

SHARING A TEACHING MOMENT

Using primary-literature-based assessments to highlight connections between sub-topics in cell biology

YEONG Foong May

¹ Department of Biochemistry
Yong Loo Lin School of Medicine
National University of Singapore

Address for Correspondence: Dr Foong May Yeong, Department of Biochemistry, Yong Loo Lin School of Medicine, MD7, 8 Medical Drive, Singapore 117597. Email: foong_may_yeong@nuhs.edu.sg

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Abstract

Equipping students with Cell Biology knowledge should extend beyond the mere dissemination of facts so as to reduce students' learning by memorisation. Making use of innovative assessments to promote student thinking has been shown to be effective especially for large classes. In this exercise, I describe a method to encourage students to synthesise their own knowledge by requiring students to write an essay based on their reading of primary literature. More importantly, the material in the article bridges two sub-topics of Cell Biology that were taught in class. After going through the article, students had to answer questions related to both nuclear transport and cell cycle regulation. With questions that prompted students to consider different cellular processes taught in separate sections in class as functioning together in the context of the cell, it was hoped that students arrive at a piece of knowledge without having me explicitly state it for them. Moreover, as the essay is an "open-book" assessment, students did not need to memorise facts but rather spent time learning outside of the lectures. The suitable use of primary literature that showcases different cellular processes operating in combination could persuade students to learn with an integrated perspective of Cell Biology.

INTRODUCTION

A challenge to teaching Cell Biology at the undergraduate level is to equip students with sufficient basic knowledge that would allow them to proceed to higher-level Cell Biology modules and to pursue research work in postgraduate studies. However, given the ever-growing amount of new information in the field of Cell Biology, it is neither productive nor useful for the students to simply teach a collection of facts for them to learn, as students' defense against the large amount of information they need to learn by simply memorising facts presented in textbooks and regurgitating them during the exams (DiCarlo, 2006).

In previous semesters, in a Cell Biology module for a class size of about 280 for 2nd year undergraduates, the topics I taught included Protein transport to various

organelles and Cell Division. Due to the large class size, the module was entirely lecture based. For evaluation of student learning in this module that I shared with 2 other lecturers, multiple-choice questions and short answer questions were traditionally used in continual assessments and examinations (Table 1). All assessments were of the closed-book format, which might have influenced the students to learn in a manner that relied more on memorisation as was often reflected in the students' feedback at the end of the modules and, possibly, at a superficial level (Scouller, 1998). As students' learning is known to be shaped by assessment modes (Gibbs & Simpson, 2004), I believed that modifying my teaching approach should be combined with changes in assessments to bring about a more effective shift in students' mindset towards learning.

Table 1. A typical student's workload from previous semester

2nd year undergraduates (class size 250 – 280 per semester)	Workload	Assessments
Number of hours per week per module	2 x 2	2 closed-book continual assessments and 1 closed-book final exam
Number of weeks per semester	13	
Average number of modules taken by each student	4	

It has been proposed that using problem-based learning (PBL) in Cell Biology encourages skills such as problem analysis, critical thinking and formulating solutions that resemble the process of scientific enquiry (Allen & Tanner, 2003). Although PBL might be more effective in smaller classes, Allen and Tanner (2003) suggested that PBL could be adapted to classes larger than 60. As our 280-student class included students with a broad background in Biology (data not shown) and that I had no teaching assistants to prepare and guide the students, it became clear to me that a full PBL that revolves around an ill-structured problem might not be appropriate for my class. In order to introduce elements of PBL such as analysis of data and encouraging students to seek out information on their own, I used the reading of primary literature and essay writing not only as a mode of assessment but also for learning (Klein, 2004). The key idea was to get students to synthesise for themselves the knowledge that there are links between different cellular processes. The skills I hoped the students would learn included critical analysis of primary data and writing an essay to explain a cellular process in their own words (DeBurman, 2002; Mulnix, 2003; Klein, 2004; Gillen, 2006). This approach might be more useful for active learning among students than traditional lectures where students are told the information directly (Crowe, Dirks, & Wenderoth, 2008; Wood, 2009) that cell processes are linked.

METHODS

In the assignment, students were asked to bridge 2 concepts taught in class, namely nuclear transport and cell cycle regulation. With the large class size of about 280 and the lecture-based format of the module, I decided that the exercises, designed with guided questions (see below), might be a good use of prescribed primary literature to start students off in their writing-to-learn exercise that should promote critical thinking skills (Hoskins, Stevens, & Nehm, 2007). No memorisation of facts was therefore required and the “open-book” format could also encourage learning outside the classroom (Wood, 2009).

A practice assignment as preparation – cyclin B1 nuclear import

The students were taught the organisation of the eukaryotic cell and of how proteins are transported into or out of the nucleus in the normal lectures. The roles played by components such as the nuclear pore channel, importin, exportin, Ran, Ran exchange factor (GEF) and Ran GTPase accelerating protein (GAP) were introduced to the students (Alberts et al., 2007; Lodish et al., 2007). Subsequently, the lectures also covered the topic of cell cycle regulation including areas such as cell cycle phases, cyclins and cyclin-dependent kinases (CDKs) (Alberts et al., 2007; Lodish et al., 2007).

Students were given a practice assignment which required them to read a scientific article and combine their knowledge of nuclear import and cell cycle regulation in answering the questions given (Table 2). The article that was chosen had techniques that had been briefly explained to them during the lectures. To help students, a write-up on how to read a scientific article (Supplemental 1) was uploaded onto the Integrated Virtual Learning Environment (IVLE). They had 1.5 weeks to complete an online assessment page set up on IVLE. Marks given

Table 2. Practice assignment on cyclin B1 nuclear transport with typical answers from students

1. What are the major functions of cyclin B1-CDK1 in the cell division cycle? (2 marks)
2. Based on the paper, what do you understand by the term “CRS”? Where is it found in cyclin B1? (3 marks)
3. What was the authors’ key hypothesis? (4 marks)
4. What were the main techniques used to examine cyclin B1 localization? (5 marks)
5. Explain succinctly how cyclin B1 might be imported into the nucleus, given that it does not have the classical NLS sequence. (6 marks)

Table 3 – assignment on p27

p27 is localised to the nucleus during the quiescent stage (G₀) of the cell cycle. In the presence of growth factors, p27 is degraded in the cytoplasm.

Read the article below. The article can be downloaded from Pubmed*.

Connor MK, Kotchetkov R, Cariou S, Resch A, Lupetti R, Beniston RG, Melchior F, Hengst L, Slingerland JM. CRM1/Ran-mediated nuclear export of p27(Kip1) involves a nuclear export signal and links p27 export and proteolysis. *Mol Biol Cell.* 2003 Jan;14(1):201-13. PubMed PMID: 12529437; PubMed Central PMCID: PMC140238.

*instructions on how to use Pubmed at IVLE in the folder where the lecture notes on Organelle Biogenesis and Protein Trafficking can be found.

Based on your reading of the article, write an essay on

“The export of p27 to the cytoplasm”

Word limit is 1000 words, One Figure is allowed.

Marking guidelines

The essay should be written in your own words. Marks will be awarded based on the organization of the essay and the clarity of your explanation of how the localisation of p27 is regulated. There will also be marks given for the proper analysis of key experiments and critical data described in the paper that is related to your answer. The physiological importance of such a regulation of p27, based on what we learnt in class, should be explained as well.

Hints: Read guidelines on “How to read_ part2” and “How to write” I have previously uploaded at IVLE, folder called “Organelle Biogenesis and Protein Trafficking”.

at the end of the questions served as a guide as to the level of details students were expected to provide in their answers. To encourage students to attempt the practice exercise, bonus marks constituting 10% of the actual assignment were given for the practice assignment. After the exercise, a 1-hour session during a lecture was used to explain what the key experimental data were that led the authors to their conclusions about how cyclin B1 was imported into the nucleus.

Graded Assessment on p27 nuclear export

In the actual assignment, students were asked to read an article (Connor et al., 2003); Table 3) and write an essay to explain how a cell cycle regulator (p27) could be degraded in the cytoplasm when it is normally observed in the nucleus. No mention was made on the fact that in early G₁, p27 was transported from the nucleus to the cytoplasm where its degradation occurs. Students had 2.5 weeks to write a 1000-word essay in their own words using relevant experiments in the article that would support the authors’ idea of how p27 degraded. The students had to put their essays through Turnitin to ensure that they did not lift more than 25% of their essays from articles. To help students plan for their essays, pointers were also provided on how to write an essay (Supplemental 2). The assignment took up 20% of the final module scores for the students.

Feedback to students on their essays

To provide feedback to the students, the scripts with comments and grades were uploaded onto IVLE to students individually. I provided comments on how the students could explain the idea of p27 nuclear export by substantiating their assertions based on the experiments described in the article and how some of them could improve upon the organisation of their essays. I also suggested how they could include constructive criticisms of the experiments in the article. The scores for the students followed a normal distribution (data not shown). There were no failures except for a few students who did not turn in the essays.

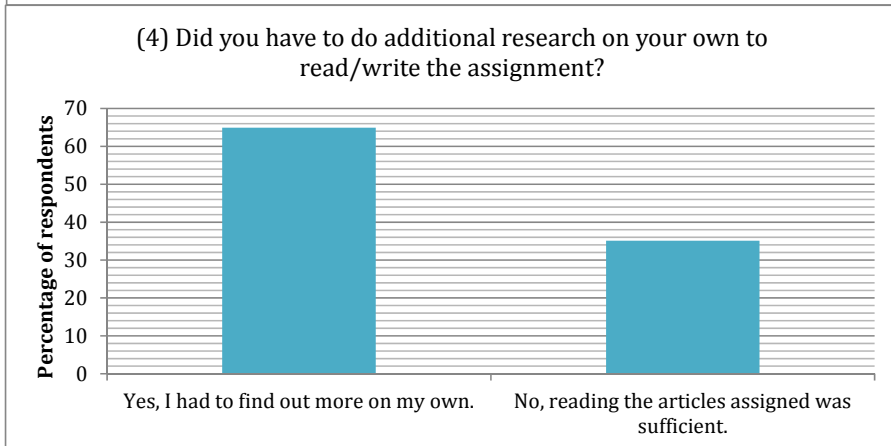
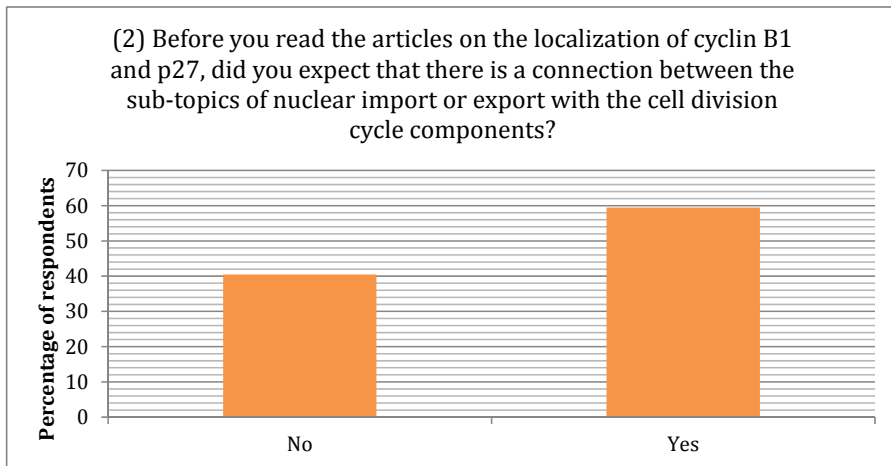
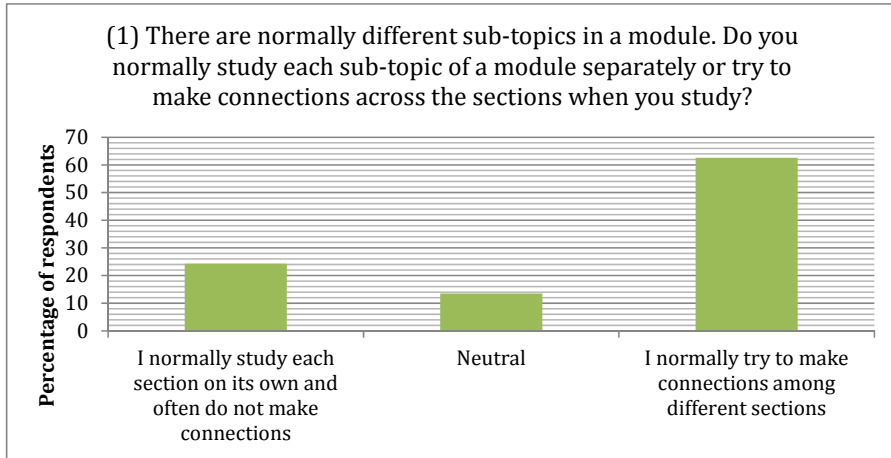
After the scripts were returned, I explained in a 1-hour lecture session how the various experiments in the article supported the main ideas proposed by the authors on p27 localisation and degradation. The key idea of p27, a cell cycle regulator itself regulated by nuclear localization, was emphasised to the students to highlight to them the need for students to make connections across sub-topics to have a holistic understanding of Cell Biology instead of studying topics in isolation.

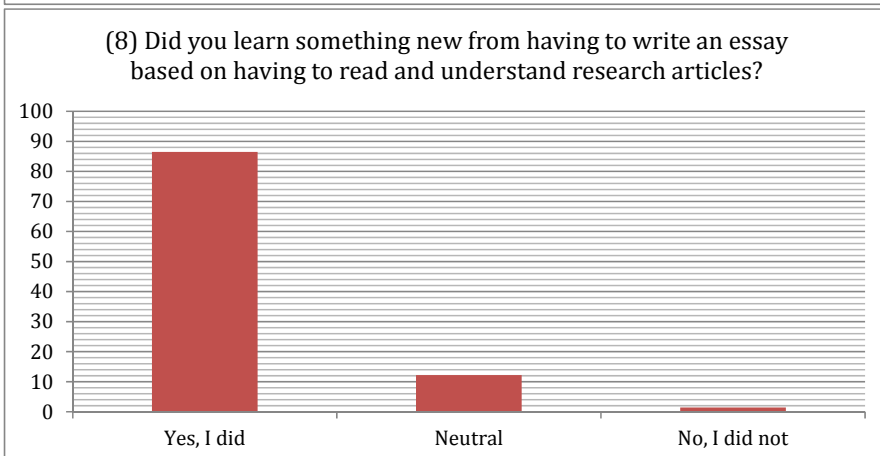
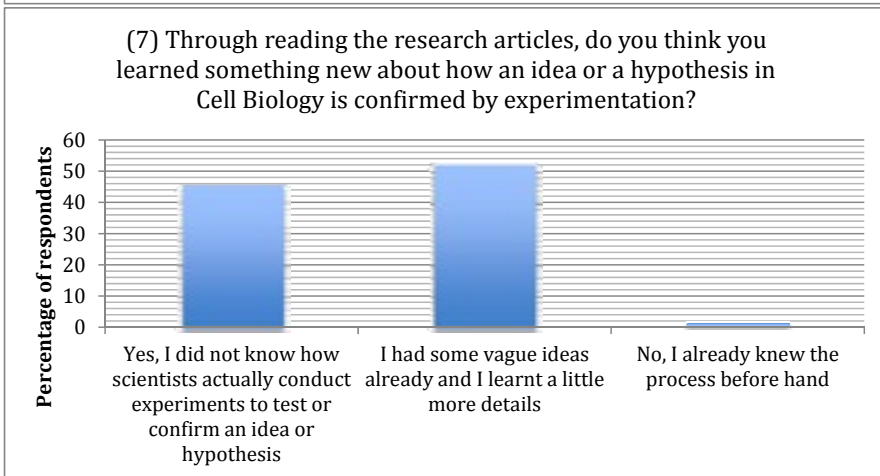
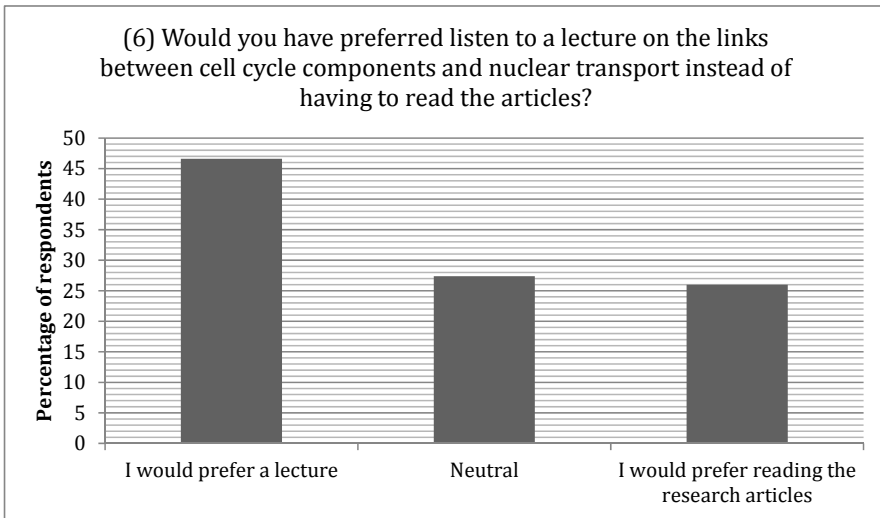
PRELIMINARY OBSERVATIONS***Student survey on assignment based on reading articles as form of assessment***

At the end of the semester, a survey (www.surveymonkey.com) was administered to students to gather students' opinions on the assignment anonymously (Table 4). As only 26% of 280 students from the class responded (Table 4), the feedback could only be taken as preliminary information for use to improve upon assignments in subsequent semesters.

About 24% of the respondents indicated that the assignment did focus their attention on ideas across two topics; with 40% of the students not previously expecting that cell-cycle components might be regulated by sub-cellular localisation. Generally, the students thought that this was a good exercise, although comments such as “time-consuming” were common, as they had to do extra reading on their own (Table 4). The assignment appeared useful in getting students to read up more on various aspects of cell biology such as nuclear export and cell cycle regulation and on technical approaches used in scientific experiments that they otherwise would not have read. This was a positive aspect of the assignment as most students in previous semesters relied on just my lecture slides with very few students actually reading the recommended course textbooks such as the *Molecular Cell Biology* (Lodish et al., 2007) (anecdotal evidence from my previous conversations with students).

Table 4. Survey data





5. If possible, give an example(s) of what you searched using Pubmed etc.	
Answered	37
Skipped	37
Examples of comments:	
<p>I generally searched for topic of interest e.g. nuclear export of p27, and read articles with regard to the import/export to try to get a better grasp of the bigger picture. p27 localisation and regulation.</p> <p>I used ScienceDirect instead of PubMed to search for additional information.</p> <p>Related work, to determine future work or whether the conjectures found in the papers were finally proven in recent works.</p> <p>I did a bit of googling to find more layman explanations for some of the jargons in the paper.</p>	
n = 74	

9. Comment briefly on what you think you learnt (if at all) from writing the essay based on the reading of a research article.	
Answered	47
Skipped	27
n = 74	
Examples of comments:	
<p>The concepts became more clear and I think I will remember it for a longer time. It's a much better approach than memorizing.</p> <p>Giving us individual comments. Extremely helpful.</p> <p>How to read a paper</p> <p>Analysis is key, because typical exam questions lack the opportunity for us to make original analysis</p> <p>Learnt to interpret data and results from experiments conducted</p> <p>Key ideas pointed out in the readings help to strengthen to concepts learnt during lectures.</p> <p>How experiments are carried out and conclusions are researched in a scientific manner.</p> <p>I know of the different techniques to test the hypothesis</p> <p>At least I appreciate reading research articles that I would not read if not compulsory. Techniques learnt before either in the module or high school were used by the people doing the research paper; this tells me that what we learn in school were actually used in real life-application by scientists. Research articles gave great insight into how scientists come up with hypothesis and their thought processes.</p> <p>I think I did learn a lot by reading the article by myself. I think writing the essay is a good way to consolidate what I had read and put it into words. It's like a check to make sure that I can reiterate what I had read to confirm that I had understood the content.</p> <p>Better understanding on how results came about.</p> <p>I really learnt how to read an article, the experimental steps and writing comments on an article. I never know papers need to include so much details and this will really help me eventually in planning for my own research. I must admit I absolutely hated the assignment, but I have to say it is those tough assignments that allow us to learn the most.</p> <p>I understand the scientific process of testing hypothesis and acquiring knowledge better now.</p>	
n = 74	

10. Any other comments (if at all) on reading a research articles as part of the learning process at the tertiary education level.		
Answered	47	
Skipped	27	n = 74
Examples of comments:		
<p>Important! To know what really goes on in research instead of having someone just telling us.</p> <p>Definitely an essential skill. I am glad that this was implemented at the level 2 module. Usually essay writing and research article reading assignments are implemented only at level 3 and 4 modules. The early exposure and training has allowed us to be better prepared and a little exposure on what it means to conduct research.</p> <p>It would be definitely useful for us when we are doing our final year project.</p> <p>An interesting part of university education, which is different from all the rote memorization just for tests and quizzes alone.</p> <p>Reading of academic papers should be done as often as possible, especially with the varying writing styles of different authors, for us students to learn to grasp the main concepts quickly as well as to get some ideas on how to write them as we form our own writing style.</p> <p>Good. Not everything depends on exam grades.</p> <p>I do feel that this is more independent learning, which should be the dominant form of education at a tertiary level. Many overseas universities are adopting such approach and are producing students who are excellent researchers and problem solvers. However, this approach will need more time on the student's side, which often, NUS students tend not to have time as the modules in NUS are often very fully packed as compared to overseas universities. Different approach I guess?</p> <p>I think reading journal or articles is outmost important for a science students especially for life sciences students. This is because a lot of theory or hypothesis were derived from experiments. Therefore, reading the original articles can help students grasp and comprehend the ideas and concepts better.</p> <p>Integrating the research paper reading into modules is a good way to encourage the students to read research papers as students usually don't like to read research paper and find them boring or difficult to understand. Having said that, reading research paper is very challenging if unguided because students have very limited knowledge on a lot of research techniques and principles behind it, unless the students have experiences in research through UROPS or FYP.</p> <p>I think reading research articles might help in giving practice to understand the mode of communication in the scientific community, but to evaluate students based on an essay written on the basis of reading research articles is not really a good gauge of student's understanding, or a good method to grade students' ability.</p> <p>Had a really really hard time reading, and each time I did, I felt like giving up! It often takes quite a while to fully understand and process the articles.</p>		

When students were queried about whether they learnt more through reading the articles, at least 53% indicated that they learnt something new compared to what they previously knew, such as the scientific process (Table 4). This sentiment was consistent with previous studies (Smith, 2001; DebBurman, 2002; Mulnix, 2003; Coil, Wenderoth, Cunningham, & Dirks, 2010) and could mean that the approach was a step towards getting students to understand the nature of scientific knowledge that might eventually translate into their overall learning of science (DiCarlo, 2006).

When polled whether they would prefer to listen to a lecture on the links between nuclear transport and cell division than find out from reading scientific articles, 47% of the students said they would prefer to listen to a lecture (Table 4). Interestingly, when asked to write down qualitative comments on the assignment, the students were generally positive about learning something new while doing the exercise of reading primary literature (Table 4). There were also several students for the idea that such an exercise should be continued. Quite a few commented (Table 4) that the skills gained from reading primary research articles could begin at the second year and not at the third year, so that they might gradually learn to be better at it by the time they were in their third year when most modules would include the reading of primary literature and fourth year when they were to take up a final year research project.

Indeed, a study (Kozeracki, Carey, Colicelli, Levis-Fitzgerald, & Grossel, 2006) indicated that increased exposure to primary literature has benefits to students in terms of confidence in dealing with actual scientific data and improves scientific literacy that would help students planning on pursuing post-graduate studies. A few students were surprised they were able to read primary articles and felt no longer intimidated by them (Table 4), which was similar to the findings of a study on the use of primary literature (Smith, 2001; DebBurman, 2002; Mulnix, 2003; Coil, Wenderoth, Cunningham, & Dirks, 2010). So while the students preferred listening to lectures to learn, the fact that a good number indicated that they learnt more about the process of scientific enquiry, could imply that the approach was a useful way of getting students to learn more on their own.

PERSPECTIVES

Previously, the students were told directly in a traditional lecture that the cell cycle regulators could be controlled at the level of sub-cellular localisation. This present approach of enabling students to find the links for themselves between different cellular processes using the reading of primary literature was a departure from the previous semesters and provided students the opportunity

to be exposed to research articles that could enrich their learning experience (DeBurman, 2002; Hoskins et al., 2007; Gillen, 2006).

There were several areas that could be improved upon in this exercise. For example, the time frame during which the students had to write the essays as well as the time for grading and commenting on the essays was short. The assignment could be given out earlier during the module so that students have time to think through the topics and plan. It took me about 2 to 3 weeks to grade these essays, which was rather tight given that it was near the end of the semester. A rubric with specific details pertaining to the aims of the exercise (Allen & Tanner, 2006) for grading could be used as reading a scientific article is relatively new to students. This might reduce some uncertainty as to what it is that is required of them that could have been an unnecessary distraction or frustration.

Furthermore, it would be important to understand the reasons behind the apparent contradiction between the students' preference to listen to a lecture on the topic and their indication that they learnt new things from the reading and writing assignment. A possible reason could be the large class size and less than homogenous background among students. Also, a student suggested this was due to time constraints in reading the article and writing the essay (Table 4). One way to address this is to cut down the details taught in this module and focus on fundamental content and analytical skills that are more relevant to students in the long-term (DiCarlo, 2006).

More importantly, the effects of this assignment on student performance could be studied in subsequent semesters, with similar assignments. For instance, although students stated that they learnt more about the scientific process, pre- and post-test questions relating to the scientific method could be given to students at the beginning and end of the module to directly assess if indeed the approach served to highlight various aspects of the scientific process not previously clear to students (Hoskins et al., 2007). Also, to ascertain if reading primary literature followed by essay-writing helps students gain content knowledge and analytical skills, one could include exam questions that test these abilities. The students' answers could then be compared to those from students taught by different lecturers in a different semester who are not doing the assignment.

Nonetheless, given that this was an open-book assessment, it served as a useful tool to compliment the traditional mode of teaching and assessment by closed-book tests that might motivate students differently (Gibbs & Simpson, 2004). Although such an approach took more time in terms of setting up and explaining the assignments, together with the fact that reading primary literature could engage higher order cognition (Crowe et al., 2008), the open format of the

assignment that allowed students to find out more outside the lecture theatre (Table 4) could promote a more constructivist mode of learning (Lord, 1997) that should be more beneficial than for students to receive content directly from me during lectures (Crowe et al., 2008; Wood, 2009; Gillen, 2006).

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Supplemental 1

LSM2103

2011/2012 YFM

How to read a paper – Part 2

For those who need some guidelines on what to look out for in a scientific article, you might want to consider the several of following points as you read the articles:

- What is the hypothesis that the authors were testing?
- What techniques were used in the study?
- What are the (dis)advantages or suitability of the techniques used?
- How were the key experiment(s) performed?
- What were the important observations made?
- What were the main conclusion(s) made by the authors arising from the experiments?
- Did the conclusions answer the questions raised in the authors' hypothesis?
- For those who read widely, did the findings from the paper contribute new and interesting ideas to what is currently known in the field?

Supplemental 2

LSM2103

2011/2012 YFM

How to Write

For those who need some guidelines on how to write a scientific essay to answer a question based on an article or others who need to review an article, the following points might be useful for you to consider as you plan your writing (yes, planning* is needed before writing):

- An introduction to give a brief overview of what is known about the subject matter.
- State the key issue(s) you want to focus on.
- Explain what hypothesis the authors of the article proposed to test. Describe the approach taken by the authors.
- State the data obtained by the authors.
- State the conclusions drawn by the authors based on their interpretation of their data.
- Evaluate the article in terms of
 - o The hypothesis - Comment on the relevance of the hypothesis in the context of the knowledge at that time.
 - o Technical quality:
 - was the approach taken good?
 - were there positive and negative controls in the experiments performed?
 - were the data clear - Eg bands on a western blot clear or ambiguous?
 - Consistency within the article - Eg how large were the error bars in a graph? Any statistical analysis performed? Significance values?
 - o Consistency of the data in this article compared with what is known from other reports – this is more likely to be important when you do your UROPS or Hons project and are writing up your literature review, when you will be reading more than one article.
 - o Did the authors make the right conclusions based on their interpretation of their own data?
 - o Did the data answer (or not) the questions /hypothesis raised by the authors?
- Discuss briefly whether you agree with their conclusions based on your examination of their data.
- Conclude with a statement on what you think overall of the article.

Note that **not all the points are applicable to all your essays** as it depends on the situation when you are asked to write the essay.

Also, the **organization could be different from what I listed above** depending on **your own preference and style of writing**.

*use a Mind-map, a scrap of paper or any other media you prefer, BUT do have an outline to organize your thoughts before banging away at your computer to type out your essays.