Available online at http://journal.um.ac.id/index.php/jps/
ISSN: 2338-9117/EISSN: 2442-3904

Jurnal Pendidikan Sains
Volume 5, Number 4, December 2017, pp. 127–134

Misconception Identification Using Two-Tier Test and POE Strategy to Improve Mass Balance Topic Mastery in Industrial Chemistry Vocational High School

Ragil Sugeng Dewantoro[1)*], **Subandi**[2)], **Fauziatul Fajaroh**[2)]
[1)]SMKN 1 Pasuruan
[2)]Chemistry Education–Universitas Negeri Malang
Jl. Veteran 11 Pasuruan 67125. E-mail: rs.dewantoro@gmail.com*

Abstract: This study used descriptive research and pre-experimental design. The first one was used to identify student misconception in the mass balance topic at macroscopic, sub-microscopic and symbolic levels. The second design aims to correct the misconceptions discovered by using the POE strategy. After three weeks the delayed test was done to find out the concept improvement using POE strategy. This design was also used to determine the effectiveness of POE strategies to achieve the aims. The results showed misconception on mass balance material with an average of 32.97%. The average POE effectiveness of 76.02% with high effectiveness criteria and retention of understanding with POE strategy after 2 weeks on average was 91.27% with very good criteria.

Key Words: misconception, mass balance, POE, industrial chemistry, two-tier test

Abstrak: Penelitian deskriptif dan pra eksperimen bertujuan untuk mengidentifikasi miskonsepsi siswa dalam neraca massa pada tingkat makroskopik, sub-mikroskopik dan simbolik. Sedangkan rancangan pra eksperimental bertujuan untuk memperbaiki miskonsepsi yang ditemukan dengan menggunakan strategi POE. Rancangan pra-eksperimental juga digunakan untuk mengetahui keefektifan strategi POE dalam memperbaiki miskonsepsi siswa pada materi neraca massa. Setelah tiga minggu dilakukan *delayed test* untuk mengetahui perbaikan konsep dengan strategi POE. Rancangan pra-eksperimental (*pre-experimental*) yang digunakan adalah modifikasi model *one group pretest-posttest design* dengan satu macam perlakuan. Hasil penelitian menunjukkan terjadi miskonsepsi pada materi neraca massa dengan rata-rata 32.97%. Selain itu didapatkan efektifitas POE rata-rata 76.02% dengan kriteria efektivitas tinggi dan retensi hasil remidi dengan strategi POE setelah 2 minggu rata-rata adalah 91.27% dengan kriteria sangat baik.

Kata kunci: miskonsepsi, neraca massa, POE, kimia industri, test *two tier*

Mass balance is an exact calculation of all incoming ingredients, which accumulates and exits within a specified time in a chemical process. The statement is in accordance with the Law of Conservation of Mass stating that mass cannot be manifested or destroyed (Wuryanti, 2016). Drawn up mass balance also illustrates the components–any component contained in the mass flow input and output. Mass balance calculations will also be the basis of other calculations in the chemical industry, such as calculating instrument specification and the energy balance (Himmelblau, 1982). Mass balance takes a role as an important matter and must be mastered by students of Industrial Chemistry vocational high school since they will learn the process of raw materials changing into products and the design and calculation of instruments used in the industrial process (Suparmi, 2010). The material of mass balance calculation on Industrial Chemistry vocational high school is taught in the subject of Chemical Engineering Principles and is closely related to other vocational subjects such as Chemical Engineering Operations, Chemical Industry Tools and also subjects of Chemical Engineering Principles II which will be studied in the next grade. The authors also conducted a simple analysis of the results of students' examination of XI Industrial Chemistry 2

Article received 11/10/2017; Approved 22/11/2017

Class SMKN 1 Pasuruan, which showed a significant correlation between regular examination results on mass balance topic with other vocational subjects.

There are several subjects studied in the mass balance topic such as 1) scale and unit conversion, 2) equations and stoichiometry of chemistry, and 3) the Law of Conservation of the Masses. These three materials need to be mastered by students in order to master the mass balance topic. Previous research has shown that students often experience difficulties or misconceptions on one of three subjects. The students were lacking the ability to convert units (Rusilowati, 2007), students also have difficulties when converting units of a derived quantity such as volume (Tariq, 2008), students often forget or incorrectly convert units (Rufaida, Budiharti, Fauzi, Fisika, & Uns, 2010). Students easily convert from larger units to smaller units but have difficulty converting otherwise (Gilman, 2013). In the field of chemistry, it was found that students have difficulty when converting mol units into other units (Nursiwin, 2013).

Some research regarding students' misconception on stoichiometry showed that students often confused between the use of the Law of Conservation of Mass and Law of Definite Proportions (Anugrah, et al, 2013). This is indicated by the use of a comparison in predicting the amount of reactor and reactor produced in a chemical reaction based on Lavoisier law and summing the reagent mass before reacting to determine the number of reaction products without considering the given mass ratio. Another misconception is to determine the mass of reagents which reacts by multiplying the reagent mass to the ratio of the element to another (Siswaningsih, 2014).

Some misconceptions related to the Law of Conservation of Mass that occur in students among others: 1) the student assumes that the gas has no mass, 2) the student assumes that the liquid is lighter than the solid, 3) in the dissolution process, for instance, salt dissolution in water, the student assumes that the salt is dissolved (Dial, Riddley, Williams, & Sampson, 2009). Dial, et al (2009), states that this misconception will hamper students' ability to understand science at higher levels of concept. If the aforementioned misconceptions are believed by the Industrial Chemistry vocational high school students, it will distract the student's ability regarding mass balance calculation. Which at the end, it declines students' learning outcomes or results on students' misunderstanding on the other related topic. The analysis result of students' regular examination of XI Industrial Chemistry 2 SMKN 1 Pasuruan showed that 81.8% of students obtained a low score from Minimum Mastery Standard (KKM) on mass balance topic as well as the other vocational related topic. Therefore, it is imperative to recover the misconception of mass balance within students in order to avoid further integration of misconception in students' cognitive structure.

There are various methods and instruments developed to identify students' misconceptions such as CRI (Certainly Response Index), interviews, multiple choice tests, multiple choice tests with an open reason, or leveled multiple-choice tests called two-tier tests. Basically, the methods and instruments developed by previous research have their own advantages and disadvantages. Such as interview methods that can inquire deeper students' misconception, but it takes a considerably long time and requires intensive training to be a reliable interviewer (Peterson and Treagust, 1989). In this case, the authors are interested in preparing a mass-scale diagnostic instrument in the form of a two-tiered test for the following reasons; two-tier tests proved to be convincingly capable of identifying misconceptions in a short time (Treagust in Chandrasegaran and Treagust, 2007). Two-tier multiple choice is also effective to assess meaningful learning in students and also serves as an effective diagnostic tool (Tamir, 2010). In addition, the two-tier test is easier to be corrected and analyzed by a teacher (Peterson and Treagust, 1989). Research in the Indonesian context also shows a positive results regarding the use of two-tier tests in identifying misconceptions on chemicals, among others, 1) Nursiwin's research (2013) on chemical calculations, 2) Maharani's research (2013) on solubility topic and 3) Asnawi's research (2015) on electrochemical topic.

Students' misconception which has been identified should be immediately resolved. Various strategies or conceptual changes and advancement by experts to avoid misconception such as Predict, Observe and Explain (POE) method; cognitive conflict strategy; Conceptual Change Text Model; Cause and Effects of Changes Model (CEC Model). Previous research indicated that laboratory learning activity using POE strategy on acid-bases materials topic could recover students' misconception (Özdemir, Bað, & Bilen, 2011). Computer simulations with POE strategy also helps to improve students' misconceptions on force and motion topics (Tao, 1996). Mental model with POE strategy also improves students' misconceptions on force and motion topics (Khanthavy & Yuenyong, 2009). POE strategy is a learning strategy that requires students' active participation. This strategy also challenges students to express what they think, develop their ability to communicate and improve their critical thinking skills (Haysom & Bowen, 2010). This is in accordance with the objectives of education in vocational schools as stated in the Regulation of the Minister of Education No. 22 of 2006 concerning on Content Standards for Basic and Secondary Education Unit stating that the Vocational High School students should have distinguished resilience, master their areas of expertise and the foundations of science and technology, have a considerable work ethic, and are able to communicate in accordance with the demands of their work, and have the ability to develop themselves.

In addition, POE is able to improve conceptual understanding to both students whose the ability is low and whose the ability is average (Costu, 2008). In fact, students' learning outcome on mass balance topic of XI Industrial Chemistry 2 SMKN 1 Pasuruan showed that students were divided into three categories of ability, namely, low, average, and high. Then, Wahyudah's research (2015) identifying students' misconception avoidance on chemical bond shows that POE is able to increase students' understanding retention. Mass balance topic which is needed in the next grade is important for Industrial Chemistry students and therefore it should be delivered through learning model which is able to improve students' understanding retention.

METHOD

This study used descriptive and pre-experimental design. The descriptive research design was used to identify student misconception in the mass balance at the macroscopic, sub-microscopic and symbolic levels. While the pre-experimental design aimed to correct the misconceptions found by using the POE strategy. After three weeks, the delayed test was done to find out the persistence of conceptual understanding improvement with the POE strategy. A pre-experimental design was also used to determine the effectiveness of POE strategies in improving student misconceptions on mass balance topic. The pre-experimental design used was the modification of the one group pretest-posttest design model with one treatment type as presented in Table 1.

Table 1. One Group Pretest-Posttest Design Model with One Treatment Type

Subject	Pre test	Treat ment	Post test	Delayed Test
Experiment Class	O_1	X	O_2	O_3

The instruments used in this study were measurement instruments and treatment instruments. The measurement instrument used was a two-tier diagnostic instrument of mass balance to identify student misconception on mass balance material. While the treatment instrument used was Lesson Plan of Mass Balance topic using the strategy POE. In this research, IDNM was validated by one chemistry lecturer of Universitas Negeri Malang and one industrial chemistry teacher from SMKN 1 Pasuruan to ensure the items are well arranged and suitable for the mass balance sheet of Industrial Chemistry Vocational High School. Suggestions from validators were used to correct the items so they are more easily understood by students and more scientifically valid. To each validator, it was submitted a question sheet, lesson outline, and validation sheet. The questions contain items that are planned as research instruments. The lesson outline contains a list of questions about the mass balance instrument that will be studied and arranged in a number of questions as an instrument in the study. The validation sheet is a scoring sheet on each item that will be filled by each validator. The validated research instrument was then tested to the students of XII of Industrial Chemistry SMKN 1 Pasuruan of the academic year 2016/2017 which was not included as a subject in the research who have taken or are taking mass balance topic learning. The test question aims to know the validity of the item, reliability, distinguishing force, difficulty level, and the amount of real time required to complete the test.

In terms of items validity and reliability, this research was assisted by data analysis computer software to calculate Pearson Correlation (r) between trial subject individual score and a total score of each question item. Meanwhile, to identify the reliability, Cronbach Alpha calculation was employed. Question item was categorized valid if r count is higher than r table and IDNM was categorized reliable if the Cronbach Alpha score is more than 65 (George D. Kuh, Ty M. Cruce, Rick Shoup, Jillian Kinzie, & Robert M. Gonyea, 2008).

RESULTS

The result of IDNM validation from both validators obtained a score of 87.77% and considered as feasible with minor revision. Then, it was revised according to the validator notes and direction. After the revision was completed, IDNM was tested on 20 students of XII Industrial Chemistry to identify its validity, reliability, distinguishing force, difficulty level, and the amount of real time required to complete the test. The testing indicated that the IDNM is reliable and its difficulty level is moderate. In addition, it took approximately 50 to 60 minutes to complete from 75 minutes given.

Then, treatment instrument in the form of Lesson Plans and Students' Worksheet with POE Strategy was also validated. The validation result showed that the Lesson Plans obtained a score of 97.28% and categorized as good, while the Students' Worksheet obtained a score of 91.32% and categorized as good. As a conclusion, the developed Lesson Plan and Students' Worksheet are feasible to be used.

From the diagnostic result, it obtained that the subject 43.49% understand, 11.09% moderately understand, 12.45% do not understand, and 32.97% misconception. Then, POE method was given to the subject class and it was given for approximately 2 x 5 learning session. During the treatment, the researchers used the developed and validated Lesson Plan and Students' Worksheet. Post-test was given after the treatment of the subject class to identify the effectiveness of POE strategy in recovering students' misconception. The comparison of students' misconception before and after the treatment was presented in Table 2.

The results of post-test on the subject indicates a conceptual improvement, it can be seen from the decline in the number of subjects with misconceptions. On average, POE strategy was able to improve the concept of the effectiveness of 76.02%. After two weeks, a delayed test was done to the subject to determine the retention of the misconceptions improvement. The comparisons of misconceptions before and after the delayed test are shown in Table 3.

DISCUSSION

The purpose of this research is to know what misconception happened on mass balance material. After performing diagnostic tests, it appears that in all the tested concepts, misconceptions happened. There are five concepts tested in this research: 1) unit conversion, 2) law of conservation of mass, 3) principles and the basis of the reaction of stoichiometry, 4) stoichiometric correlations and composition, and 5) excesses in chemical reactions. Then, it will be discussed the misconception that occurs in each submaterial.

Unit Conversion

Unit conversion learning is the basically simple topic and should be taken by students since the elementary education. However, the diagnostic test showed that some students of Industrial Chemistry still misunderstood upon unit conversion. The diagnostic test indicated that 18.75% students experienced misconception on unit conversion. In IDNM, unit conversion concept is tested by four items; number 1, number 2, number 3, and number 4. Students experienced different misconception on the four items although the four items have a similar difficulty level.

Question item number one ask students to convert a larger unit to a smaller unit, for instance, students are asked to convert kg to g or m to cm. While question number 2, students are given a chance to convert a smaller unit to a larger unit. A number of 12.50% students experienced misconception on the question number 1 and 18.75% students experienced misconception on the question number 2. This is in line with Gilman's research (2013) argues that students tend to easily convert a larger unit to a smaller unit. In other words, converting a unit to a larger unit is a considered difficult rather than to a smaller unit.

Further, questions number 4 and 3 ask students to solve the power of two and three exponential unit conversion. Students experienced misconception on question number 3 was 18.75% while on question number 4 was 25.00%. Taylor and Tariq (2008) report that students are basically easy to calculate areas size rather than volume. One major reason argued by them is students do not master exponential numerical operation, for instance, students consider 3^2 is similar with 3^3 or equal to 9. This will hamper students particularly if they need to deal with more complicated exponential calculation.

Law of Conservation of Mass

In IDNM, the law of conservation of mass concept is tested by having four questions, question number 5, 6, 7, and 8. Questions number 5 and 6 ask students regarding the law of conservation of mass concept on physical changes of matter process without a chemical reaction. Questions number 7 and 8 ask students regarding the law of conservation of mass within dissolution process.

Table 2. Misconception on Diagnostic Test and Post-test (after treatment)

No.	Tested Concept	Question Number	Diagnostic Test (%)	Avg (%)	Post Test (%)	Avg (%)	Effectiveness (%)
1	Unit Conversion	1	12.50	18.75	3.13	4.69	75.00
		2	18.75		3.13		
		3	18.75		6.25		
		4	25.00		6.25		
2	Law of Conservation of Mass	5	12.50	21.88	0.00	3.91	82.14
		6	12.50		3.13		
		7	31.25		3.13		
		8	31.25		9.38		
3	Stochiometry Principle and Basics	9	28.13	32.03	6.25	9.38	70.73
		10	18.75		12.50		
		11	34.38		9.38		
		12	43.75		9.38		
4	The Correlation of Stoichiometry and Composition	13	31.25	40.63	9.38	7.29	82.05
		14	34.38		6.25		
		15	56.25		6.25		
5	Excess in chemical reaction	16	43.75	52.34	15.63	15.63	70.15
		17	43.75		25.00		
		18	65.63		0.00		
		19	56.25		21.88		
			Avg	32.97%	**Avg**	8.18%	76.02%

Table 3. The Comparisons of Misconceptions Before and After The Delayed Test (after two weeks)

No.	Tested Concept	Question Number	Diagnostic Test (%)	Avg (%)	Delayed Test (%)	Avg (%)	Retention (%)
1	Unit Conversion	1	3.13	4.69	6.25	9.38	95.08
		2	3.13		6.25		
		3	6.25		12.50		
		4	6.25		12.50		
2	Law of Conservation of Mass	5	0.00	3.91	6.25	14.84	88.62
		6	3.13		18.75		
		7	3.13		15.63		
		8	9.38		18.75		
3	Stochiometry Principle and Basics	9	6.25	9.38	9.38	15.63	93.10
		10	12.50		18.75		
		11	9.38		25.00		
		12	9.38		9.38		
4	The Correlation of Stoichiometry and Composition	13	9.38	7.29	18.75	12.50	94.38
		14	6.25		9.38		
		15	6.25		9.38		
5	Excess in chemical reaction	16	15.63	15.63	25.00	28.13	85.19
		17	25.00		34.38		
		18	0.00		21.88		
		19	21.88		31.25		
			Avg	8.18%	**Avg**	16.09%	91.27%

Students who experienced a misconception on question 5 and 6 were 12.50%. Question number 5 explains physical changes of matter from solid matter to gas, while question number 6 explains physical changes of matter from gas matter to liquid. Students who experienced misconception on both questions consider the solid matter is heavier than liquid and liquid is heavier than gas. This is in line with the research conducted by Dial (2009) which shows that some students consider the solid matter is heavier than liquid matter and liquid matter is heavier than gas.

Questions number 7 and 8 give students how the law of conversion of mass in the dissolution process of sugar in water. An amounted to 31.25% of students experienced a misconception. 12.5% of students experienced misconception and considered sugar will be dissolved and the liquid mass is equal to water mass (choice B), 18.75% of students experienced misconception and considered that sugar was reacted with water and thus the mass of water increased (choice A). Johnson and Scott (1991) conduct a research regarding misconception on dissolution concept. Several misconceptions found are 1) sugar dissolved and became a smaller and lighter particle, 2) sugar dissolved in liquid and liquid is lighter than solid sugar, 3) sugar dissolved in liquid and sugar particle vanished. The three aforementioned misconceptions are similar to those found within this research and occurred within 12.5% research subject. Meanwhile, 18.75% misconception occurred within research subject since they do not comprehend chemical reaction characteristic.

Stoichiometry Principle and Basics

Question number 9, 10, 11, and 12 on IDNM aim to examine students' conceptions of principles and basics of stoichiometric reactions. In the case of numbers 9,10 and 11, diagrams are used because based on previous research, students are more aware of the material of the reaction equation which is given in the form of diagrams (Cotes & Cotuá, 2014). According to four questions given to students, it was known misconception that occurred in the study subjects are as follows.

First, the subject did not understand the meaning of equation of the equivalent reaction. According to the subject's understanding of equivalent equation of reaction, the equation is only from equating the number of atoms on the side of the reaction with the product side. Thus, according to subjects, it is allowed to write the coefficient in the form of fractions (choice of reason "B" at number 9).

Second, the subject assumed that the terms of the equivalent equation of the reaction are only the number of atoms on the product side and the same plane, whereas, by rule, the ratio of coefficients in the equation of the reaction must be expressed in the simplest comparison (choice of reason "A" at number 9).

Third, the subject did not understand the symbol of an element, for example, because the reaction of aluminium and oxygen produces aluminium oxide (Al_2O_3) there was a subject which assumed that the Aluminium element symbol is Al 2. (choice of reasons "C" and "D" at number 12).

The Correlation of Stoichiometry and Composition

Questions number 13, 14, and 15 aim to examine the subject's understanding of the relationship between stoichiometry and composition. Particularly, it is to test students' understanding of the ratio of volume, pressure, temperature, mass, and mole between two or more different gases. According to three questions given to students, it was known misconception experienced by the subjects are as follows. (1) The subject assumed that the coefficient ratio in the equation of the reaction equals to the mass ratio. (2) The subject assumed a mole ratio equal to the mass ratio. (3) The subject considered the volume ratio to be equal to the mass ratio

If it is related to the previous research which one of them is done by Krisnawati, (2013), states that the level of student's understanding on Basic Chemistry Law material only average 24,84% with "low" criterion, so this research as answer to research conducted by Krisnawati, et al, that one of the causes of low understanding of students in the material is because students have misconceptions.

Excess in Chemical Reaction

The last concept tested in IDNM is about excesses in chemical reactions. Questions numbers 16, 17, 18, 19 deal with excesses in chemical reactions. This concept is a quite difficult concept for the subject where only 14.84% subject who understands this concept. Previous research from Krisnawati, et al (2013) also mention that students' understanding of excess in a chemical reaction is low. On average, the misconceptions about excesses in chemical reactions are high, this is what causes the low level of student understanding. Therefore, remedial steps are needed to correct misconceptions. The misconceptions found in this study are also similar to the misconceptions found by Dahsah & Coll (2008) that students assume the reagents with the smallest number of moles will be the limiting reagents. In addition, some students also assume that the reagents with the smallest coefficient will be a limiting reagent.

In questions number 16 and 17 there is no calculation because of the use of diagrams, while on the questions number 18 and 19 there are calculations. The number of students experiencing misconceptions in the two groups of questions is not the same and the probability of misconceptions on problems with calculations is higher. This is in line with what is examined by Scott (2012) that the ability of math (counting) of a person is very influential on one's ability in chemistry.

On average, it can be concluded that as much as 32.97% have a misconception on mass balance topic.

Based on Özmen & Ayas (2003) research, one factor that is suspected to be the cause of the high misconception about stoichiometry and law of conservation of mass is because teachers emphasize to memorize and apply the calculation formula but provide less information regarding the concepts. In addition, the concept of stoichiometry and law of conservation of mass are more elusive sub-microscopic representation than macroscopic things (Rahayu & Kita, 2010).

The average effectiveness of the POE strategy in improving the balance sheet misconception is 76.02%. Coeu & Niaz (2012) conduct a study to determine the effectiveness of POE in improving misconceptions on evaporative and condensation materials, the results show that POE has a high effectiveness with an average of 85.94% in improving misconceptions on evaporation and condensation topic. Another comparison is from Juita's (2013) study, which concludes that POE has moderate effectiveness with an average of 45%. From these two studies, it can be concluded that POE has a high effectiveness in improving mass balance misconception.

CONCLUSION

According to the results and discussion, it can be summed up that there is a misconception on the mass balance topic with an average of 32.97%, with details on each sub-material as follows, unit conversion 18.75%, law of conservation of mass 21.88%, principles and basics of stoichiometric reactions 31.25%, stoichiometry and composition 40.63% and excess in chemical reaction 52.34%. Employing POE strategy as a remedial attempt is effective in improving misconceptions on mass balance topic with an average efficacy of 76.02% and considered as highly effective.

Because the misconceptions found in the mass balance material are considerably high, there is a need for preventive measures using POE strategies in learning to prevent their major misconceptions on mass balance topic.

ACKNOWLEDGEMENT

The author conveyed his gratitude to the parties who have allowed to do this research that is SMKN 1 Pasuruan and Master degree scholarship grant at Universitas Negeri Malang, East Java Provincial Education Office.

REFERENCES

Asnawi, R. (2015). *Miskonsepsi pada materi elektrokimia ditinjau dari kemampuan berpikir ilmiah siswa*. Tesis Tidak Diterbitkan, (Perpustakaan Digital Universitas Negeri Malang), 1.

Chandrasegaran, a. L., Treagust, D. F., & Mocerino, M. (2007). The development of a two-tier multiple-choice diagnostic instrument for evaluating secondary school students' ability to describe and explain chemical reactions using multiple levels of representation. *Chemistry Education Research and Practice*, *8*(3), 293. https://doi.org/10.1039/b7rp90006f.

Coºtu, B. (2008). Learning Science through the PDE-ODE Teaching Strategy/ : Helping Students Make Sense of. *Eurasia Journal of Mathematics, Science & Technology Education, 4*(1), 3–9.

Coºtu, B., Ayas, A., & Niaz, M. (2012). Investigating the effectiveness of a POE-based teaching activity on students' understanding of condensation. *Instructional Science*, *40*(1), 47–67. https://doi.org/10.1007/s11251-011-9169-2.

Cotes, S., & Cotuaì, J. (2014). Using Audience Response Systems during Interactive Lectures To Promote Active Learning and Conceptual Understanding of Stoichiometry. *J. Chem. Edu*, *91*, 673–677.

Dahsah, C., & Coll, R. K. (2008). Thai grade 10 and 11 students_understanding of stoichiometry and related concepts, (February 2006), 573–600.

Dial, K., Riddley, D., Williams, K., & Sampson, V. (2009). Addressing Misconceptions, a demonstration to help the student understand the law of conservation mass. *Sci Teach*, *76*(7).

George D. Kuh, Ty M. Cruce, Rick Shoup, Jillian Kinzie, & Robert M. Gonyea. (2008). Unmasking the Effects of Student Engagement on First-Year College Grades and Persistence. *The Journal of Higher Education*, *79*(5), 540–563. https://doi.org/10.1353/jhe.0.0019

Gilman, J. (2013). Have You Met Ric? Student Misconceptions of Metric Conversions and the Difficulties Behind Metric Unit Estimation. *A Master's Project Submitted in Partial Fulfillment of the Requirements for the Degree of Master of Science in Education*, (Department of Mathematical Sciences State University of New York at Fredonia).

Haysom, J., & Bowen, M. (2010). Predict, Observe, Explain/ : activities enhancing scientific understanding. *National Science Teachers Association Press Kearney,* (Arlington, Virginia, USA).

Himmelblau, D. M. (1982). *Basic principles and calculations in chemical engineering*. Prentice Hall. https://doi.org/10.1021/ed040pA322

Anugrah, I.R, Nahadi, Wiwi, & Siswaningsih. (2012). *Mengungkap Miskonsepsi Topik Stoikiometri pada Siswa Kelas X Melalui Tes Diagnostik Two-Tier*. Jurusan Pendidikan Kimia FPMIPA UPI.

Johnston, K., & Scott, P. (1991). Diagnostic teaching in the science classroom: teaching/learning strategies to promote development in understanding about conservation of mass on dissolving. *Research in Science & Technological Education*, *9*(2), 193–212.

Juita, D., Darman, D. R., Kurniawan, T., & Yusmanila, D. (2013). Predict-Observe-Explain-Write Model: Bagaimana Model Pembelajaran Tersebut Meningkatkan Pemahaman Konsep dan Motivasi Siswa terhadap Materi Fisika? *Prosiding Seminar Kontribusi Fisika*.

Khanthavy, H., & Yuenyong, C. (2009). The Grade Student's Mental Model of Force and Motion through Predict– Observe – Explain (Poe) Strategy. *Khon Kaen University, Thailand*.

Krisnawati, I., Prayitno, & Fajaroh, F. (2013). *Menggali Pemahaman Konsep Siswa Madrasah Aliyah tentang Stoikiometri dengan Menggunakan Instrumen Diagnostik Two-Tier Indah* (Unpublished master's thesis). Jurusan Kimia FMIPA Universitas Negeri Malang, Malang.

Maharani, T. Y., Yahmin, & Prayitno. (2013). *Menggali Pemahaman Siswa SMA pada Konsep Kelarutan dan Hasil Kali Kelarutan dengan Menggunakan Tes Diagnostik Two-Tier* (Unpublished master's thesis). Universitas Negeri Malang, Malang.

Nursiwin. (2013). *Menggali Miskonsepsi Siswa SMA pada Materi Perhitungan Kimia Menggunakan Certainty of Response Index*. Program Studi Pendidikan Kimia FKIP UNTAN.

Ozdemir, H., Bag, H., & Bilen, K. (2011). Effect of Laboratory Activities Designed Based on Prediction, Observation, Explanation (POE) Strategy on Pre Service Science Teachers' Understanding of Acid-Base Subject. *Western Anatolia Journal of Educational Science*, 169–174.

Özmen, H., & Ayas, A. (2003). Students' Difficulties In Understanding Of The Conservation Of Matter In Open And Closed-System Chemical Reactions. *CHEMISTRY EDUCATION: RESEARCH AND PRACTICE Educ. Res. Pract*, *4*(4), 279–290.

Peterson, R. F., Treagust, D. F., & Garnett, P. (1989). Development and Application of A Diagnostic Instrument to Evaluate Grade-11 and -12 Students ' Concepts of Covalent Bonding and Structure Following A Course of Instruction, *26*(4), 301–314.

Rahayu, S., & Kita, M. (2010). An Analysis of Indonesian and Japanese Students' understandings of Macroscopic and Submicroscopic Levels of Representing Matter and Its Changes. *International Journal of Science and Mathematics Education*, *8*(4), 667–688. https://doi.org/10.1007/s10763-009-9180-0.

Rufaida, S. A., Budiharti, R., Fauzi, A., Fisika, P., & Uns, F. (2010). Profil Kesalahan Siswa Sma Dalam Pengerjaan Soal Pada Materi Momentum Dan Impuls. *Pendidikan Fisika FKIP UNS*.

Ani, R. (2007). *Diagnosis Kesulitan Belajar Fisika Siswa SD, SMP, dan SMA dengan Teknik General Diagnostic dan Analytic Diagnostic*. In Seminar Nasional Penelitian, Pendidikan dan Penerapan MIPA 2007. Fakultas Matematika dan Ilmu Pengetahuan Alam UNY.

Scott, F. J. (2012). Is mathematics to blame? An investigation into high school students' difficulty in performing calculations in chemistry. *Chemistry Education Research and Practice*, *13*(3), 330–336.

Siswaningsih, W., Anisa, N., Komalasari, N. E., & Indah, D. (2014). Pengembangan Tes Diagnostik Two-Tier Untuk Mengidentifikasi Miskonsepsi Pada Materi Kimia Siswa Sma. *Jurnal Pengajaran MIPA*, *19*(1), 117–127.

Tamir, P. (1971). An alternative approach to the construction of multiple choice test items. *Journal of Biological Education*, *5*(6), 305–307.

Tao, P.-K. (1996). Confronting students' alternative conceptions in mechanics with the Force and Motion Microworld. *Department of Curriculum Studies, The University of Hong Kong, Pokfulam Road, Hong Kong*.

Tariq, V. N. (2008). Defining the problem: mathematical errors and misconceptions exhibited by first-year bioscience undergraduates. *International Journal of Mathematical Education in Science and Technology*, *39*(7), 889–904. https://doi.org/10.1080/00207390802136511.

Wahyudah, E. (2015). *Keefektifan pendekatan perubahan konseptual dengan teknik Predict-Observe-Explain (POE) dan animasi terhadap pemahaman konsep ikatan Kimia peserta didik kelas X SMA Negeri 3 Kediri / Eva Wahyudah* (Unpublished master's thesis). Graduate School of Universitas Negeri Malang, Malang.

Wuryanti, S. (2016). Neraca Massa dan Energi. *Politeknik Negeri Bandung*.