Tell Them or Show Them? How to Improve Science Students' Skills of Critical Reading.

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Abstract

Short sessions are commonly offered to improve specific learning skills of tertiary students, but their effectiveness is seldom assessed. We tested the effectiveness of a short session (1-2 hours duration) demonstrating how to critically read a journal article to improve the critical reading and writing skills of postgraduate science students. The effectiveness of this intervention was then measured by students' performance of critiquing scientific journal articles. Students critiqued one article before and one following the training session in a crossed, before-after-treatment design, with half the students writing a critique of Article A first and the other half writing a critique of Article B first. Following the teaching intervention students switched articles for the second critique. Two markers carried out scoring of critiques, each blind to the identity of students and whether the work was completed before or after the intervention. Thirteen (Marker 1) and 12 (Marker 2) of the 18 students scored higher for the second critique. Students with the lowest initial grades showed the greatest improvement. Our results show that a one-off, short skills intervention, can improve critical reading skills when compared to the more common practice of providing written instructions or guidance.

Introduction

Critical reading and writing are essential skills for university study (De Avila & Torres 2010; Loveland-Cherry, Bearinger & Taliaferro 2012; von Lacum, 2009). By graduation, students are expected to have developed "the ability to read complex and demanding texts accurately, critically and insightfully" and to have "the ability to think critically, to analyse and evaluate claims, evidence and arguments, and to reason and deploy evidence clearly and logically" (James Cook University's Graduate Attribute Statement http://www.jcu.edu.au/policy/allatoh/JCUDEV_007031.html accessed 21 January 2013). Thus, these skills should be well developed amongst postgraduate students, but it is common to hear academic supervisors or thesis advisors lament that students do not show the required critical analysis in their writing (Clarke, Schull, Coleman, Pitt & Manathunga, 2011). Lack of this ability invariably results in written work of a low standard. Weak writing often reflects basic problems related to poor interpretation of source material and lack of clarity in a student's thinking and understanding (Hall, Hawkey, Kenny & Storer 1986; Thomas 2001). Academic skills programs aimed at improving students' writing tend to focus on flaws in grammar, paragraph structure and expression, while the more basic association between poor writing and poor reading comprehension is more difficult to diagnose and to correct via teaching interventions.

Writing a critique of a journal article can be particularly challenging for many students, as the task demands well-developed skills for critical reading (Dobson & Feak 2001, p. 187; O'Regan & Johnston 2001; Woodward-Kron 2003). Yet, in spite of its intrinsic importance, students rarely receive guidance on how to critique an article beyond a set of

questions or instructions to guide their reading (Ingham –Broomfield, 2008; du Prel, Rohrig & Blettner 2009).

Universities offer a range of programs to teach students necessary study skills in a variety of formats including semester long subjects, workshops of various durations and, more recently, online support. A common practice is to offer written resources or a one-off short course or workshop. Brief, 1-2 hour courses or workshops (referred to as 'sessions' in our work below), usually in the form of a lecture or tutorial, are appealing because their short duration means that subject coordinators may be more willing to incorporate a 'study skills session' as part of a subject's lecture timetable or such short courses can be made available by universities' central study skills units several times a semester if required. The former delivery mode has two very important benefits: 1) the skill is taught using discipline-specific content, thus maximising the effectiveness of the approach (Cotterell, 2001; Garside, 1996; O'Regan & Johnston, 2001; Pithers & Soden, 2000 Wingate, 2006) and 2) it reaches a larger number of students than specific "extra-curricular" study skills courses as many students, often those most in need, tend not to attend the not-for-credit courses offered by central study skills units.

Despite the recognised need for evidence-based approaches to improve teaching and learning (Moran & Malott 2004), the effectiveness of teaching strategies for general study skills remains under-researched (Gettinger & Seibert 2002; Hadwin & Winne 1996). In particular, there is a paucity of studies that evaluate the effectiveness of targeted interventions aimed to enhance specific study skills at university level. Limited evidence from specialised disciplines, in particular medicine and nursing suggests that such interventions can be effective: Lee, Joynt, Ho, Gin, and Hazlett (2007) found that the percentage of medical students improving their test result was 16% higher in the group that attended an intervention program consisting of three lectures and two workshops, compared to a control group that had not. However, other studies are inconclusive as shown for example by that of Miller and Mount (2001), where a two-day clinical workshop resulted in short term improvement in motivational interviewing skills of counselors although this improvement was not reflected in the clients' responses. While advice for students and instructors on how to approach critical reading is found in abundance (Clarke, Schull, Coleman, Pitt & Manathunga, 2011; du Prel, Rohrig & Blettner 2009; Ingham –Broomfield, 2008; Harris, 2006; Smallbone & Quinton, 2011, and many others) the efficacy of the interventions provided or tools made available have seldom been evaluated.

A research-intensive university, James Cook has a large annual intake of postgraduate coursework students and many of these have ambitions to progress to higher degree research studies. The increasingly strict time limits on postgraduate candidatures places strong incentives for the effective and efficient acquisition of the skills required for the critical reading of the scientific literature. For some years one of the authors (LC) has been using a cognitive modeling approach (Gettinger & Seibert, 2002) where in a single, 90-minute workshop, she demonstrates the skill of critical reading by showing students (i.e., thinking aloud) the thinking process involved in the critical reading of one specific journal article. Considering the importance of postgraduate students being able to critically read the scientific literature (Smallbone & Quinton, 2011), we sought to evaluate the effectiveness of this intervention.

Because of the scarcity of information pertaining to the effectiveness of interventions aimed at improving students' critical reading, especially in the context of the natural sciences,

our specific aim was to test the effectiveness of a short (90 min) demonstration session, embedded in the teaching timetable of a subject, to teach the skills of reading a journal article and subsequently writing a critique. We posed the following research question: Do students' grades for critiques improve following the attendance of the demonstration session?

Methods

Experimental Design

Participating students were enrolled in either a postgraduate coursework program or in one of the Bachelors Honours programs in the School of Earth and Environmental Sciences at James Cook University. These students were required to take an introductory Research Methods subject coordinated by the senior author.

The design of our study consisted of comparing students' scores for article critiques before and after a short demonstration of the relevant study skills. During the fifth and eighth week of a 13-week course, students were required to write critiques of two selected research articles, designated here as article A and article B. The scores for the two critiques contributed 10% of the final grade for the subject. Before writing the first critique in week 5, students were provided by standard instructions given for this type of assignment (Appendix). Students had two weeks to complete the work. They then attended a 90-minute session that demonstrated the skills for the critical reading of a scientific research paper using a third, unrelated article (see details below). In week 8, students critiqued the alternate article. The guidelines were the same as for the first assignment. To differentiate between the effect of the demonstration session and the effect of the differences between articles A and B, (and to ensure that staff marking the critiques were blind to which submission was written before and after the demonstration session) half of the students, selected at random, were asked to review Article A first (Group A) while the other half reviewed Article B first (Group B). Following the demonstration session the students who had critiqued Article A first were given Article B and *vice versa.*

We choose articles A and B because they were relevant to the students' major discipline (environmental science) and because they had strengths and weaknesses that could be identified without being familiar with the narrowly focused subject matter of the articles. Although different in subject matter, we considered the two articles to be similar in their level of difficulty in terms of theoretical content, experimental approach, and complexity of language.

Marking the Critiques

To account for the variation between markers, (referred to as Marker 1 and Marker 2 throughout the study) the two authors marked critiques independently and the results are presented separately for comparison. Marker 1 is a learning adviser specialising in the teaching of study skills with prior research training in a related discipline, and Marker 2 is the coordinator and main lecturer of the subject. Critiques were all marked within a short period following the submission of the second assignment. Each critique was coded by a random number so that the markers were blind to the identity of the student and to whether a student critiqued article A or article B first.

Assignments were awarded marks for two groups of criteria: "Elements of content" (which focused on the student's analysis of the scientific information in the article - 60 points) and "Elements of style" (which focused on the structure, grammar and clarity of argumentation of the critique - 40 points). Students were given the marking scheme prior to

the first assignment. We assigned the grading breakpoints as used in the Faculty of Science and Engineering at James Cook University and many other Australian tertiary institutions (i.e. Fail <50%, Pass 50-64%, Credit 65-74%, Distinction 75-84%, High Distinction 85-100%).

Students were told about the research from the beginning and asked to sign an informed consent form, agreeing to voluntary participation. Only students who attended the skill session and handed in both critiques were included in the study.

The Demonstration Session

The session was designed to demonstrate the process of reading a scientific article to students, focusing on the way the reader (LC) approached the article used for the demonstration. Students were asked to read the article before the session and were encouraged to participate by being invited to ask questions at any time. The demonstration article was chosen because 1) it was short, 3 pages, so the probability that students would have read the article before the session was high, thus maximising the benefits of the session; 2) it had the classical format of a scientific research article, with Introduction, Methods, Results and Discussion sections; 3) it did not use complicated terminology and methods so it was easy to read, and 4) it had some important flaws as well as good points.

The session was based around a presentation of 32 slides. The first two slides stressed the importance of critical reading of scientific articles in general and presented the objectives of the session as mentioned above. Slides 3-25 analysed the article being reviewed, using as a basis the written guidelines given to students before their first critique (Appendix). Briefly, the stated objectives of the study were identified, experiments were analysed only to the point of evaluating elements of experimental design (i.e., presence/absence of appropriate controls, identification of sample sizes), results and interpretations were identified and checked for correspondence with original objectives, studies that were cited for comparison were assessed for relevance, and acknowledgement of limitations of the study by the authors was identified. In order to show students the attitude of the reader to the text, extracts of text were shown alone first and then with annotations such as would be made by a reviewer in the margins of the article. The analysis of the Discussion briefly included identifying and assessing support for arguments and the validity of comparisons to other studies. Slides 26 – 32 concerned the writing of the critique and stressed the following points: a) the need for clear identification of the article; b) presence of an identifiable summary that provides a brief but full account of article (i.e., including main objective, methods, main results, main conclusion); c) summary and evaluation should be distinct and not overlap; d) evaluation by clearly highlighting both positive and negative aspects; e) the correspondence between initial objectives and conclusions; and f) inclusion of an overall assessment of the article based on written critique.

Before the session, students were asked to write a paragraph giving their general impression of the article stating how readable it was and whether there were any positive or negative points they wanted to highlight. The purpose of this step was to get a general impression as to how critical the students had been while reading the article before exposure to the lecturer's demonstration. Fourteen of 19 students present (74 %) found the article well written and easy to understand, three students did not comment on the writing but focused only on the content, and two found the article "difficult to follow". In terms of scientific content, nine (47%) students had only positive comments to make, while 10 students (53%) made some negative comments, though nine of these were expressed very generally and only one student clearly identified some of the main flaws of the article. Given that the article had some important weaknesses in its scientific content and approach, this questioning showed

that a large proportion of the students had not identified these in their reading, or had not recognised the significance of the flaws in terms of the overall quality of the article. This confirmed that the article was appropriate for the demonstration. Although we did not ask for written evaluations of the session, the informal feedback was that students found it very useful and had been unaware of many of the issues that were raised.

We purposely avoided giving students a written model critique of the demonstration article because we wanted to test the effect of the session alone, and this could have been confounded if the students had a model to follow in their second assignment. For the same reason, students did not receive feedback on their first critique until the second assignment was submitted (also see section above). These two conditions were essential for the validity of the study.

Data Analysis

We used paired t-tests to compare the scores before and after the session, testing the null hypothesis that students' scores for the second critique were not higher than for the first one. Pairs of before and after scores of the two student groups were analysed separately.

To further investigate if the session specifically affected the critical attitude of students as readers, Marker 1 performed a fine-scale evaluation of each critique in three domains contingent on reading the article with a critical approach: (1) level of support students provided for the claims they made about the article, scored semi-quantitatively, 2) identification of methodological problems, scored quantitatively and 3) linking methodological problems to the overall quality of the study, scored semi-quantitatively.

Results

Comparison of Scores and Grades before and after the Session

Eighteen students met the criteria for inclusion in this research (19 attended the session but one failed to submit by the due date, and 2 did not attend the session).

Independently of which article was read first, most students obtained a higher score with their second critique (72% of students for marker 1, n=13, and 67% Marker 2, n=12). Overall, for Marker 1 and 2 respectively, 11 and 10 students scored more than 5 points higher in the second critique than in the first, while only 1 and 3 students scored more than 5 points lower in the second critique than in the first. For the rest of the students, scores for the second critique were within 5 points of the first critique (Figure 1). There were however some differences between markers and between the two groups of students.

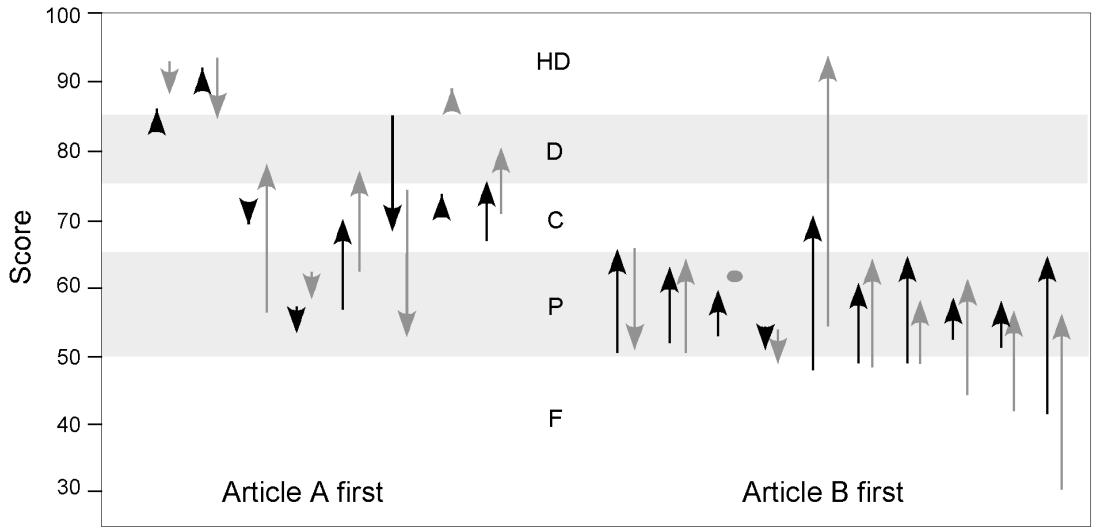


Figure 1. **Student scores before and after the teaching intervention. Pairs of arrows represent individual students. Start of arrow shows score obtained for first assignment, point of arrow shows score obtained for second assignment. Marker 1 dark arrows, Marker 2 grey arrows. Alternating horizontal bands indicate grades awarded based on scores (F=fail, P=pass, C=credit, D=Distinction and HD=high distinction). Oval symbol for the third student critiquing article B first indicates identical scores by Marker 2 for both assignments.**

Variability between markers.

For the two markers, the direction and magnitude of change between the first and second critiques were both remarkably similar (paired t-test p (two tail) = 0.55 n=36 (Figure 1). There were, however, two noteworthy divergences in scores: For the third student in Group A the score of Marker 1 changed little between the first and second critique but Marker 2 considered the second critique markedly better than the first and for the first student in Group B the magnitude of change was similar but in opposite directions. Considering that neither marker was aware of students' identity or the submission order of assignments, and that marking was against a rubric with identical assessment criteria but performance indicators developed specifically for each of the two articles, the observed scoring anomalies only highlight the real, but contentious issue of error variation in the grading process (Hanlon, Jefferson, Molan & Mitchell, 2005).

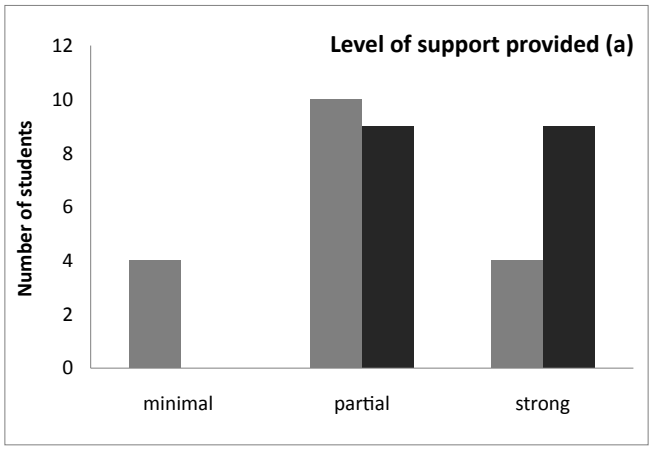
Variability between groups.

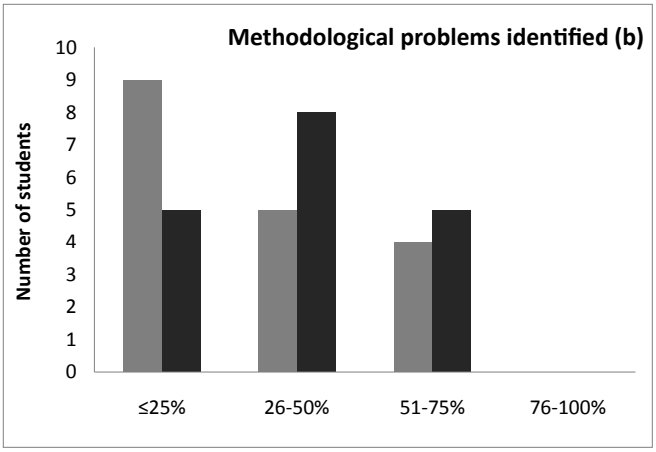
The proportion of students gaining a higher score on the second assignment differed markedly between the two groups of students. For Group A, five students (63%, Marker 1) and four students (50%, Marker 2) obtained a higher score for the second critique, whereas corresponding numbers for the Group B were nine students (90%) for Marker 1 and seven students (70%) for Marker 2 (Figure 1). The change in scores between the first and second critiques for the two groups of students was significant for Group B (one tail t-test, p=0.0003) but not for Group A (one tail t-test, p=0.375). These results, combined with the observation that students in Group A gained higher scores even in the pre-intervention assignment than students in Group B (p=<0.001, mean score first assignment, markers 1 & 2; A=73.7%, Group B=49.7%), prompted us to examine if the two groups differed in their academic ability. We thus calculated the mean Grade Point Averages (GPA, range 1.5-7) for the two groups, and found that they were significantly different (GPA 6.0 ±0.2 SE for Group A, and GPA 5.0

±0.2 SE for Group B, t test p<0.001). Although students were assigned to the two groups 'randomly' it is not unlikely that they should differ in academic ability[1].

Scores on assessment criteria contingent on critical reading

Marks for three domain-specifically dependent critical reading skills all improved after the demonstration session. Ninety-four percent of students provided partial to strong support for their own claims in their second critique, compared to 66.7% in their first critique (Figure 2a). Fifty percent of students identified at least a quarter of methodological problems in the first article that they read, increasing to 72% in the second critique (Figure 2b), and the proportion of students who showed at least some ability to extrapolate methodological problems to the quality of the overall study improved from 28 to 44% (Figure 2c).





[1] When selecting at random from a pool of 18 students a group of 8 (Group A) and a group of 10 (Group B), the chance that there will be an average of 50% more 'above average' students in group A than in Group B is about 21%. (Result of a Monte Carlo simulation by BG)

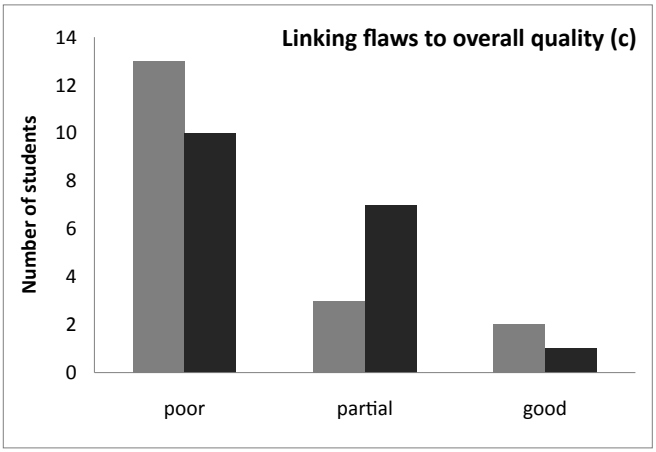


Figure 2. **Improvements in the results for the three domains closely linked to the critical reading of journal articles. Pale bars show critiques submitted before demonstration session, dark bars show critiques submitted following the demonstration session. (a) Level of support students provided for their claims made about the critiqued article; (b) proportions of methodological problems identified in the critiqued articles; (c) degree to which students linked the methodological flaws identified to the overall quality of the critiqued article.**

Discussion

The results obtained in this research give us confidence to continue with the demonstration sessions for improving students' skills of critical reading and writing. The proportion of students whose marks improved ranged from 50% of the students in a group (4 students in the Group A when assessed by Marker 2) to 90% (9 students in the Group B when assessed by Marker 1). Students demonstrated pronounced quantitative improvement in all three fine-scale indicators of critical reading of research articles.

The two groups of students responded differently to the demonstration session: Participation benefitted more students, and to a greater extent, in Group B than in Group A. These results can be explained by the identified differences in academic ability between the two groups of students. Group A had a significantly higher GPA than Group B indicating higher overall academic achievement. Furthermore, Group A students achieved higher scores in the first assignment than in Group B students, with several students in Group A scoring relatively highly in their first assignments, leaving little "room" for improvements in the second assignment. The group with the lower GPA (Group B) showed the greater response, suggesting strongly that the demonstration session was more beneficial to those students starting out from a lower skill base. This interpretation is further supported by the observation that most improvements in grade between the first and second critiques involved students receiving the lower grades for the first assignment (fail to pass or pass to credit). Tan et al. (2011), in a similar crossover experimental design investigating the effectiveness of team-based learning in clinical neurology, found a larger effect amongst weak students and called for corroboration by further studies. The present study thus strengthens the conclusion that teaching interventions that foster greater engagement – that is, team based learning as in the study of Tan et al. (2011) or an interactive demonstration session as in our present study, benefits weaker students more than academically strong students.

In this study we used learning outcome measures to test the effectiveness of a teaching intervention to improve students critical reading skills. This approach has been

criticised, mainly because of the difficulty of accounting for the uncontrolled effects of student's individual characteristics and circumstances on their performance (Berk 2005; Fenwick, 2001). This caution is especially relevant when a comparison spans a relatively long period of time (for example over a semester or a year) and students are exposed to many other possible sources of learning. Our short term approach (over a few weeks) helped to minimise influences from other sources of learning and, although the variability among students is inevitable (but realistic, and teaching interventions, if they are to be useful, must "work" for groups of varied individuals), we examined individual student's performance in a paired before/after treatment design, and we showed that demonstration of the critical reading skill is more effective than providing written guidance for the same skill. The poorest performing students benefited the most from this intervention, and those students already doing well on the first assignment showed relatively little change in their mark/grade (with the exception of the sixth student in Group A for both Markers).

This study had several limitations, but these do not detract from the overall findings. This research suffered from a relatively small sample size and even randomly chosen groups may differ substantially by chance when the sample sizes are small. Although the experimental design could have been improved by having a control group of students not attending the demonstration session, this was not possible for ethical reasons. On the other hand the chosen experimental design has fortuitously demonstrated the significance the between group variation of the effectiveness of a teaching intervention, that is not uncommon in smaller, postgraduate classes.

Finally, our study would have benefited from a debriefing discussion to seek students' perceptions of how the session did or did not help them with the task of reading an article and then writing a critique. It is likely however, that the timing of such a discussion (that is, before or after the release of the marks) and the direction and magnitude of difference in the marks received for the first and second assignment would have influenced students' opinion of the usefulness of the session and thus a comparison of performance may be a more reliable indicator of the value of the short demonstration session when compared to the provision of written instruction or guidance.

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Appendix 1: Guidance given to students prior to the completion of the first assignment

How to write a critique of a scientific article

For reading:

After you have read the article once, read it again as you try to answer the questions below. They are to guide you through the type of information you need to search for as you read. Do not be surprised if you need to read the article several times.

1. What was the objective of the study? Is there a set of questions?
2. Is there a hypothesis(s) clearly stated? If yes, which one? If not, can you deduce it?
3. Do the authors explain why is the study important?
4. Are there any concepts defined? If yes, which ones? Are these definitions clear to you?
5. Do you find the information given in the introduction directly relevant to the main objective of the study? If your answer is no, write down which parts are not relevant and why.
6. Do the methods provide enough information if you wanted to duplicate the study? If not, what is missing?
7. Are the methods all relevant to address the questions of the study?
8. Do you see any problems? (Check for assumptions, sample size, experimental design. Note if you can actually determine these things from your reading).
9. Is there a clear statement of how the data were analysed?
10. Are there any limitations of the methods addressed by the authors
11. What are the main results as stated by the authors?
12. Check the data presented (in figures, tables or in the text). Do you agreed with the authors?
13. Do the results correspond to answers to the questions proposed in the introduction?
14. How are the authors interpreting the results? Do you agree?
15. How do the results compare to those of other studies? (The discussion should present the results in view of other studies). If different, are the authors providing possible explanations?
16. Is the interpretation of results generalised beyond the system studied? Do you agree?
17. Do the authors discuss any problems in their study? Do you think there are any?
18. Does the discussion answer the questions posed in the introduction?
19. Is the article providing a significant contribution to scientific knowledge?

For writing:

1. Identify the article your are reviewing
2. Provide a short summary outlining the article, its main purpose and main argument or conclusion
3. Provide your analysis of the article. Remember that this should include strengths as well as weaknesses.