Teaching about nature of science through short lab activities in Hong Kong classroom

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Contents

Abstract

The study evaluated the effectiveness of using short, school lab investigations to teach about the nature of science (NOS). A manipulated lab inquiry approach was used, which modified the investigations in ways that students were compelled to experience certain NOS aspects. An investigation about apple browning was used to teach about the underdetermination of scientific theory, and the outcomes were compared with the teaching using the case of dinosaur extinction. Pre-test and post-test were used to assess grade eight students' views in the contexts of the apple browning investigations and the case of dinosaur extinction. Both the apple browning investigation and the case of dinosaur extinction were found effective in enhancing students' views on underdetermination, but the apple browning investigation can produce greater transfer of learning across contexts. The significance of this approach to NOS teaching for East Asian regions was discussed.

Keywords: nature of science, scientific investigation, manipulated lab inquiry, underdetermination of scientific theory

Introduction

Nature of science (NOS) has been widely recognized as one of the major goals of science education by science educators and in many important science curriculum reforms and science standards documents (AAAS 1993; McComas and Olson 1998; NGSS Lead States 2013; NRC 2012). In the Next Generation Science Standards (NGSS) of the United States, nature of science is considered an important element closely associated with the Practices and Crosscutting Concepts (NGSS Lead States 2013). Despite decades of efforts in promoting it, disappointingly, NOS is still not an emphasized part of instruction in most science classrooms (Lederman 2007).

Among the common approaches to NOS teaching: generic NOS activities (Lederman & Abd-El-Khalick, 1998), historical and contemporary case studies, and lab investigations, lab investigations are most able to engage students personally to experience how science is working (Allchin et al., 2014). The NGSS (2013) states that 'students cannot comprehend scientific practices, nor fully appreciate the nature of scientific knowledge itself, without directly experiencing those practices for themselves.' (Executive summary, p.2).Despite the empirical evidence supporting the effectiveness of lab investigations in teaching about NOS (Deng et al, 2011), ordinary school lab activities are often limited in many ways for NOS learning. One commonly agreed problem is the lack of explicit attention to NOS aspects (Akerson, Abd-El-Khalick, & Lederman, 2000). Another important problem is that school lab activities are usually hugely different from authentic science (Chinn and Malhotra 2002), particularly in the East Asian regions. In an analysis comparing the PISA science performances of the top East Asian regions with their Western counterparts (Lau et al., 2015), East Asian regions (Hong Kong, Japan, Korea, Taipei and Macau) in general had less hands-on activities and investigations, and performed relatively weaker in identifying scientific issues. It seems that East Asian regions had not placed heavy emphasis on scientific investigations despite their top PISA performances, which is partly a result of the highly exam oriented culture of the East Asian communities. Hong Kong is the East Asian region having most hands-on activities and investigations, but the lab activities were still dominated by lab experiences and low-level cookbook experiments (Yip and Cheung 2004; Tsang 2004) that hardly foster students understanding of NOS.

It is against the above background that this study sets out to develop a new approach to NOS teaching using short lab activities that are ordinarily done and accepted by schools and teachers in East Asian regions. Clough (2006) contended that NOS instruction would be adopted by teachers when it only requires minor modifications of existing curriculum and teaching practices. Lederman and Lederman (2004) showed that ordinary school lab activities can be used for NOS teaching when the NOS aspects are explicitly attended to. Lau and Chan (2013) developed a new approach to NOS teaching called manipulated lab inquiry, where ordinary lab activities are modified to make particular NOS aspects salient so that students are engaged in deep and personal reflection of what science is. This study aims to further develop this approach for another important NOS aspect, underdetermination of scientific theory, and compare this approach with science case study in fostering students' NOS understanding.

There is wide consensus on the NOS aspects for science education: (a) tentativeness; (b) empirically based; (c) subjective as a human endeavor and theory-laden; (d) involving inference, imagination, and creativity; (e) socially and culturally embedded; and (f) developed from a combination of observation and inferences (Lederman, 2007; McComas & Olson, 1998). Tentativeness of science actually roots largely in underdetermination, which is that one can never determine if a scientific theory is absolutely true given a particular set of evidence. There could be alternative theories that can explain the evidence equally well. So the relation between theory and data is never certain but underdetermined. Underdetermination of scientific theory has constituted an important part of the nature of science because many attacks on the methodology of science arise out of it (Lauden 1990).

Manipulated lab inquiry for NOS learning

This approach aims to provide students with direct personal experience of how an NOS aspect is working during school lab inquiries. The first study of manipulated lab inquiry used a very common biology investigation in Hong Kong – how heat affects vitamin C contents of fruit juices, to target an important NOS conception, theory-laden observation (Lau & Chan, 2013). Students were first given two contrary theories about the inquiry: heat would or would not destroy vitamin C. They were then asked to find out the vitamin C contents in the heated and unheated juices using DCPIP titrations; indeed, all the juices were identical in vitamin C content. The interesting findings were that the groups holding the theory that heating would destroy vitamin C turned out finding greater differences in vitamin C content between the two samples than the groups being told that heating had no effects. In the post lab discussions, the students were surprised after finding that their experimental results had been biased by their 'theories' in mind, from which the concept of theory-laden observations was introduced and reflected upon. This pedagogical approach has captured the elements of the conceptual change model (Hewson et al. 1998) that a discrepant event is first used to confront learners' preconceptions and create cognitive conflicts, from which learners are guided to make sense of the informed conceptions. This approach is both explicit and reflective, the two elements considered to be at the heart of effective NOS teaching (Abd-El-Khalick and Lederman 2000). Moreover, compared to the decontextualized NOS activity using gestalt pictures (e.g. morphing man) (Lederman & Abd-El-Khalick, 1998), this approach illustrates theory-ladenness in the context of lab inquiry, which is likely more convincing to students that science is theory-laden (Clough, 2006).

Built on the above study, this study aims to provide further evidence for the manipulated lab inquiry as an effective approach to learning different NOS aspects. In this study, the investigation about the cause of apple browning was employed to show the underdetermination of scientific theory (Duhem 1954). A simple understanding of underdetermination is that one can never determine if a scientific theory is true given a particular set of evidence because other alternative hypotheses or theories could also account for the evidence equally well.

Methods

The research is pretest-posttest, quasi-experimental design, with two classes of twenty nine and thirty four grade 9 students taught respectively with the manipulated lab inquiry of apple browning and the case of dinosaur extinction as a control. The main research question is: *What is the effectiveness of the manipulated lab inquiry of apple browning, as compared to the case of dinosaur extinction, in fostering students' understandings about underdetermination of scientific theory?*

The study was conducted in a secondary girl school in Hong Kong, which admitted the top 20% of primary students and was using English as a medium of instruction. The two classes taking part in the study had no large differences in academic performance and other background factors since the students were randomly assigned to the two classes from grade eight. The two classes were taught by the same biology teacher, Miss Chung, in order to reduce the impacts of the teacher variable. Miss Chung had taught biology and science for over 7 years. She is a competent science teacher with a master degree in science education, and had learned about the nature of science and its teaching in the teacher training courses. In the study, she worked closely with the researcher to develop detailed lesson plans for the two classes. The lessons were observed by the researcher to ensure that the teaching plan had been enacted properly.

Apple browning investigation

The investigation is outlined in Table 1. Different groups in a class were asked to design the investigation as guided by two different task sheets. One suggests exposure to oxygen as a hypothesis for apple browning and thus emphasizes the antioxidant property of ascorbic acid solution in the prevention of browning. Another hypothesis suggests enzyme action as the cause of apple browning and points to the acidic nature of ascorbic acid solution in preventing browning. Actually both are required for browning: the polyphenols in apple are oxidized into brown substances by polyphenol oxidase when exposed to oxygen (Nicolas el al. 1994). Therefore, when apple browning is inhibited by ascorbic acid solution, the result gives support to both hypotheses – they are underdetermined by the empirical observations. In the post-lab discussions, when students were reporting their findings and conclusions, they were surprised by that the same test and data could lend support to two different hypotheses. This formed a discrepant event that confronted the preconceptions of the students that scientific conclusion can be straightforwardly proven by data. Then, using an interactive dialogic approach, the students were guided to explicitly reflect on their preconceptions about the reliability of scientific conclusions or scientific knowledge in general, from which the concept of underdetermination and other related NOS aspects were explained.

Table 1. Manipulated lab inquiry used to teach about underdetermination of theory

	Student groups given the oxygen hypothesis	**Student groups given the enzyme hypothesis**
Problem	Why does apple turn brown when peeled and exposed in air?	
Hypothesis	Exposure to oxygen	Enzymes released when the cells are damaged during peeling
Testing	Compare the degree of browning of apple slices with and without being immersed into ascorbic acid solution.	
Results	Apple slices treated with ascorbic acid solution show less browning than those without treatment.	
Conclusion	Apple browning is caused by exposure to oxygen, since ascorbic acid as an antioxidant can prevent browning	Apple browning is caused by enzymes released when cells are damaged, since ascorbic acid can prevent browning by denaturing the enzymes
NOS conception	Both conclusions are supported by the data and thus underdetermined.	

Case of dinosaur extinction

As a control for the manipulated lab inquiry, the case of dinosaur extinction was used to illustrate the underdetermination of theory. There are two rival theories explaining the extinction of dinosaur 65.5 million years ago. The *asteroid impact theory* attributes the dinosaur extinction to a big asteroid impact producing dust that blocked the sunlight for a long time, leading to hostile climate changes and shortage of food for the dinosaurs (Schulte et al. 2010).The *volcanic eruption theory*, however, regards the frequent volcanic eruptions as the main cause for the climate changes leading to dinosaur extinction. The asteroid theory was supported by a huge crater formed around 65.5 million years ago, the special quartz formed by strong impact and large amount of soot left by catastrophic fire. One piece of evidence is particularly crucial: the soil layer at the time of dinosaur extinction is rich in iridium, an element rarely found on earth surface but rich in asteroids. However, much of the evidence for the asteroid impact theory can be accounted for by volcanic eruption theory as well. Volcanic eruption can also cause big fires, and most importantly, magma is also rich in iridium. The evidence is thus unable to determine which theory is correct - underdetermination. The controversy has been lingering for over 30 years until recently a group of scientists claimed that asteroid impact is the main cause for dinosaur extinction after reviewing all the available evidence (Schulte et al. 2010).

In the classroom, the teacher first introduced the impact theory as a 'perfect' explanation to the dinosaur extinction. Then, the arguments of the volcano theory were brought out as a discrepant event that confronted the students' understanding about science, before the concept of underdetermination of theory was introduced. The teaching largely paralleled that of the apple browning lab inquiry except that it was not hands on and was about authentic science.

Assessment of Understandings of underdetermination

The assessment of NOS understanding in this study does not presume that one's NOS views are necessarily universal, domain general and context independent, which are the major problems of many NOS instruments (Lederman, Wade, & Bell, 1998). Therefore, the tests were constructed respectively in the contexts of the apple browning experiment and the case of dinosaur extinction for the treatment and control classes. The two tests consist of identical items: two-tier multiple choice questions that first ask students whether they think experimental conclusions/scientific theories are absolutely true and the reasons underlying their views (Table 2). The tests were administered as pretest and posttest. The tests were developed after reviewing the literature (e.g. Lederman et al. 2002; McComas and Olson 1998) and trialed on 13 students with post-test interviews. The test was then examined by another science educator to establish face and content validity. However, due to the small sample size of this study and the categorical nature of the test items, no statistical data were obtained to support the validity and reliability of the test, which would require further work on that.

Sandoval (2005) has distinguished two types of NOS understandings: *practical epistemologies* and *formal epistemologies*, with the former pertaining to how students view their school experiments and the latter about how they view formal science. To find out how students' practical and formal epistemologies are affected by different NOS teaching approaches, each class was assessed by an additional post-test in the different context: treatment class in the context of dinosaur extinction, and control class in the context of apple browning investigation.

Table 2. Assessment items for students' views of scientific theory as truth and their underlying reasons

I think one of the theories/hypotheses is (Choose only one):	
	1. absolutely true (will never become wrong in the future).
	2. true at the moment but it may become wrong in the future.
	3. never absolutely true.
because (can choose more than one):	
	a. The results have proven the conclusion/theory without doubt. (*Absolute proof*)
	b. The experiment/evidence may have errors. (*Errors*)
	c. The existing results are not strong enough to prove the conclusion/theory true. More evidence is needed. (*Inadequate evidence*)
	d. The same results can also support another conclusion/theory. (*Weak underdetermination*)
	e. The same results can support an infinite number of conclusions/theories. (*Strong underdetermination*) f. Even if ascorbic acid can prevent apple browning, it does not necessarily mean that the browning is caused by an enzyme. Or, Even if there was really a meteorite impact or volcano eruptions happening 65 million years ago, it does not necessarily mean that they had caused the dinosaur extinction. (*Contextual underdetermination*)

Results and discussions

Students' views in the pre-test and post-test are compared using Wilcoxon rank test since they were repeated measures of the same students. The levels of scientific theory as truth as shown in items 1-3: absolute truth, tentative, and never absolute truth, are ranked 1,2,3 respectively. The levels of understanding of underdetermination as shown in items f, d, e: contextual, weak and strong, are also ranked 1,2, 3 respectively, while 0 is given to those not choosing any underdetermination option. The higher score thus represents a more constructivist, anti-realist view that regards scientific theory not as truth and underdetermined by its evidence.

For the lab class, there found significant growth in views toward scientific theory being never true, z=-2.53, p=0.011, and toward strong underdetermination, z=-3.79, p=0.000 (Table 3). The effect sizes r ($z/\sqrt{N}$) are 0.47 and 0.70 respectively, a medium to high size effect. As for the control class, there was also significant change in views toward strong underdetermination, z=-2.48, p=0.013, with an effect size of 0.43. The results indicate that both the manipulated lab inquiry and the case of dinosaur extinction can effectively foster students' understanding about underdetermination. To find out if students' views on scientific theory as truth are related to their views on underdetermination, Kendall rank correlation was calculated in posttest. Only in the dinosaur class the correlation is close to be significant, Kendall's tau= 0.30, p=0.065.

The students held various reasons for why scientific theory does or does not represent absolute truth (Table 4). In the lab class, there were substantial changes in views from pre-test to post-test: none believing in absolute proof and much more believing in *inadequate evidence* and *underdetermination* as the causes of scientific theory being tentative. *Error*, the main reason that students chose in the pretest, became less important in the posttest after the students were aware of the uncertainty between data and conclusion. Much more students chose *inadequate evidence* because underdetermination partly arises from the lack of evidence to discriminate between alternative hypotheses. In the dinosaur class, however, the views of pre-test and post-test showed no great differences because the students were already holding more constructivist views in the pre-test. It seems that students' NOS views are context-dependent, with more constructivist views regarding authentic science than school science.

Table 3. Comparisons of students' views between pre-test and post-test using Wilcoxon Sign rank test

	Change from pre-test to post-test	
Class	**Scientific theory as truth**	**Underdetermination**
Lab class (n=29)	+0.27* (1.83)	+1.1* (1.52)
Dinosaur class (n=34)	0 (2.10)	+0.47* (1.44)

*The difference between pre-test and post-test is significant, p<0.05

Figures in blankets are pre-test scores.

Table 4. Reasons of students in support of their views on scientific theory as truth

Class	Test	Absolute proof	Error	Inadequate evidence	Underdetermination
Lab class (n=29)	Pre-test	17.2%	75.9%	44.8%	72.4%
	Post-test	0%	65.5%	69%	96.6%
Dinosaur class (n=34)	Pre-test	5.9%	70.6%	64.7%	94.1%
	Post-test	2.9%	73.5%	67.6%	94.1%

Some of the students' responses in class could show how the lab experience changed their NOS views:

S1: In the past I used to think science experiment gives certain answers, but now I know it is not!
S2: I never think of a different conclusion can be made from the same experiment!
S3: This experiment confused me – is science reliable or not?
S4: Can I ask if all true scientific experiments are like that? This really changed my view about science.

Conclusions

The findings of the study show that both manipulated lab inquiry and scientific case study are effective in fostering students' understanding that scientific conclusions and theories are tentative and not truth because of the underdetermination between data and theories. Manipulated lab inquiry is superior to scientific case study in that the NOS learning can be transferred across contexts - from the apple browning experiment to the case of dinosaur extinction, whereas scientific case study has its effects more limited to its teaching context. Alternatively, we can construe the findings as manipulated lab inquiry having effects on both the practical and formal epistemologies of students (Sandoval 2005). The superiority of manipulated lab inquiry over scientific case study likely stems from the personally reflective experiences provided to students. These findings, in couple with that of the first study on manipulated lab treatment (Lau and Chan 2013), have provided empirical support to manipulated lab inquiry as a potentially fruitful and efficient way of NOS teaching in secondary classroom. The manipulated lab inquiry, however, is better conducted in connection scientific case study so that students would not discount the learning as a school 'game' and can transfer their understandings to authentic science (Crawford, 2012). This is what Clough (2006) advocates to move along the continuum from the decontextualized, to school lab to authentic contexts, where students would have their NOS conceptions consolidated and expanded.

The value of this approach to NOS teaching is that it only needs a little modification of ordinary, short school experiments, which makes it likely adopted by frontline teachers and schools in East Asian regions where exam pressure and overemphasis on content learning form the major hindrance to NOS teaching in spite of decades of efforts in promoting it. Moreover, the manipulated lab inquiry can also be used for learning a variety of concepts and skills beyond the NOS aspects. The NGSS encourages nature of science, science practices and crosscutting concepts to be learned in an integrated manner, and the apple browning investigation can serve these ends as shown in Table 6. When scientific investigations can be conducted in this manner with explicit focuses on science processes and NOS understandings, the performance of East Asian regions in procedural and epistemic knowledge of science as assessed in PISA 2015 would be enhanced.

Table 5. Connections of the apple browning investigation with science practices, nature of science and crosscutting concepts of NGSS.

Investigation of apple browning	Science practices	Nature of science	Crosscutting concepts
• Students discuss under what conditions an apple would turn brown		• Scientific knowledge assumes an order and consistency in natural systems • Science addresses questions about the natural and material world	• Patterns
• Students propose hypothesis for the cause of apple browning	• Asking questions (propose testable questions for investigation)		• Cause and effect (multiple hypothesis)
• Students design	• Planning and	• Scientific knowledge is	

experiment to test the two hypotheses - browning due to oxygen exposure or due to enzyme actions.	carrying out investigations (identify independent and dependent variables, control confounding variables, measure variables accurately, etc.)	based on empirical evidence • Scientific investigations use a variety of methods	
• Students analyze and present the results	• Analyzing and interpreting data • Constructing explanation		
• Students are engaged in argument about which of the two hypotheses is correct based on the evidence, and what further evidence is needed to draw a conclusion.	• Engaging in argument from evidence • Constructing explanation	• Scientific knowledge is based on empirical evidence • Scientific knowledge is open to revision in light of new evidence (e.g. underdetermination of scientific theory, errors and uncertainties of data) • Science is a Human Endeavor (e.g. human judgement needed to make conclusion)	• Cause and effect (multiple causes)

Nonetheless, the conclusions have to be taken cautiously in view of the limitations of the study: small sample size and no delayed post-test. The conclusions may be limited to the contexts of the study only. Further study is needed to develop and validate the manipulated lab inquiry approach in various contexts of school experiments that target different NOS aspects, and assess its effects in longer period through longitudinal study. On the other hand, this apple browning lab is only a simulated case of underdetermination that the problem can be easily avoided by using other means to cut off the oxygen instead of using ascorbic acid. However, from the perspectives of the students who do not know the roles of ascorbic acid, the experience of underdetermination is real.

References

Abd-El-Khalick, F., & Lederman, N. G. (2000). Improving Science Teachers' Conceptions of the Nature of Science: A Critical Review of The Literature. *International Journal of Science Education, 22*(7), 665–701.

Akerson, V. L., Abd-El-Khalick, F., & Lederman, N. G. (2000). Influence of a Reflective Activity Based Approach on Elementary Teachers' Conceptions of Nature of Science. *Journal of Research in Science Teaching, 37*(4), 295–317.

Allchin, D., Andersen, H.M. & Nielsen, K. (2014). Complementary Approaches to Teaching Nature of Science: Integrating Student Inquiry, Contemporary Cases and Historical Cases in Classroom Practice.Science Education 98:461-486.

American Association for the Advancement of Science (AAAS). (1993). *Benchmarks for Science Literacy: A Project 2061 Report.* New York: Oxford University Press.

Chinn, C. A., and Malhotra, B. A. (2002). Epistemologically Authentic Inquiry in Schools: A Theoretical Framework for Evaluating Inquiry Tasks. *Science Education, 86,* 175–219.

Clough, M. P. (2006). Learners' responses to the demands of conceptual change: Considerations for effective nature of science instruction. *Science & Education 15* (5), 463-494

Crawford, B. (2012). *Moving the essence of inquiry into the classroom: Engaging teachers and students in authentic research.* In K. C. D. Tan & M. Kim (Eds.), Issues and challenges in science education research: Moving forward (pp. 25 – 42). Dordrecht, The Netherlands: Springer

Deng, F., Chen, D.-T., Tsai, C.-C., & Tsai, C. S. (2011). Students' views of the nature of science: A critical review of research. *Science Education, 95*, 961 – 999.

Duhem, P. (1954). *The Aim and Structure of Physical Theory*, trans. from 2nd ed. by P. W. Wiener; originally published as La Théorie Physique: *Son Objet et sa Structure* (Paris: Marcel Riviera & Cie.), Princeton, NJ: Princeton University Press.

Hewson, P. W., Beeth, M. E., and Thorley, N. R. (1998). *"Conceptual Change Teaching." In International Handbook of Science Education.* edited by B. J. Fraser and K. G. Tobin. Dordrecht: Kluwer.

Lau, K. C. and Chan, S. L. (2013). online first. *Teaching About Theory-Laden Observation to Secondary Students Through Manipulated Lab Inquiry Experience.* Science & Education. Springer. DOI 10.1007/s11191-013-9589-2.

Lau, K. C., Ho, S. C. and Lam, Y. P. (2015). *Effective classroom pedagogy and beyond for promoting scientific literacy: Is there an East Asian model.* In Khine (Ed.) Science Education in East Asia. Springer International Publishing.

Lederman, N. G. (2007). "Nature Of Science: Past, Present, and Future." In Handbook of Research on Science Education. edited by S. K. Abell and N. G. Lederman. Lawrence Erlbaum Associates Publishers, Mahwah, NJ. , p. 831–880.

Lederman, N. G. & Abd-El-Khalick, F. (1998). Avoiding de-natured science: Activities that promote understandings of the nature of science. In W. F. McComas (Ed.), *The nature of science in science education: Rationales and strategies* (pp. 83–126). Boston: Kluwer Academic Publishers.

Lederman, N. G., Abd-El-Khalick, F. S., Bell, R. L., and Schwartz, R. S. (2002). Views of Nature of Science Questionnaire (VNOS): Toward Valid and Meaningful Assessment Of Learners' Conceptions of Nature of Science. *Journal of Research in Science Teaching, 39*, 497–521.

Lederman, N.G., Wade, P.D., and Bell, R.L. (1998). "Assessing Understanding of The Nature of Science: A Historical Perspective." In The Nature Of Science in Science Education: Rationales and Strategies, 331–350. edited by McComas, W. The Netherlands: Kluwer Academic.

McComas, W. F., and Olson, J. K. (1998). "The Nature of Science In International Science Education Standards Documents." In The Nature Of Science in Science Education:

Rationales and Strategies, 331–350. edited by McComas, W. The Netherlands: Kluwer Academic.

National Research Council (NRC). (2012). *A Framework for K–12 Science Education: Practices, Crosscutting Concepts, and Core Ideas.* Washington, DC: National Academies Press.

NGSS Lead States. (2013). *Appendix H of Next Generation Science Standards: For States, By States.* Retrieved from http://www.nextgenscience.org/

Nicolas, J., Florence C. Richard‐Forget, Pascale M. Goupy, Marie‐Josèphe Amiot, Serge Y. Aubert. (1994). Enzymatic browning reactions in apple and apple products. *Critical Reviews in Food Science and Nutrition, 34*(2), 109-157. DOI:10.1080/10408399409527653

Sandoval, W. A. (2005). Understanding students' practical epistemologies and their influence on learning through inquiry. *Science Education, 89*(4), 345–372.

Schulte, P. et al. (2010). The Chicxulub Asteroid Impact And Mass Extinction at The Cretaceous-Paleogene Boundary. *Science , 327* (5970), 1214-1218. DOI: 10.1126/science.1177265

Tsang, W. K. (2004). Evaluation on the implementation of MOI guidance for secondary schools: 1999–2002 commissioned by the Education and Manpower Bureau to the Hong Kong Institute of Education Research of The Chinese University of Hong Kong.

Yip, D. Y., & Cheung, S. P. (2004). Scientific literacy of Hong Kong students and instructional activities in science classrooms. *Education Journal, 32*, 2.

Appendix

Name:______________ Class:________________ Date : ________________

Lab task sheet

Question

Why does an apple turn brown after being cut?

Hypothesis (only one is provided in each task sheet)

Cutting an apple exposes it to air. The oxygen in air oxidizes the iron–containing compounds in the apple to produce a brown colour substance. OR

The apple turns brown because of an **enzyme**. When exposed to air, this enzyme catalyzes the formation of a brown colour product at the cut surface.

Prediction (only one is provided in each task sheet)

Dip the apple into a solution of ascorbic acid will slow down the browning. It is because ascorbic acid is an **anti–oxidant**, which would prevent the oxidation process on the cut surface. OR

If the enzyme is inactivated by **acid,** there will be no or less browning.

Procedure

1. Prepare three beakers containing 0.5% ascorbic acid, 2% ascorbic acid, and water respectively.
2. Cut an apple to obtain three slices of similar size.

3. Immediately dip the apple slices into the three beakers of solutions for one minute.
4. Take the apple slices out and place them on three watch glasses.
5. Take a photo of the three apple slices at the start and every 10 minutes thereafter for a period of 30 minutes.
6. Compare the browning of the three apple slices with the help of the photos.

Result

	Degree of browning (relative units)		
Time (min)	Water	0.5% Ascorbic acid	2% Ascorbic acid
0			
10			
20			
30			

Discussion

1. Describe the results.
2. Do the results support the hypothesis? Explain your answer.

Conclusion