Journal of Turkish Science Education
http://www.tused.org

June 2016, Volume 13, Issue 2, 27-36
ISSN:1304-6020

Effects of the Natural Product Mini Project Laboratory on the Students Conceptual Understanding

Aliefman HAKİM[1], Liliasari[2], Asep KADAROHMAN[2], Yana Maolana SYAH[3]

[1] Dr., Study Program of Chemistry Education, University of Mataram, Lombok-INDONESIA
[2] Assoc. Prof. Dr. Science Education Program, Indonesia University of Education, Bandung-INDONESIA
[3] Assist. Prof. Dr., Organic Chemistry Division, Institut Teknologi Bandung, Bandung-INDONESIA

Received: 30.10.2015 **Revised:** 17.05.2016 **Accepted:** 23.05.2016

The original language of article is English (v.13, n.2, June 2016, pp.27-36, doi: 10.12973/tused.10165a)

ABSTRACT

This research aims to examine an application of the natural product mini project laboratory in order to improve the students' conceptual understanding. This research was carried out by using quasi-experimental methods. Participants consisted of 31 students of chemistry education department (experimental class) and 28 students of chemistry department (control class) at 6th semester academic year 2012/2013 from one of state university in the West Nusa Tenggara, Indonesia. Experimental class used natural product mini project laboratory model (NP-MPLM) and control class used verification laboratory model. Research results showed that students used the natural product mini project laboratory more conceptual understanding than the students used verification laboratory. The average N-gain of conceptual understanding for experiment class was 0.56 while for the control class was 0.34. The highest N-gain in the experimental class was 0.73 for UV spectroscopy concept while the smallest N-Gain was 0.34 for thin layer chromatography concept. Before the application of the natural product laboratory mini project, the highest percentage of misconception in the experimental class occurred in metabolites category (44.09%) and the highest percentage of do not know the concept occurred in UV spectroscopy (59.68%). After the application of the natural product mini project laboratory, the highest percentage of misconceptions occurred in separation of chemical components (35.48%) and the highest percentage of do not know the concept occurred in NMR spectroscopy (29.03%).

Keywords: The Natural Product Mini Project Laboratory; Conceptual Understanding; Misconceptions; N-gain.

INTRODUCTION

Natural product chemistry (NPC) concepts taught in a hierarchy of complex concepts into simple concept consist of characteristic of secondary metabolites, variation structure, biosynthesis/biogenesis vs molecular structure, structure determination, common properties, synthesis of terpenoids, steroids, polyphenols (polyketides and phenyl propanoid), flavonoids, and alkaloids (Hakim et al., 2012). Most of the NPC concepts consist of the abstract concept. If the students have not reached the level of formal operations, the abstract concept will lead students to misconceptions. This argument is supported by Kazembe (2010) which states that the NPC learning often encounter misconceptions. Misconceptions are often observed in chemistry as well as in the other science disciplines (Kingir & Geban, 2014). In this period of time, several labels were generated to refer to these ideas, such as "pre-conceptions,"

Corresponding author e-mail: aliefmanhakim27@gmail.com

"misconceptions," "alternative conceptions," and "intuitive knowledge" (Özdemir, 2015). It is necessary to identify the current knowledge of students for eliminate misconceptions which interfere with learning (Harman, 2014).

Piaget (2001) states that knowledge is constructed in the mind of the learner through assimilation and accommodation. Assimilation process occurs when someone complemented the original concept without changed, while the accommodation process occurs when someone changed the original concept to improve it. Adaptation is a balance between assimilation and accommodation. Based on the explanation, misconceptions are generally divided into: the initial concept incomplete and incorrect initial concept altogether. Misconception is difficulty to remove because misconception is a permanent and continuous process (Kazembe, 2010).

Meaningful learning is very important for student (Hakim, et al., 2016; Gunes, et al., 2015; Bezen, et al., 2016). Laboratory activities can make meaningful learning by improving students' conceptual understanding and overcoming misconceptions (Hakim, et al., 2013; Roth, 1992). The students will achieve meaningful learning by forming a link between the new information and the existing information.

This research aims to examine an application of the natural product mini project laboratory in order to improve the students' conceptual understanding.

METHODOLOGY

This study uses a quasi-experimental research with a nonequivalent control group design (Cresswell, 2007). Participants consisted of 31 students of chemistry education department (experimental class) and 28 students of chemistry department (control class) at 6th semester academic year 2012/2013 from one of state university in the West Nusa Tenggara, Indonesia. Experiments class used the natural product mini project laboratory (Hakim, et al., 2016) and control class used verification laboratory.

The natural product mini project laboratory begins with a problem to be solved by the students. The problem is "how do you isolate one of the secondary metabolites of a leaf from *Artocarpus altilis*, heartwood from *Hopea odorata*, a rhizome of *Curcuma xanthorrhiza*, a rhizome of *Kaemferia pandurata*, a rhizome of *Curcuma aeruginosa*, and rind, pulp, and seed of *Cassia grandis* to be studied further?".

Structure of the natural product mini project laboratory consist of (Hakim, et al. 2016): (1) Laboratory activities training (Students practice in groups, 3-4 students per group, to isolate a secondary metabolite from the rhizome of *Curcuma longa*), (2) Orientation problem (Students were given the problem. Each group worked on one plant sample. Plant samples consist of a leaf from *Artocarpus altilis*, heartwood from *Hopea odorata*, a rhizome of *Curcuma xanthorrhiza*, a rhizome of *Kaemferia pandurata*, a rhizome of *Curcuma aeruginosa*, and rind, pulp, and seed of *Cassia grandis*), (3) Designing laboratory activities (Students undertook a literature review of various sources and made proposals for experiments), (4) Presenting laboratory activities proposal (Students communicated proposals to the other groups through a presentation), (5) Implementation of laboratory activities (Students implemented their proposal and collected data from sample preparation, extraction, fractionation, and purification of secondary metabolites), (6) Results reporting & presentation (Students made a report of their investigation and communicated it to other groups through presentations), (7) Evaluation of the laboratory activities and analysis of the complex concepts (Students evaluated the laboratory activities that have been performed. Students infer complex concepts from information that has been obtained during laboratory activities such as secondary metabolite nomenclature, common properties of secondary metabolites, characteristics of secondary metabolite structures, separation of chemical components, and identification of secondary metabolite structures).

The natural product mini project laboratory provides opportunities for students to design their own activities to isolate secondary metabolites. Students design procedures for isolate secondary metabolites from plant samples that have not been reported in other natural product laboratory experiments (Halpin, et al., 2010; Walsh, et al., 2012; Nazri, et al., 2012; Carroll, et al., 2012).

Table 1. *Example Question of The Precondition Test*

Questions	Answer
How to improve efficiency of the maceration extraction? a. Sample surface area is enlarged b. Reduce the amount of solvent c. Reduce the amount of sample d. Container extraction is enlarge e. Increase the amount of solvent Reason .... Degree of Certainty: 0 1 2 3 4 5	A Reason: Enlarge the sample contact with the solvent can be done by increasing the surface area of the sample

Table 2. *Example Question of The Natural Product Chemistry Concept Test*

Concepts	Questions	Answer
Metabolites categories	A compound can be classified into the categories of primary metabolites if they meet the following criteria EXCEPT .... a. It is formed through the main metabolic pathways b. The main constituent in every organism c. It is found the same in every organism d. It is necessary for the existence of an organism e. It is used by organism to defend itself Reason: a. Primary metabolites are not formed through primary metabolic process b. Primary metabolites are not directly used for growth c. Primary metabolites are not used as a basis of growth of organisms d. Primary metabolites are not involved in the process of reproduction of organisms e. Primary metabolites do not play a role in the process of environmental control Degree of Certainty: 0 1 2 3 4 5	E Reason: e

Experimental class used natural product mini project laboratory model (NP-MPLM) and control class used verification laboratory models. The instruments used are precondition test containing 15 questions and natural product chemistry concept test containing 35 questions. The forms of test used modified CRI technique (Hakim, et al., 2012). Example guestion of precondition tes and natural product chemistry concept test can be seen in Table 1 and Table 2.

The validity of the instrument is determined by using content validity experts. The instrument has also been tested for validity and reliability by 34 students who have enrolled natural product chemistry course in the previous year. Reliability of test scores estimated from Kuder-Richardson formula 20 (Cohen, et al. 2013). The reliability of each test is 0.83 and 0.99 for the precondition test and natural product chemistry concept test respectively.

Data processing is done by calculating the normalized gain scores and test two mean differences (t test or Mann-Whitney test). Percentage understand concepts, misconceptions, and do not know the concept was analyzed with the following provisions modified CRI (Hakim, et al., 2012)

Table 3. *Terms CRI Modified for Each Answer Given*

Answers	Reasons	CRI value	Description
True	True	> 2.5	Understand the concept of well
True	True	< 2.5	Understand the concept but are not confident with the answers given
True	False	> 2.5	Misconceptions
True	False	< 2.5	Do not know the concept
False	True	> 2.5	Misconceptions
False	True	< 2.5	Do not know the concept
False	False	> 2.5	Misconceptions
False	False	< 2.5	Do not know the concept

FINDINGS

The NPC Conceptual Understanding

The study involved eleven concepts that can be applied in natural product chemistry laboratory consisting of: metabolites categories, function of secondary metabolites (SM), structure of SM, characteristic of SM, nomenclature of SM, isolation of SM, separation of chemical components, thin layer chromatography (TLC), UV spectroscopy, IR spectroscopy, and NMR spectroscopy.

The highest increase students' mastery of the concept in class control occurred in function of SM by 51.15% (medium category) and the lowest increase occurred in the separation of the chemical components by 17.47% (poor category). In the experimental class, the highest increase occurred in UV spectroscopy at 72.85% (high category), while the lowest increase occurred in thin layer chromatography of 34.35% (medium category).

Table 4. *The Score of Natural Product Chemistry Laboratory Concepts*

Concepts	Experiment class %			Control class %			Λ N-gain
	Pretest	Posttest	N-gain	Pretest	Posttest	N-gain	
Metabolites categories	30.82	78.49	66.94	32.97	55.20	40.40	26.54
Function of SM	37.63	77.06	63.98	33.69	62.01	51.15	12.83
Structure of SM	36.20	97.49	42.65	35.48	73.12	27.29	15.36
Characteristic of SM	28.23	73.66	57.48	29.03	51.34	35.88	21.60
Nomenclature of SM	33.87	80.11	71.51	33.33	55.91	38.07	33.45
Isolation of SM	29.17	73.92	63.02	28.76	53.49	39.55	23.47
Separation of chemical components	24.37	68.10	54.40	25.81	36.56	17.47	36.93
TLC	25.27	53.23	34.35	20.43	53.76	39.95	-5.60
UV spectroscopy	34.41	87.63	72.85	37.63	61.29	32.47	40.38
IR spectroscopy	35.48	79.03	53.87	32.26	53.23	19.03	34.84
NMR spectroscopy	26.88	53.23	37.96	30.65	50.54	30.59	7.37
Average	31.12	74.72	56.27	30.91	55.13	33.80	22.47

The highest difference between the experimental class and the control class happened to separation of chemical components and UV spectroscopy concept, while the lowest difference occurred in thin-layer chromatography concept. The average n-gain experiment class was 56.27% and control class was 33.80%. It showed that used of the natural product mini project laboratory more effective in improving natural product chemistry laboratory concepts.

Statistical calculations such as normality test, homogeneity, and the mean difference test of improved natural product chemistry laboratory concepts of the experiment class and control class is presented in Table 5. Test two mean differences students conceptual understanding was a significant differences between the experimental class and the control class that occurred in the concept of secondary metabolites structure, secondary metabolites characteristic, isolation of secondary metabolites, separation of chemical components, UV spectroscopy, and IR spectroscopy with a experiment class superior than control class

Table 5. *Statistical Calculations Students' Mastery of Natural Product Chemistry Laboratory Concepts*

Concepts	Normality test (α = 0.05) Sig.		Explan.		Hom (F)	t test or Mann-Whitney test (α = 0.05)		
	Exp	Cont	Exp	Exp		t or U	p	Explan.
Metabolites categories	.000	.000	Not normal	Not normal	Not hom (0.015)	u=333.50	.108	Not sig.
Function of SM	.000	.000	Not normal	Not normal	Hom (0.953)	u=390.50	.488	Not sig.
Structure of SM	.033	.060	Not normal	Not normal	Hom (0.972)	u=287.50	.025	Sig.
Characteristic of SM	.043	.001	Not normal	Not normal	Hom (0.162)	u=296.00	.035	Sig.
Nomenclature of SM	.000	.000	Not normal	Not normal	Hom (0.081)	u=287.50	.170	Not sig.
Isolation of SM	.285	.233	Normal	Normal	Hom (0.210)	t=2.881	.006	Sig.
Separation of chemical components	.023	.001	Not normal	Not normal	Hom (0.233)	u=180.50	.000	Sig.
TLC	.052	.001	Normal	Not normal	Hom (0.290)	u=376.50	.373	Not sig.
UV spectroscopy	.000	.000	Not normal	Not normal	Hom (0.837)	u=232.00	.001	Sig.
IR spectroscopy	.000	.000	Not normal	Not normal	Not hom (0.006)	u=266.50	.006	Sig.
NMR spectroscopy	.000	.000	Not normal	Not normal	Hom (0.498)	u=403.50	.626	Not sig.

Percentage of understand concepts, misconceptions and do not know the concept of modified CRI data analysis can be seen in Table 6. The result of pretest shows that the highest of misconception in the experimental class occured on metabolites category (44.09%), while the highest pretest of misconception in the control class occured on structure secondary metabolites (33.84%). The highest pretest percentage of do not know concept in the experiment class occurred on UV spectroscopy (59.68%), while the highest pretest percentage of do not know concept in control class occured on separation of chemical (53.57%).

The highest posttest percentage of misconception in the experimental class occured on separation of chemical components concept (35.48%), while the highest posttest percentage of misconception in the control class occured on nomenclature of SM (32.14%). The highest posttest percentage of do not know concept in the experiment class occurred on NMR spectroscopy concept (29.03%), while The highest posttest percentage of do not know concept in control class occurs on isolation of SM concept (34.52%).

Table 6. *Percentage Recapitulation of Understand Concepts, Misconceptions and Do not Know Concept*

Concepts	Experiment class						Control class					
	Pretest			Posttest			Pretest			Posttest		
	U	M	D	U	M	D	U	M	D	U	M	D
Metabolites categories	0.43	4.09	5.48	5.27	9.35	.38	8.57	2.14	9.29	9.52	3.81	6.67
Function of SM	4.73	7.63	7.63	6.34	5.05	.6	6.19	9.76	4.05	9.05	0.24	0.71
Structure of SM	8.95	3.47	7.58	0.56	8.95	0.48	3.21	8.84	7.95	7.14	5.00	7.86
Characteristic of SM	3.39	1.45	5.16	1.77	7.74	0.48	7.68	5	7.32	0.71	0.54	8.75
Nomenclature of SM	0.97	8.71	0.32	5.81	7.74	.45	6.79	5.71	7.5	7.14	2.14	0.71
Isolation of SM	8.28	1.18	0.54	6.67	4.73	.60	9.05	4.52	6.43	5.71	9.76	4.52
Separation of chemical components	2.90	3.87	3.23	1.61	5.48	2.90	6.07	0.36	3.57	5.36	6.07	8.57
TLC	9.35	2.26	8.39	9.35	5.32	5.32	5	1.25	3.75	2.68	4.11	3.21
UV spectroscopy	0.97	9.35	9.68	3.87	.06	.06	5.71	9.64	4.64	6.07	0.71	3.21
IR spectroscopy	2.26	0.97	6.77	9.03	.45	4.52	3.93	7.86	8.21	8.93	.93	2.14
NMR spectroscopy	9.35	7.42	3.23	6.77	4.19	9.03	3.21	6.79	0	1.79	7.86	0.36
Average	1.05	1.85	7.09	9.73	8.46	1.80	5.95	9.26	4.79	6.74	0.83	2.43

U = Understand Concepts
M = Misconceptions
D = Do not Know Concept

DISCUSSION

Implementation of the natural product mini project laboratory can increase the conceptual understanding of NPC concept better than verification laboratory. The implementation of laboratory activities give the student opportunity to design their own experiments will provide a significant challenge for learners (Hakim, et al., 2016; Hartings, et al., 2015; Çibik & Yalçin, 2013). Through this challenge, students will be motivated to study the books and collecting information from other sources which will further help the students understand the implemented concepts in practical activities.

The highest percentage n-gain of the experiment class occured in UV spectroscopy (72.85%) and the lowest percentage n-gain occured in thin layer chromatography (34.35%), while the highest highest percentage n-gain of the control class occured in function of secondary metabolites (51.15%) and the lowest percentage n-gain occured in the separation of the chemical components (17.47%). Our analysis of the results is based on the argument that the students implemented the natural product mini project laboratory are given the opportunity to determine its own structure of isolated compounds based on UV, IR, and NMR spectra. From the three kinds of spectroscopy, UV spectroscopy is the most simple and easy to understand. The control class determined the structure of isolated compounds based on UV, IR and NMR spectra of standard compounds, so the control class just compared spectra data with the structure of standard compounds.

The students studied NPC often encounter misconceptions (Kazembe, 2010). This is in line with the average pretest results that showed a high percentage of misconceptions in both class. After the learning process, the misconceptions percentage decreases with experimental class (18.46%) and control class (20.83%). Learning is performed on both classes using the laboratory activities. The results are consistent other reseachs that laboratory activities reduce misconceptions (Prilliman, 2012; Setyadi & Komalasari, 2012).

The result of pretest showed that the highest misconception had occured in the experimental class for metabolites category (44.09%), while the highest pretest percentage in control class of misconception had occured for structure of secondary metabolites (33.84%). The highest pretest percentages of do not know concept occured in experiment class for UV spectroscopy (59.68%), while the highest pretest percentages of do not know concept occured in control class for the separation of chemical component (53.57%). The result can be caused by differences in the learning experience of students. The experiment class derived from chemical education courses and control class from chemical studies program.

The result of posttest showed that the highest misconceptions in experimental class had occured in separation of chemical components (35.48%), while the highest posttest percentage of misconceptions in the control class had occurred in nomenclature of secondary metabolites (32.14%). The highest posttest percentage of do not know concept in the experiment class occured in NMR spectroscopy (29.03%), while the highest posttest percentage of do not know concept in the control classes occurred in isolation secondary metabolites (34.52%). This is understandable because the concept of chemical separation involves the experience of students to separating secondary metabolites from samples in laboratory stage. Separation of secondary metabolites followed a complex series with differentces of secondary metabolites properties. This could potentially lead students to misconceptions. Nomenclature of secondary metabolites that have a high percentage of misconceptions on the control class can be caused by secondary metabolites nomenclature not followed the IUPAC but by trivial naming. This is due to the structure of secondary metabolites that are relatively large thus causing systematic IUPAC name is too long for secondary metabolites.

NMR spectroscopy remains elusive for learners because the concept is relatively complex (compared to UV and IR spectroscopy). Secondary metabolite isolation was difficult to understand by students from control class. The students used verification laboratory only followed the specified procedures in the laboratory manual, so no chance for student to try different alternatives in conjunction with the isolation of secondary metabolites. Analysis of the verification laboratory activities suggests that no meaningful learning takes place in the verification laboratory (Hartings, et al., 2015; Burand & Ogba, 2013; Domin, 1999).

CONCLUSIONS

Students conceptual understanding who using the natural product mini project laboratory was significantly higher for the structure of secondary metabolites, secondary metabolites characteristic, isolation of secondary metabolites, separation of chemical components, UV spectroscopy, an IR spectroscopy than students who using verification laboratory. Before learning process the highest percentage of misconceptions occurred in the experimental class for metabolites category (44.09%) and the highest percentage of do not know occurred in on UV spectroscopy (59.68%), and after learning process the highest percentage of misconceptions occurred in the experimental class for separation of chemical components (35.48%) and the highest percentage of do not know concept occurred in NMR spectroscopy concept (29.03%).

REFERENCES

Bezen, S., Aykutlu, I., & Bayrak, C., (2016). Conceptual Comprehension of Pre-Service Physics Teachers Towards 1st Law of Thermodynamics. *Journal of Turkish Science Education*, 13(1), 55-75.

Burand, M.W. & Ogba, O.M. (2013). Letter Writing as a Service-Learning Project: An Alternative to the Traditional Laboratory Report. *Journal of Chemical Education*, 90, 1701–1702.

Cohen, R. J., Swerdlilk, M. E., & Sturman, E. D. (2013). *Psychological Testing and Assessment: An Introduction to Tests & Measurement*, *8th edition*. Qeensland: Humanities & Social Sciences.

Carroll, A.M., Kavanagh, D. J., McGovern, F. P., Reilly, J.W., & Walsh, J. J. (2012). Nature's Chiral Catalyst and Anti-Malarial Agent: Isolation and Structure Elucidation of Cinchonine and Quinine from *Cinchona calisaya. Journal of Chemical Education*, 89, 1578−1581.

Çibik, A., S. & Yalçin, N. (2013). The Effect of Project Based Learning Supported with Analogies Method on Success and Understanding Level for Electric Current Concept. *Journal of Turkish Science Education*, 10, 108-136.

Cresswell, J. W. & Crack P. V. L. (2007). *Designing and Conducting. Mixed Method Research. Sage Publication*: London & New Delhi.

Domin, D. S. (1999). A review of laboratory instruction styles. *Journal of Chemical Education*, 76, 543-547.

Gunes, P., Katircioglu, H, & Yilmaz, M. (2015). The Effect of Performance Based Evaulation on Preservice Biology Teachers' Achievement and Laboratory Report Writing Skills. *Journal of Turkish Science Education*, 12, 71-83.

Gültepe, N. & Kılıç, Z. (2013). Scientific Argumentation And Conceptual Understanding Of High School Students On Solubility Equilibrium And Acids And Bases. *Journal of Turkish Science Education*, 10(4), 5-21

Hakim, A., Liliasari &Kadarohman, A. (2012). Student Understanding of Natural Product Concept of Primary and Secondary Metabolites Using CRI Modified. *International Online Journal of Educational Sciences*, 4, 544-553.

Hakim A., Liliasari, Kadarohman A., Syah, Y. M., & Musthapa I. (2013). Learning Through Innovative Natural Products Chemistry Laboratory. Proceeding of The Science Education Seminar Future Directions: Between Hope and Reality. February 2013. Mataram: University of Mataram.

Hakim, A., Liliasari, Kadarohman, A., & Syah, Y.M. (2016). Making a Natural Product Chemistry Course Meaningful with a Mini Project Laboratory. *Journal of Chemical Education*, 93, 193-196.

Halpin, C.M., Reilly, C., & Walsh, J.J. (2010). Nature's Anti-Alzheimer's Drug: Isolation and Structure Elucidation of Galantamine from *Leucojum aestivum. Journal of Chemical Education*, 87, 1242-1243.

Harman, G. (2014). The Determination of Misconceptions About "The Passage of Substances Through Cell Membrane" By Employing Prediction-Observation-Explanation Method. *Journal of Turkish Science Education*, 11(4), 81-106.

Hartings, M. R., Fox, D.M., Miller, A.E., & Muratore, K.E. (2015). A Hybrid Integrated Laboratory and Inquiry-Based Research Experience: Replacing Traditional Laboratory Instruction with a Sustainable Student-Led Research Project. *Journal of Chemical Education*, 92, 1016–1023.

Kazembe, T. (2010). Combining Lectures with Cooperative Learning Strategies to Enhance Learning of Natural Products Chemistry. *Chemistry*, 19, 1-15.

Kingir, S. & Geban, Ö. (2014). 10th Grade Students' Conceptions about Chemical Change. *Journal of Turkish Science Education*, 11(1), 43-62.

Nazri, M. M., Samat, F. D., Kavanagh, P.V., & Walsh, J. J. (2012). Nature's Cholesterol-Lowering Drug: Isolation and Structure Elucidation of Lovastatin from Red Yeast Rice-Containing Dietary Supplements. *Journal of Chemical Education*, 89, 138–140.

Piaget, J. (2001). *The Psychology of Intelligence*. New York: Routledge.

Prilliman, S.G. (2012). An Inquiry-Based Density Laboratory for Teaching Experimental Error. *Journal of Chemical Education*, 89, 1305–1307

Roth, K.J. (1992). Science Education: It's Not Enough to Do or Relate. *Relevant Research*, 47, 245-252.

Sadi, Ö. (2014). Students' Conceptions of Learning in Genetics: A Phenomenographic Research. *Journal of Turkish Science Education*, 11(3), 53-63.

Setyadi, E. K. & Komalasari A. (2012). Misconceptions about Temperature and Heat in Class at SMA Muhammadiyah 1 Purworejo, Central Java. *Berkala Fisika Indonesia*, 4, 46-49

Sevim, S. (2013). Promoting Conceptual Change In Science Which Is More Effective: Conceptual Change Text Or Analogy? *Journal Of Turkish Science Education*, 10(3), 24-36

Walsh, E. L., Ashe, S., & Walsh, J.J. (2012). Nature's Migraine Treatment: Isolation and Structure Elucidation of Parthenolide from *Tanacetum parthenium. Journal of Chemical Education*, 89, 134–137.

Özdemir, Ö. F. (2015). A Qualitative Inquiry about Students' Conceptualizations of Force Concept in terms of Ontological Categories. *Journal of Turkish Science Education*, 12(1), 29-42.