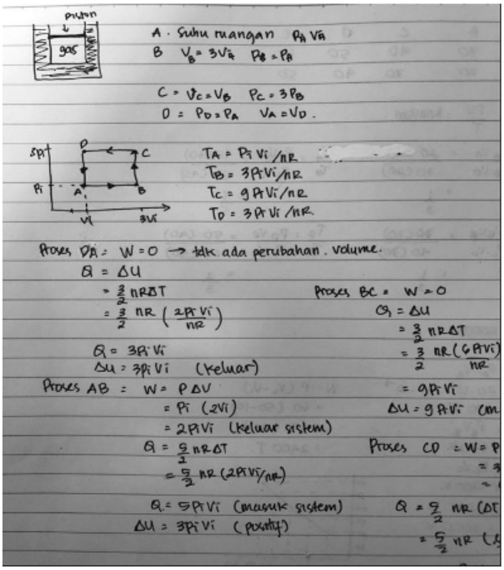
The use of representation survey (adapted from Kohl, 2008)

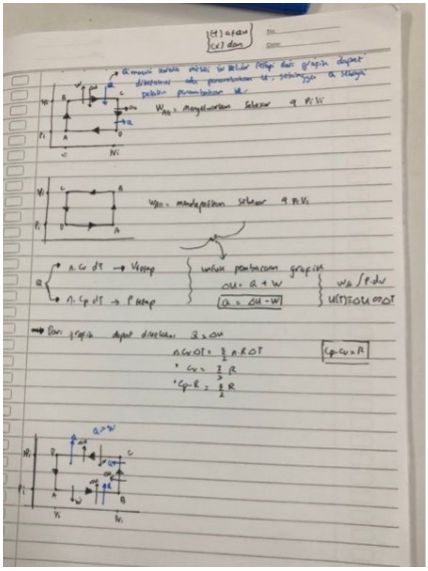
Please use check (√) for the statement based on this scale:
1: strongly disagree
2: disagree
3: neither agree nor disagree (neutral)
4: agree
5: strongly agree

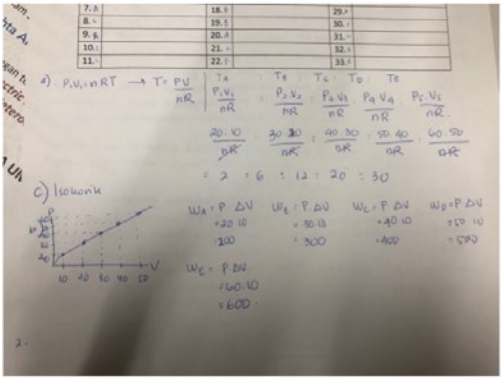
No	Statements	1	2	3	4	5
1.	When I am drawing a diagram (e.g., P-V diagram) that include numbers, I check to make sure that the diagram and the math match well					
2.	I am good at figuring out how closely related different representations are (words, equations, pictures, diagrams, etc.)					
3.	I feel motivated to learn in general					
4.	I often use MR (drawing pictures, diagrams, graphs) when solving physics problems					
5.	When I use MR, I do so because it makes a problem easier to understand					
6.	When I use MR, I do so because I will be more likely to get the right answer					
7.	When I use MR, I do so because the instructor (or the book) tells me that I should					
8.	I am good at representing information in multiple ways to explain it to my peers (words, equations, pictures, diagrams, etc.)					
9.	How often you use the following in solving physics problems, and how comfortable you feel when doing in the form of **diagrams** representation					
10.	How often you use the following in solving physics problems, and how comfortable you feel when doing in the form of **equation or numbers**					
11.	How often you use the following in solving physics problems, and how comfortable you feel when doing in the form of **graphs**					
12.	How often you use the following in solving physics problems, and how comfortable you feel when doing in the form of **written explanations**					

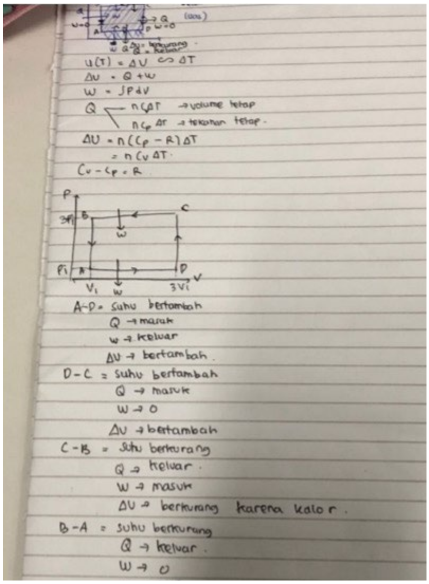
APPENDIX F

Examples of the participants’ work



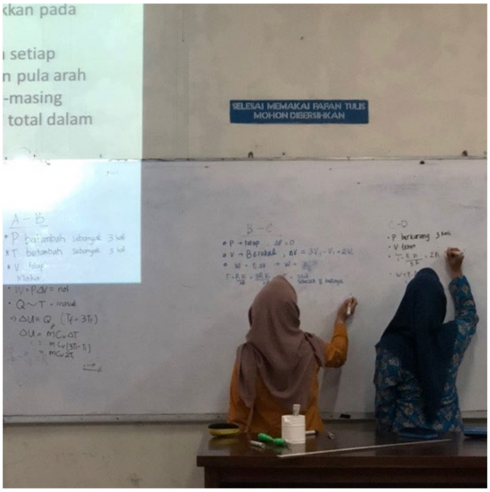






APPENDIX G

The example of activities in the classroom involving the use of some representations such graphs, equations, verbal descriptions, video, and demonstration.



APPENDIX H

Interview Protocols

The use of Multiple Representations (MR) in learning physics

1. Physics is involved several representations such as equations, graphs, diagrams, pictures. What do you think about the role of the MR-based instructional approach?
2. Is it necessary to be able to read the graph, diagram, making a visual representation in learning physics? Explain your answer.

Previous experiences/knowledge:

1. How were your learning experiences with this approach? Did you use several representations? Can you mention it, including the physics concept that you use?
2. What is the most important to be skilled in using representation in order to obtain as much as possible results in learning physics?
3. What are the difficulties that you found when you learned physics, especially in the thermodynamics concept?
4. What would you recommend to a friend who started to study physics-related the use of representations?
5. How do you employ MR to solve the problem (the researcher might provide the student with the physics problem and ask them to solve it by making a graph/diagram/picture)?
6. Do you feel that including diagrams/pictures/graphs in the physics problem makes you more interested in solving the problem?

The future:

1. What do you think about the use of multiple representations in physics teaching and learning?
2. Are you going to use this approach when you become a physics teacher in the future?
3. What will you emphasize to your students when you teach physics with MR in the future?
4. How do you see your role as a future physics teacher?
5. Can you imagine how you teach physics (especially the concept of thermodynamics – you can choose one sub-topics that you like) using several representations in the future?

Cylinder A
Cylinder B
Cylinder C
20°C Nitrogen
20°C Hydrogen
80°C Hydrogen
Hot plate
$\frac{V_1}{V_2} = \frac{2}{1}$
Process #1
State B
State A
Process #2
Pressure
Volume
$3P_i$
P_i
V_i
$3V_i$
Q_{in}
Q_{out}
W
$T_A = \frac{P_iV_i}{nR}$
$\frac{V_1}{V_2} = \frac{Ah}{A\frac{h}{2}}$
A
2 L
B
1 L
100 g
75 C
Room Temperature 25 C
200 g
50 C
movable piston
ideal gas
water
$T_B = \frac{3P_iV_i}{nR}$
$T_1 = \frac{PV_1}{n_1R}$
$T_2 = \frac{PV_2}{n_2R}$
$T_C = \frac{9P_iV_i}{nR}$
Free air
Identical piston which is free to move
$T_D = \frac{3P_iV_i}{nR}$