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Conceptual Change Texts to Improve Teachers' Misconception at Verbal and Visual Representation on Heat Conduction Concept

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Abstract

Heat Conduction is a scientific concept that related to daily life. Learning about heat conduction is usually only discussed at the macroscopic level, whereas at the sub-microscopic level never be a concern from elementary students until to the teachers. This study aims to identify the effect of using Conceptual Change Text on the teacher's representation on the heat conduction concept. A quasi-experimental method using a one-group pretest-posttest design was used in this study. The instrument was a diagnostic test, the data were analyzed from the comparison of participants' representations (5 elementary teachers) before and after treatment, the results showed that teacher representation was better after treatment. This research also reinforces that the representation of the sub-microscopic level is an important aspect of the learning process. Science learning needs to be developed and equipped up to the sub-microscopic level both verbal or visual to make science lessons more meaningful and easily understood by students.

Key words: Heat Conduction, Sub-microscopic level, Diagnostics test

INTRODUCTION

Teacher's understanding of science is a prerequisite for teaching science (Widodo, Rochintaniawati, & Riandi, 2017), that is one of the key factors to helping teachers deliver their understanding of the science content (Banda, Mumba, Chabalengula, & Mbewe, 2011). Teachers must have a good understanding of this because if teachers don't have it they will be given a bad quality of teaching. Even when the teacher has a good pedagogical knowledge (Rollnick, 2017). The consequences when teachers do not have a good understanding of science content they will provide a misconception into a student (Anam, Widodo, & Sopandi, 2017; Widodo et al., 2017). Teachers' and students' misconception usually are not in general understanding or something that can be observed with senses (concrete). This kind of understanding called a macroscopic level of representation. In science have three levels of representation 1) macroscopic level (concrete); 2) sub-microscopic, abstract level but according to phenomena that appear at the macroscopic level. This level is characterized by concepts, theories, and principles used to explain what is observed at the macroscopic level, for example, the movement of electrons, molecules, or atoms; and 3) symbolic, used to represent macroscopic phenomena through the use of mathematical equations, graphs, mechanisms, analogies, formulas, and model kits (Johnstone, 1991).

The sub-microscopic level never be a focus in science learning, teachers only represents understanding at the macroscopic level, makes students only know scientific phenomena that are very general/surface without knowing what the reason or the cause of the phenomenon is scientifical. To find out the reasons/causes of a phenomenon, it is necessary to understand

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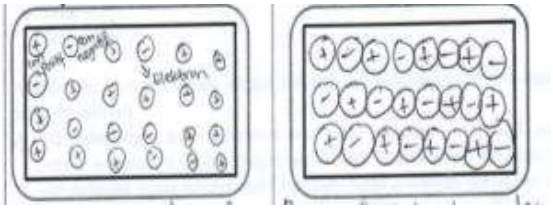
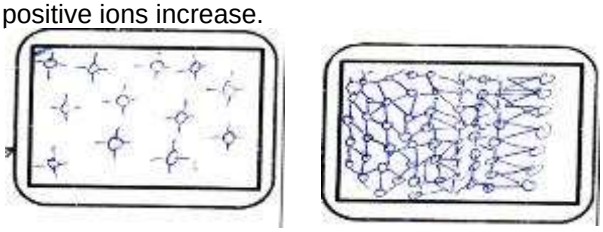
representation at the sub-microscopic level related to the basic concepts that discuss the particles making up the material because that being a basic concept, this concept is also a part that is often discussed in research related to understanding and misconception students (Banda et al., 2011; Liu & Lesniak, 2005; A. Yilmaz & Alp, 2006). In addition, many educators and researchers agree and assert that the concept of material particles is the heart of the concept of science lessons at the next level (Snir, Smith, & Raz, 2003).

Research conducted by Anam et al., (2017) dan Anam, Widodo, & Sopandi (2019) shows that verbal and visual representations of teachers and pre-service teachers on heat conduction still need to be improved (misconceptions). They assume that when heated particles of metal will enlarge positive ions increase. There are also those who think that when heated particles will increase and the bonds become stronger. Pictures of the thoughts of teachers and prospective teachers can be seen in Figure 1.



Before heated After heated

Teacher's visual representation shows that when the metal is heated the particles enlarge and positive ions increase.



Before heated After heated

Pre-service teacher's visual representation shows think that when heated particles will increase and the bonds become stronger.

Figure 1. Example of teacher's dan pre-service teacher's visual representation on heat conduction

Based on these studies the teacher's representation on sub-microscopic level of heat conduction needs to be improved because giving an understanding about particles or sub-microscopic levels can help students to make them understand about a phenomenon in science (Sopandi, Kadarohman, Rosbiono, Latip, & Sukardi, 2018; Treagust, Chittleborough, & Mamiala, 2003; Wu, Krajcik, & Soloway, 2001). Explanation of the basic concepts of the particle and its characteristics will certainly make students more successful in learning other topics in science and also supplies in the next stage because every new information is added to what is already known on the topic previously studied (Lee & She, 2010) especially if the basic concepts are studied as early as possible. However, this sub-microscopic level not only became a problem for the students' but also for their teachers too especially at the primary school. So, this research will analyze teachers' understanding at primary school about the sub-microscopic level and the effect of using Conceptual Change Text (CCT) with experiment assisted to increased teachers' understanding at the sub-microscopic level both verbal and visual.

CCT is reading material based on the conceptual change approach. CCT was chosen because it can help readers to change their conceptions more effectively and can find students or readers' misconceptions based on their reasons and can provide more meaningful explanations of scientific concepts (Yilmaz, Tekkaya, & Sungur, 2011). CCT is used to introduce theories that can make readers believe that they have a misunderstanding about a concept and CCT can help them to change conceptions to be in accordance with scientific conceptions. (Ozkan & Selcuk, 2015)

METHOD

A quasi-experimental using one group pretest and posttest design was used in this study. The subject of this study were 5 teachers school in a primary, who teaches in the fifth grade with the latest educational background of Bachelor degree (S1) from the primary teacher education, mathematics education, chemistry education, and agriculture. The instrument of this study was written test in the sub-microscopic representation at conduction concept there are reasoning

question (the sub-microscopic level at verbal); the categories of this level depend on their answers and drawing (the sub-microscopic level at visual). The instrument was given before and after teachers learn with the CCT with experiment assisted to make sure the impact of these treatments on teachers.

The CCT used in this study follows the conceptual change pattern developed by Posner, Strike, Hewson, & Gertzog (1982) starting with 1) dissatisfaction, this section aims to get the initial conception of the reader; 2) Intelligibility, regarding the concepts given; 3) Plausibility, accepting and getting new conceptions that are following scientific conceptions, 4) Fruitful, this section asks readers to give new conceptions after they read CCT.

The test was validated in two steps. Firstly, it was validated by three experts in the field of science education at elementary school. The validators are two university lecturers with doctoral degree in science education and a teacher who has a doctoral degree in elementary education. They made an agreement of more than 80% that this instrument meet the purpose of the study.

Secondly, this test was trialed to determine the empirical validity of this instrument. Correlation scores of 0.73 on Pearson Product Moment cores with $p < 0.05$ suggests that the test has good differentiate power. Because this instrument includes a drawing test, the participants' drawings (visualization) were classified into six categories. The categories are adapted from Dikmenli (2010) and Köse (2008). An explanation of the category of participants' drawing can be seen in Table 1.

RESULT AND DISCUSSION

The sub-microscopic level is a representation that explains more detail about the phenomena that occur at the macroscopic stage. Representation at the sub-microscopic level in this study will discuss verbally and visually to get detailed information on what the teacher thinks about the concept of conduction. Figure 2 will show the representation that the teacher has at the sub-microscopic level both verbally and visually.

Figure 2 gives information that at the beginning teachers don't have conception at the sub-microscopic level both verbal or visual. The teacher who can give a correct answer is only 20% at verbal and nothing (0%) at visual. this happens because the teacher can only represent their scientific conception only at the macroscopic level, the teacher has difficulty explaining why this can happen.

Table 1. The Categories of students' drawings

Categories	Explanation
Scientific Drawing (SD)	Respondents provide comprehensive visualizations that are in accordance with the scientific conceptions.
Partial Drawing (PD)	The response provides a visualization that almost close to the scientific conception with minor deficiencies in the visualization.
Misconception Drawing (MD)	Respondents provide less precise visualizations or different with scientific conception but they draw visualization at the sub-microscopic level.
Undefined Drawing (UD)	Respondents provide visualizations that are not understandable, even though the visualization given is at the sub-microscopic level.
Non-Microscopic Drawing (NMD)	Respondents provide visualization, but not at the sub-microscopic level.
No Drawing (ND)	Respondents do not provide visualization at all or they just write their answers.

Thus, from this it can be seen that conception at the sub-microscopic level or related to the concept of solid particles is not understood by the teacher even though particles are the basic concept to study into the next science concepts (Banda et al., 2011; Snir et al., 2003). Based on this study the majority of teachers have good representation at the macroscopic level while at the sub-microscopic level only one person can give verbally correct answers and none has a visual representation that is in accordance with the scientific conception of the concept of conduction and everyday phenomena. This teacher's understanding of scientific conceptions like this will lead to less optimal learning processes, while teacher understanding is a prerequisite for teaching science (Widodo et al., 2017). Therefore in this study, trying to give teachers treatment to improve their understanding of sub-microscopic levels of representation. Because the role of teacher understanding is one of the main keys in the learning process (Ball, Thames, & Phelps, 2008). If the teacher does not understand a concept they will produce poor quality in science learning (Daehler & Shinohara, 2001).

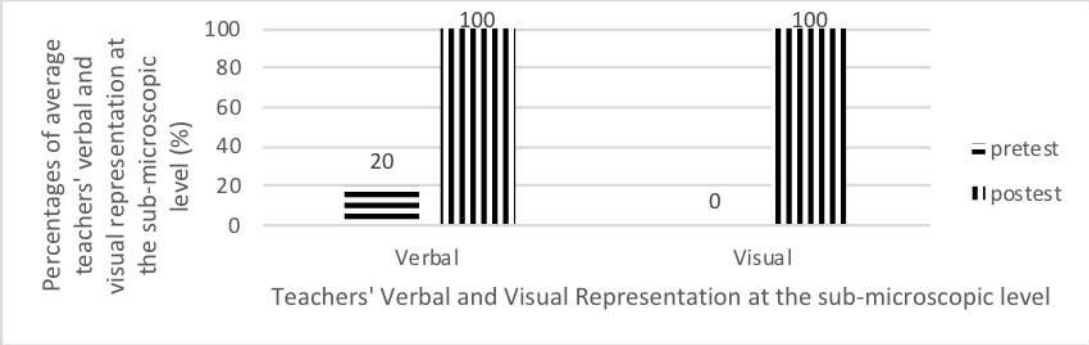


Figure 2. Percentages of teachers' verbal and visual Representation at the sub-microscopic level

This is because teachers in this study are not familiar with this level. They never studied science until the sub-microscopic level. In general, they only learn something that is seen or observed. Whereas when viewed from an educational background there are 3 teachers with science backgrounds, even if they are learning science since in elementary schools, junior and senior high school. However, because the sub-microscopic level is not a concern, the teacher's answer is related to how the heat transfer process is not in accordance with the scientific conception. But after giving the treatment the teachers' verbal and visual representation is increased so well, their verbal and visual representation becomes 100%. It can be seen that in verbal representations, the majority of teachers are initially misconceptions because they think that when a metal is heated the particles will enlarge. after being treated, their verbal representation is in accordance with the scientific conception that heated metal particles will vibrate and this vibration will be transmitted to all parts of the metal so that the heat energy will reach all parts of the metal. This change in verbal representation also impacts on their visual representation. Figure 3 shows the teacher's responses to the heat conduction process.

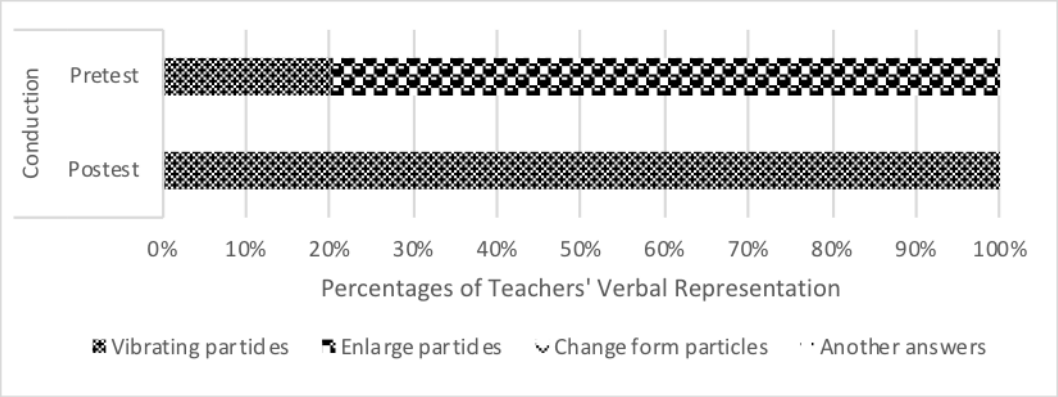


Figure 3. Percentages teachers' verbal representation at sub-microscopic level

Based on Figure 3, it can be seen that the teacher's answer at the sub-microscopic level of the conduction concept mostly (80%) chooses that the phenomenon of heat transfer is because the particles are enlarged and only 20% give an answer correctly. This shows that the teacher's conception regarding the representation of sub-microscopic (particle) levels about conduction heat transfer is not well studied by most teachers who are the subject of this study. They analogize the answers at the sub-microscopic level using what they have understood at the macroscopic level, while understanding the occurrence of heat requires insight/knowledge about the concept of particles (Çoruhlu, 2017).

The lack of knowledge about particle movements or vibrations in solids (metals) when heated causes misconceptions in this concept (Adadan, Irving, & Trundle, 2009; Adadan, Trundle, & Irving, 2010). This misconception may also have to do with confusion about the characteristics of solids particle. It is widely known that many assume that the macroscopic level characteristics that can be observed from matter are similar to the characteristics at the sub-microscopic level as well (Papageorgiou, Johnson, & Fotiades, 2008). From this lack of understanding at the sub-microscopic level, it will easily be regarded as the initial failure to direct their students in scientific conception.

The results of this pretest show that if the teacher only understands the macroscopic level of course their understanding will be the same as what the students have, especially if the understanding is only a very general understanding. This certainly will be very influential in the learning process, understanding and development of students' thinking in science lessons. If the teacher's understanding is the same as students' understanding, the teacher not only cannot facilitate well in the learning process. However, it is likely that they will convey misconceptions to their students (Tekkaya, Cakiroglu, & Ozkan, 2004; Widodo et al., 2017).

After the teacher is treated by using CCT with the assisted experiment on the sub-microscopic level representation. The understanding of all the teacher's changes became a scientific conception or 100% of them can provide correct answers at the verbal representation, they understand that the occurrence of heat transfer is not due to particle enlargement but the vibrations particles, starting from particles close to the heat source will experience very strong vibrations that can cause other surrounding particles to vibrate accompanied by the presence of heat energy. Because the phenomenon of vibration particle occurs continuously, it causes heat conduction.

The teacher's visual representation is a very important part of this study because the teacher who has a good conception will certainly provide a visual representation that is in accordance with the scientific conception they have mastered. The visual representation given by the teacher before and after the treatment changes very drastically from the beginning no one can describe it according to the scientific

conception, it has to be according to the whole scientific conception, to see how the results of the visual representation given by the teacher on the conduction concept can be seen in Figure 4.

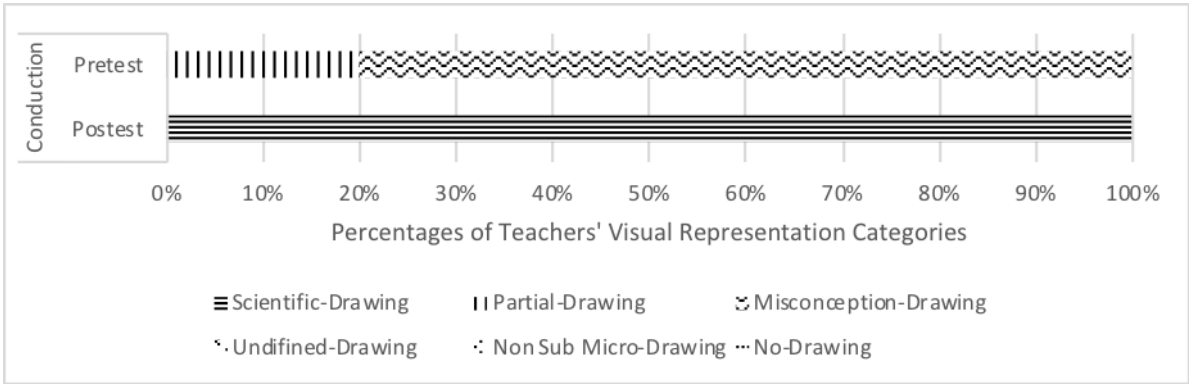
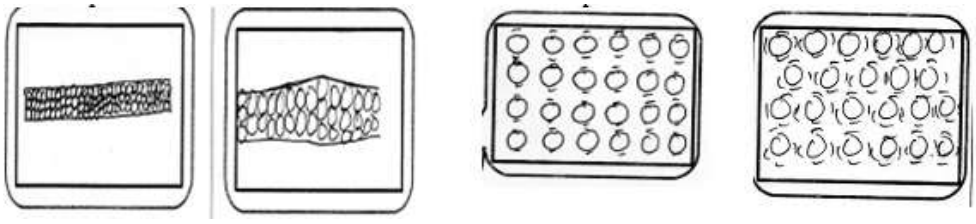


Figure 4. Percentages categories of teachers' visual representation

Figure 4 shows that the visual representation given by the teacher does not initially belong to the Scientific Drawing (SD). The picture given by the teacher majority belongs to the Misconception-Drawing (MD) categories was 80% and Partial Drawing (PD) was 20% in the concept of conduction even though there is one teacher who answers correctly at the sub-microscopic verbal level but the visual representation given is not in accordance with the scientific conception. However, after being given treatment teachers' visual representation changes become 100% in the scientific conception (SC) category.

These visual representations are useful tools to know what is actually in the teacher's mind regarding the concept of heat conduction. In these drawing test can describe what actually happens in solids particles when heated. Using a drawing test also can find out what misconceptions or alternative conceptions the teacher or student has (Bahar, Ozel, Prokop, & Usak, 2008; Köse, 2008) with these drawing test we can figure out the mental model of respondents about the concepts (Dikmenli, 2010). The teachers' visual representation is very various but most of them give a misconception drawing. All the teachers never draw the sub-microscopic level in science learning. Figure 5 shows the example of teachers' drawing about the heat conduction concept.

This teacher has a visual representation that the particles are small and very tight, then after being heated, they become more tenuous, bigger and the number of particles becomes smaller than before. The visual representation of this teacher is included in the misconception drawing, the teacher also provides consistent explanations both verbally and visually.



Before treatment After treatment

Figure 5. Example of teachers' 3 visual representation about heat conduction process

After giving treatment the visual representation given by the teacher changes to be in accordance with the scientific conception. Based on the drawings made, it can explain the phenomenon that before being heated the solid particles experience vibrations at their equilibrium

points but after being given heat energy the vibrations change to become stronger so as to cause vibrations to other particles around it. The visual representation given by this teacher falls into the category of Scientific-Drawing.

Based on the visual representation made by the teacher this reinforces the notion that the teacher does not have a visual representation that is in accordance with the scientific conception related to the transfer of heat by conduction at the sub-microscopic level. This revealed that the teacher's understanding was not accordance with scientific conceptions. That understanding will become an idea in the mind of the teacher and is used to explain and illustrate a scientific phenomenon (Jansoon, Coll, & Somsook, 2009; Supriyatman et al., 2018). This analysis of visual representation proves that the teacher's understanding is relatively weak. The teacher cannot provide a visual representation that is in accordance with the scientific conception.

Elementary teachers should have a good understanding of the basic concepts of the material they teach so that they can equip and train students towards better understanding not only memorizing what is given in the subject matter (Atwood, Christopher, Combs, & Roland, 2010; Krall, Lott, & Wymer, 2009). From this inadequate understanding will affect the learning process of students (Widodo et al., 2017). The results of the pretest about the teacher's understanding will affect the teacher's ability to teaching science. Because of the weak content of their knowledge, pedagogical activities are difficult to integrate because both are one entity (Rollnick, 2017). Although the teacher has good abilities on pedagogical aspects. However, if the teacher does not have adequate knowledge content, the learning done is ineffective and influences the teacher's self-confidence in teaching (Flores, 2015).

Based on the results of this study, science learning needs to be improved not only at the macroscopic level (phenomena that are visible, felt and sensed) but should be developed and equipped up to the sub-microscopic level. Because if learning science is only at the macroscopic level elementary school students already have a correct understanding of the scientific phenomenon without being given learning or treatment especially on phenomena that are contextual to their lives (Anam et al., 2019). So, teachers must improve their competence both in understanding and teaching science at the sub-microscopic level so that the learning process given to students becomes better and easier to understand.

CONCLUSION

Based on the results of the study, it was found that the teacher's conception of heat conduction concepts was not very satisfactory. This is because of their understanding only at the macroscopic level of representation and very few at the sub-microscopic level. However, the using of conceptual change text with experiment assisted can improve the verbal and visual representation of the teachers become in accordance with scientific conception. This study also provides a suggestion that the representation of sub-microscopic levels is an important aspect that must be understood by the teacher to produce better and more meaningful science lessons for students.

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REFERENCES

Adadan, E., Irving, K. E., & Trundle, K. C. (2009). Impacts of multi-representational instruction on high school students' conceptual understandings of the particulate nature of matter. *International Journal of Science Education*, *31*(13), 1743–1775. https://doi.org/10.1080/09500690802178628

Adadan, E., Trundle, K. C., & Irving, K. E. (2010). Exploring Grade 11 students' conceptual pathways of the particulate nature of matter

in the context of multirepresentational instruction. *Journal of Research in Science Teaching*, *47*(8), 1004–1035. https://doi.org/10.1002/tea.20366

Anam, R. S., Widodo, A., & Sopandi, W. (2017). Representation of Elementary School Teachers on Concept of Heat Transfer. *Journal of Physics: Conference Series*, *895 (2017)*(012159), 1–6. https://doi.org/10.1088/1742-6596/895/1/012159

Anam, R. S., Widodo, A., & Sopandi, W. (2019). Teachers, pre-service teachers, and students understanding about the heat conduction. *Journal of Physics: Conference Series*, *1157*(2), 1–7. https://doi.org/10.1088/1742-6596/1157/2/022012

Atwood, R. K., Christopher, J. E., Combs, R. K., & Roland, E. E. (2010). In-Service Elementary Teachers' Understanding of Magnetism Concepts Before and After Non-Traditional Instruction. *Sci. Educator*, *19*(1), 64–76. Retrieved from http://www.etsu.edu/cas/math/mathexcellence/documents/2010_Spring__Vol_19-_No_1__Science_Educator.pdf#page=66%5Cnpapers3://publication/uuid/4DCC9CE0-76E3-4415-9156-524CBD810E3D

Bahar, M., Ozel, M., Prokop, P., & Usak, M. (2008). Scientific student teachers' ideas of the heart. *Journal of Baltic Science Education*, *7*, 78–85.

Ball, L. D., Thames, M. H., & Phelps, G. (2008). Content knowledge for teaching: What makes it special? *Journal of Teacher Education*, *59*(5), 389–407. https://doi.org/10.1177/0022487108324554

Banda, A., Mumba, F., Chabalengula, V. M., & Mbewe, S. (2011). Teachers' understanding of the particulate nature of matter: The case of Zambian pre-service science teachers. *Asia-Pacific Forum on Science Learning and Teaching*, *12*(2), 1–16.

Çoruhlu, T. Ş. (2017). Pre-Service Science Teachers ' Conceptions of the " Conduction of Heat in Solids ". *Journal of Baltic Science Education*, *16*(2), 163–174.

Daehler, K. R., & Shinohara, M. (2001). A Complete Circuit is a Complete Circle : Exploring the Potential of Case Materials and Methods to Develop Teachers '. *Research in Science Education*, *31*, 267–288.

Dikmenli, M. (2010). Misconceptions of cell division held by student teachers in biology: A drawing analysis. *Scientific Research and Essays*, *5*(2), 235–247. https://doi.org/10.1073/pnas.1306508110

Flores, I. M. (2015). Developing preservice teachers ' self-efficacy through field-based science teaching practice with elementary students. *Research in Higher Education Journal*, *27*, 1–19.

Jansoon, N., Coll, R. K., & Somsook, E. (2009). Understanding Mental Models of Dilution in Thai Students. International Journal of Environmental & Science Education. *International Journal of Environment & Science Education*, *4*(2), 147–168.

Johnstone, A. H. (1991). Why is science difficult to learn? Things are seldom what they seem. *Journal of Computer Assisted Learning*, *7*, 75–83. https://doi.org/10.1111/j.1365-2729.1991.tb00230.x

Köse, S. (2008). Diagnosing Student Misconceptions: Using Drawings as a Research Method. *World Applied Science Journal*, *3*(2), 283–293. Retrieved from papers3://publication/uuid/758267A6-5EC4-48F5-AA77-C623E2E11B46

Krall, R. M. N., Lott, K. H., & Wymer, C. L. (2009). Inservice elementary and middle school teachers' conceptions of photosynthesis and respiration. *Journal of Science Teacher Education*, *20*(1), 41–55. https://doi.org/10.1007/s10972-008-9117-4

Lee, C. Q., & She, H. C. (2010). Facilitating students' conceptual change and scientific reasoning involving the unit of combustion. *Research in Science Education*, *40*(4), 479–504. https://doi.org/10.1007/s11165-009-9130-4

Liu, X., & Lesniak, K. M. (2005). Students' progression of understanding the matter concept from elementary to high school. *Science Education*, *89*(3), 433–450. https://doi.org/10.1002/sce.20056

Ozkan, G., & Selcuk, G. S. (2015). Effect of Technology Enhanced Conceptual Change Texts on Students' Understanding of Buoyant Force. *Universal Journal of Educational Research*, *3*(12), 981–988. https://doi.org/10.13189/ujer.2015.031205

Papageorgiou, G., Johnson, P., & Fotiades, F. (2008). Explaining melting and evaporation below boiling point. Can software help with particle ideas? *Research in Science & Technological Education*, *26*(2), 165–183. https://doi.org/10.1080/02635140802037336

Posner, G. J., Strike, K. A., Hewson, P. W., & Gertzog, W. A. (1982). Accommodation of a scientific conception: Toward a theory of conceptual change. *Science Education*,

66(2), 211–227. https://doi.org/JST.JSTAGE/jnms/75.361 [pii]

Rollnick, M. (2017). Learning About Semi Conductors for Teaching—the Role Played by Content Knowledge in Pedagogical Content Knowledge (PCK) Development. *Research in Science Education*, *47*(4), 833–868. https://doi.org/10.1007/s11165-016-9530-1

Snir, J., Smith, C. L., & Raz, G. (2003). Linking Phenomena with Competing Underlying Models: A Software Tool for Introducing Students to the Particulate Model of Matter. *Science Education*, *87*(6), 794–830. https://doi.org/10.1002/sce.10069

Sopandi, W., Kadarohman, A., Rosbiono, M., Latip, A., & Sukardi, R. R. (2018). The Courseware of Discontinuous Nature of Matter in Teaching the States of Matter and Their Changes. *International Journal of Instruction*, *11*(1), 61–76. https://doi.org/10.12973/iji.2018.1115a

Supriyatman, Suhandi, A., Rusdiana, D., Samsudin, A., Wibowo, F. C., & Mansyur, J. (2018). Design of Experimental Problem Solving-Based Learning Program to Improve Mental Model and to Enhance Mental-Modeling Ability. *Jurnal Pendidikan Fisika Indonesia*, *14*(July), 73–82. https://doi.org/10.15294/jpfi.v14i2.6279

Tekkaya, C., Cakiroglu, J., & Ozkan, O. (2004). Turkish pre-service science teachers' understanding of science and their confidence in teaching it. *Journal of Education for Teaching: International Research and Pedagogy*, *30*(1), 57–68. https://doi.org/10.1080/02607470320001623 16

Treagust, D. F., Chittleborough, G., & Mamiala, T. L. (2003). The role of submicroscopic and symbolic representations in chemical explanations. *International Journal of Science Education*, *25*(11), 1353–1368. https://doi.org/10.1080/09500690320000703 06

Widodo, A., Rochintaniawati, D., & Riandi. (2017). Primary School Teachers' Understanding of Essential Science Concepts. *Cakrawala Pendidikan*, *3*(XXXVI), 522–528. https://doi.org/10.21831/cp.v36i3.11921

Wu, H. K., Krajcik, J. S., & Soloway, E. (2001). Promoting understanding of chemical representations: Students' use of a visualization tool in the classroom. *Journal of Research in Science Teaching*, *38*(7), 821–842. https://doi.org/10.1002/tea.1033

Yilmaz, A., & Alp, E. (2006). Students' understanding of matter: The effect of reasoning ability and grade level. *Chemistry Education Research and Practice*, *7*(1), 22–31. https://doi.org/10.1039/B5RP90013A

Yilmaz, D., Tekkaya, C., & Sungur, S. (2011). The Comparative effects of prediction/discussion-based learning cycle, conceptual change text, and traditional instructions on student understanding of genetics. *International Journal of Science Education*, *33*(5), 607–628. https://doi.org/10.1080/09500691003657758

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