# JOURNAL CLUB:
## *A Forum to Encourage Graduate and Undergraduate Research Students to Critically Review the Literature*

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New faculty encounter challenges as they strive to set up their research lab and start a research group. Familiarity with current literature is crucial to conducting sound research, and including a formal education in this aspect of research can be beneficial to graduate research students and concurrently guide the research group's publishing goals. The involvement of undergraduates has the added benefit of encouraging these students to pursue graduate studies in engineering.[14] It should be noted that a previous version of this manuscript without the assessment component was published in the 2006 ASEE conference proceedings as paper # AC 2006-2663.[1]

The training of students in advanced research is by nature mostly experiential; the inclusion of strategic instruction varies considerably. Most advisors train their students with the same methods by which they were trained, with slight modifications and adaptations. Experiential training in the laboratory can include demonstration strategies such as having students watch difficult procedures three times then repeat those procedures three times under supervision before conducting the procedure independently. Mentoring has received attention recently including publications from the Howard Hughes Medical Institute[2] and the National Academy of Science.[3] Some aspects of the training of students in research are not typically done in a strategic fashion, however. Reading, understanding, critiquing, and assimilating facts, suggestive data, and theories from the literature is a skill that students traditionally have had to "pick up along the way" during their research experience. Few have studied the process for how students approach literature reviews; those that have done so discovered it is an involved and iterative process.[4] This manuscript asserts that strategic instruction in this area leads to more productive research students sooner by counteracting literature lethargy, strengthening technical backgrounds, and bolstering the quality of research conducted in a lab group. A model of instruction is described and then assessed.

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While involving students in structured literature critiques is not widely practiced, it is not a new concept and has been found to be beneficial.[1, 5] Such structured guidance has been implemented for undergraduates in life sciences subjects,[6] hospital physicians and graduate students of molecular medicine, and first-year chemical engineering students.[7] Courses focused on research methods are becoming more common in a variety of fields.[8] Courses focused on written / oral communication skills include formal / informal seminars and written critiques by other students,[9] implementation of annual progress reports for graduate students,[10] research project driven writing for non-native writers,[11] mentoring relationships to improve oral and written proficiency of international graduate students,[12] and studio writing courses for undergraduate researchers.[13] Advice on conducting graduate seminars is available in *The New Professor's Handbook*, where the authors assert, "a seminar program can go a long way in helping graduate students acquire the knowledge and skills to become independent researchers."[15]

Academic research is a "publish or perish" type of environment.[16] Limited advice exists in the literature to help new faculty publish,[16-18] and this manuscript asserts that making manuscript writing and literature review an area of strategic instruction will increase the publishing productivity of a new faculty member's research group. Some articles provide strategic instruction for newer faculty on writing grant proposals and scholarly papers to persuasively communicate concepts and ideas in science and engineering.[16] Particularly prolific writers (in the educational psychology field) were interviewed on why they were so productive.[17] These individuals identified four categories including collaboration, passion / curiosity, research skills, and time management. Collaboration was identified as the most common attribute of prolific writers who collectively broke this into "mentoring received, mentoring given, collaboration with colleagues, and collaboration as feedback in the writing process." The passion / curiosity category revealed the variety of self-motivations of prolific writers. In the research skills category, four subareas were identified that included focused research in a given unexplored area of the field, knowing the literature, writing skills, and research management via thinking of new avenues of the research field to explore. Time management was the fourth most common attribute of prolific writers who worked to eliminate distractions so they could write, scheduled regular writing instead of sporadic writing, and forced deadlines to get the paper submitted.[17] The literature-review course described here is structured to directly teach a) collaboration between students in a research group as well as between the professor and students, b) increasing knowledge of the literature, c) writing skills, and d) deadlines. This Journal Club indirectly contributes to a) curiosity and enthusiasm in the research field, and b) research management by directly discussing new directions of research.

The Journal Club activities described have been run consecutively each semester for six years in one professor's research group comprised of graduate students on research assistantships, undergraduate students paid hourly, as well as a limited number of prospective students interested in the group's research. It was run as a weekly group meeting in 2004 and 2005; beginning in spring 2006, it was formalized into a one-credit-hour class with a department-approved syllabus, learning objectives, and formalized reports. Assessment of literature prowess was conducted at the very beginning of Fall 2008 (to catch Spring 2008 participants), as well as at the end of the Fall 2008, Spring 2009, and Fall 2009 semesters. Journal Club utilizes a discussion format, which is particularly beneficial for young researchers because it demonstrates and promotes practice of logic skills, critical thinking, and verbalization of ideas.[19]

This literature seminar provides a forum within which to a) mentor students to read, discuss, and understand papers in their research field, and b) discuss attributes of academia related to scholarly writing and publications. Two years of assessment data show that this structured approach decreases students' apprehensions and intimidation of technical literature and improves their ability to write and publish technical papers.

## STARTING UP THE WEEKLY LITERATURE REVIEW MEETINGS

The experiential advice provided has been developed during the author's six years as a tenure-track assistant professor and first half-year as an associate professor. The author's research group (and thus class participants) has been comprised of Ph.D. students, M.S. students, and part-time Research Experience for Undergraduates (REU) students on NSF- and DOE-funded research projects. The group has earned 18 awards at regional / national conferences, published 35 proceedings articles, one book chapter, and 11 archival journal articles in the last six years. The suggestions included herein are a culmination of strategies that have been most successful in mentoring neophyte researchers to obtain a satisfactory familiarity with the literature and in maintaining knowledge of more senior group members on the current literature.

When starting a formalized literature review session, it helps to clearly convey the purpose and importance of the activity. The following is an excerpt from the class syllabus:

> *"The purpose of Journal Club is to encourage everyone in the group to remain abreast of the literature. The discussion of articles tangentially related to your research will benefit you by increasing the breadth of your knowledge. Your depth of understanding and retention of articles in your own research area will increase as you practice and prepare for leading discussions. The discussion questions will increase the depth of your knowledge. In addition, your involvement in discussions will teach you to think critically and will aid in developing your own experiments and skills. More specifically, after completion of the course, you will be able to:*

- *Critically read current literature in electrokinetics and microdevices.*
- *Lead a discussion on a research article.*
- *Demonstrate the ability to adapt techniques from articles into your own lab work.*
- *Critique techniques and conclusions asserted in the literature.*
- *Conduct a literature search and obtain articles available on-campus and off-campus.*
- *Analyze data to determine trends and present this to the group.*
- *Compile a survey of literature on a subject and organize it for oral presentations, and*
- *Write a research article using your survey of the literature and the articles presented / discussed during the semester."*

Secondly, it is important to remain organized and to communicate well in advance the student's assigned article and presentation date. The author tried a number of approaches including a) student selection of articles, b) article selection throughout the semester, and c) professor-assigned articles. Article selection during a semester either by the professor or the student is not recommended because of high logistical overhead. The most efficient and effective approach has been to ask the students to conduct a literature search on a specified topic in advance of the first meeting of the semester. Each student brings their top five articles from this search and quickly summarizes the merits of the articles (based on reading the abstracts) for the group. The professor and students select the two or three that the student will present during the semester. By the following Journal Club meeting, each student e-mails the entire group an electronic copy of the article. The professor prepares and distributes a schedule summarizing presenter dates and article citations. This approach facilitates a paperless Journal Club and promotes examination of supplemental electronic documentation that journals publish online.

One recommended approach is to develop a syllabus for each semester outlining objectives of the Journal Club, the schedule, and expected performance; this can be published on the lab's website and updated throughout the semester.[20] Formalizing Journal Club into a one-credit-hour directed individual study course with a full five-point (A through F) grading scale helped students prioritize reading the articles. In some departments, REU students can use the credits toward technical elective requirements. The professor benefits by documenting the course in annual faculty evaluations as student credit hours taught. An example grading rubric is:

*"Grades*

- *Daily grade = 30%*
- *Presenter's grade = 30%*
- *Presentation & Final Report = 40%*

*Letter grade scale:*

- *90 – 100 % A*
- *80 – 90 % B*
- *70 – 80 % C*
- *60 – 70% D*
- *< 60 % F*

*Daily Grades*

- *The main activity in this course is the critical reading of assigned articles and integral involvement in discussions.*
- *Your daily grade at each meeting will be computed as follows:*
  - *(30%) Prompt attendance*
  - *(30%) Demonstrate prior knowledge of article (having read it prior to the meeting)*
  - *(40%) Discussion of topics including asking questions, assessment of content, interpretations, etc.*

*Presenter's Grade*

- *On the days you lead discussions, you will need to prepare a written article summary (two to three paragraphs), article review (see example), and an outline of discussion items. The grading rubric is:*
  - *(30%) Preparation demonstrated via a thorough article review*
  - *(30%) Article summary*
  - *(40%) Outline and discussion of topics including answering and asking questions, assessment of content, interpretations, etc.*

*Remember, you do not have to be an expert on the article, just a guide."*

The biggest return from a literature review effort will likely be in the form of student productivity in research writing. The frequent interactions incrementally guide students toward greater scientific rigor, quality presentations / posters, laboratory / simulation methodologies, and stronger written manuscripts. Each semester, students complete individual oral presentations and write a final report on their research in archival journal article format; both must include well-developed literature-review sections. One useful resource for students that provides guidance is an article on "Attributes of Exemplary Research Manuscripts Employing Quantitative Analysis."[18] An excerpt from the syllabus on expectations with presentations and final reports is included below:

*"Oral Presentation: Research Progress and Relation to the Literature*

*One oral presentation will be scheduled at the end of the semester.*

*Graduate Students: This presentation of ~10 minutes is to include a motivation, background and literature review, premise of your research project, experimental description, results including plots of data, and interpretations / conclusions.*

*Undergraduate Students: This presentation of ~6 minutes is to include a literature review and overview of your research project and results.*

*Final Report: Compiled Survey of the Literature*

> *Graduate Students: A final report (12 – 15 pages, double-spaced), formatted and written in the same tone and polished state as an archival journal article, will be due at the end of the semester. A minimum of 15 references must be discussed at the level commiserate with published journal articles.*
>
> *REU Students: A final report (5 – 8 pages, double-spaced) will be due at the end of the semester and will include the same sections as a traditional archival journal article. Your assigned article and >4 others pertinent to your own research project should be included."*

Once a formalized Journal Club activity is in place in a faculty member's lab group, it can be adapted and expanded to include non-REU undergraduates not already conducting research. The format is also conducive to students at varying skill levels. When a Journal Club is first implemented, the students are at approximately the same skill level. Once established, the more senior members voluntarily engage in peer-to-peer mentoring. For example, graduate students will guide first-time students through conducting an initial database search to locate relevant articles (A document guiding students on a literature search is provided on the author's webpage.[20]) With regard to scheduling, the newest students are added to the end of the rotation of presenters so that they have time to observe how more advanced students structure an article summary and article review, as well as lead discussions. The climate is such that when a student doesn't understand an article, they can freely admit this and the group discusses individual understandings until a consensus is reached.

## GUIDING THE QUALITY OF PRESENTATIONS AND DISCUSSIONS

Students do not possess an innate ability to glean information from dense technical articles. It is necessary to strategically demonstrate and teach how to read an article and lead a discussion on the topic. The entire course is a learning experience for the students, even taking it semester after semester. The first Journal Club session of the semester is a perfect time to provide an example summary and review, and demonstrate guiding a discussion.

The author advises her students to begin studying a technical article by reading the abstract, introduction, and conclusions first. Next, it can be beneficial to read the figure captions, and study the figures and any tables. The students are then advised to start back at the beginning and read through the article, taking notes or underlining as is comfortable. Re-read paragraphs or sections as necessary, then leave the article overnight and read it again the following day to prepare the article summary, discussion notes, and article critique for Journal Club. The students are advised to proofread their notes and to practice their summary and discussion questions before the class. After the meeting, the article summary and discussion notes are posted on the research group's website as well as in the lab group's EndNote and Dossier databases for easy reference.[21, 22]

A Journal Club session starts with the student's article summary, which acts as a brief overview of the introduction / purpose of the article and its applicability to his / her research project. The format that has been most educational for the students is to have them critique the article as if they have been solicited as a journal reviewer to assess the quality of the manuscript and make a recommendation for publishing concurrent with suggested edits / feedback to the authors. Students are provided examples of recent reviews that the professor has conducted and guided to provide at least the following:

A. *A summary of the entire article and its context in the field.*
B. *An assessment of the content organized by section.*
C. *An assessment of language and miscellaneous.*
D. *A critique of figures / tables.*
E. *An overall assessment and recommendation to the editor (accept, accept with revisions, resubmit for re-review after major revisions, do not accept).*

This written critique is provided either in hardcopy or electronic form at the beginning of the session. The facilitating student then begins an interactive discussion of the article structured by the written critique, the article sections, or open format with predetermined questions. The professor provides an example in the first session, but gives the students complete latitude to conduct their article discussion in their desired format. Discussions cover five main areas including novel or adaptable research methods, fundamental equations and assumptions in any theory sections, trends and comparisons between experimental / theoretical results, and a critique of conclusions based on the data. These are further enumerated below:

1. The research methods
   a. *What was novel about the techniques?*
   b. *Was there anything that could have been done better?*
   c. *Were all variables properly controlled?*
   d. *Can we adapt anything in our own lab?*
2. Theory (if included in the article)
   a. *What fundamental equations did the authors start with?*
   b. *Did the assumptions they made make physical sense within their system?*
   c. *What are the limitations of the final equations?*
3. Experimental / theoretical results provided in the paper
   a. *What trends are shown by the figures?*
   b. *What questions are left unanswered?*
   c. *Were the author's conclusions consistent with the data?*

4. Conclusions

   a. *What is the next logical step for this research to take?*

   b. *How would you conduct research to answer any unanswered questions?*

   c. *How will it benefit the research conducted in our lab?*

5. Overall

   a. *What was well written, well explained, well communicated in the paper?*

   b. *What was poorly written / explained / etc. in the paper?*

   c. *What data analysis / presentation strategies were most effective?*

Developing the technical vocabulary and confidence to discuss dense technical articles is a skill that develops with practice. Leading a discussion is a skill that is developed via practice and perceptive efforts. The art of leading a discussion sometimes requires strategic guidance, however. As a supplement, students are provided with four resources: "Tips for Leading Discussions,"[23] "Giving Presentations and Leading Discussions,"[24] "Chapter 3: Conducting Discussions" from *The New Professor's Handbook*,[15] and "Chapter 4: Organizing Effective Discussions.[19]

These sources all agree that the foremost goal is to establish a nonthreatening climate that is inviting to open discussion. Very frequently, the students are concerned that they will appear "dumb" and so they rush through their prepared notes so quickly that other students do not have the time to comprehend the information and are relegated to observers of a monologue. As a secondary facilitator, it is necessary for the advisor / instructor to slow or stop the presenter and ask questions for understanding. The discussion resources suggest that a facilitator can de-emphasize their role in the discussion by asking open-ended questions.[23] This invites involvement by the group and enriches the depth of discussion of the article.

Journal Club sessions usually end with a discussion on how to apply the findings for future research. It is beneficial to conduct Journal Clubs in a room with a round table for discussions and a whiteboard where brainstorms can be graphically demonstrated. The author has found that discussions sometimes migrate to topics that more trained individuals take for granted, such as order of authorship, or that the research appears perfectly conducted in a preplanned linear fashion. Senior research students who have had the experience of developing a poster or presentation are often conflicted that their own work did not progress in a clean, linear fashion. It is good to discuss that when writing an article, the authors have the advantage of hindsight; they can describe what worked and progress logically from start to finish. As students are challenged with writing their own first drafts of articles, they find that chronology is not always a logical progression of the research story. These discussions add another dimension of unplanned mentoring that occurs within a successful research group.

## THE MERITS OF THIS STRATEGY

As a portion of the course grade, students are asked to write a final-semester report on their research as described earlier. Non-REU students are asked to conduct a literature search and write a review article. For both, contextualization of the Journal Club articles is emphasized. As M.S. or Ph.D. students' research projects progress, they develop their final reports into manuscripts for submission to journals. The publication trends for the author's research group while utilizing this approach are included in Figure 1. Increases were seen over time

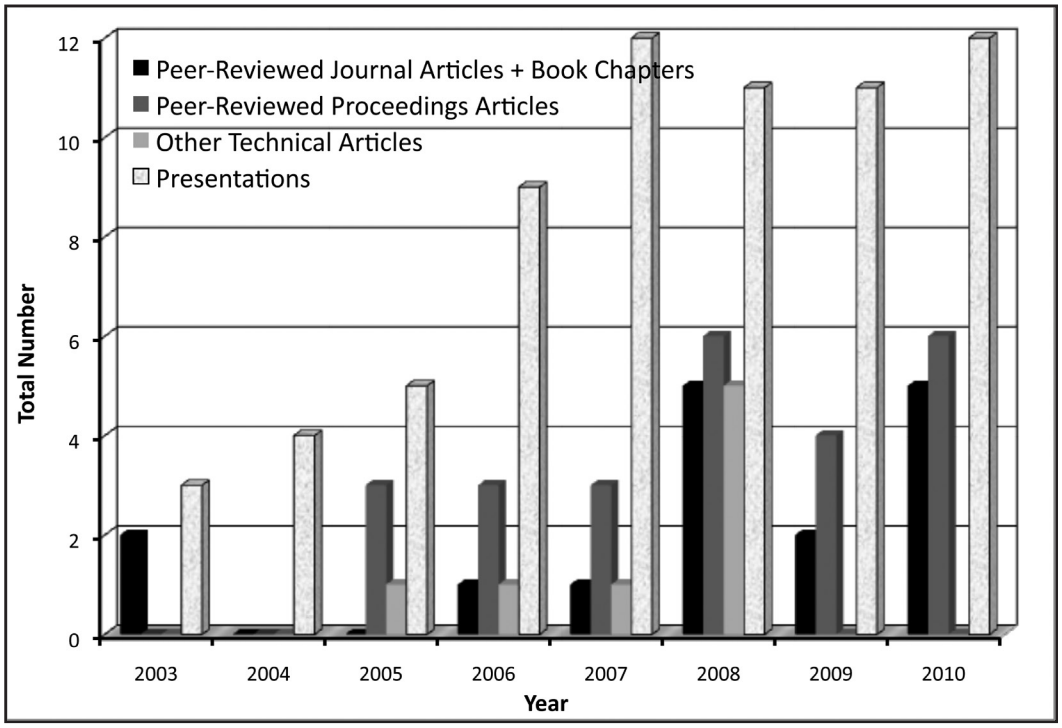


***Figure 1.*** *Total peer-reviewed journal articles (black, first bar), peer-reviewed proceedings articles (dark gray, second bar), other non-peer-reviewed technical articles (light gray, third bar) and presentations (textured, fourth bar) for the research group from 2003 to mid-2010.*

in all categories, most notably in the peer-reviewed articles and proceedings categories. Due to time for peer-review, a total of eight manuscripts are in press or under review for this research group at the time of this article submission.

In addition to the merits of an organized and sustained discussion of current literature, a Journal Club activity can also add dimension to a new faculty member's growing credentials. The author advises developing this activity into a course not only because it will help sustain participant motivation, but it can also be included in a tenure and promotion packet as a "new course developed." A Journal Club course can also be included in your student-contact hours calculation on annual review forms. Additionally, if the class is opened to all interested undergraduate and graduate students (*i.e.*, non-lab group members), it can lead to increased enthusiasm for your research area within the student population and potentially encourage an undergraduate student to pursue an advanced degree in your area.

When considering adopting a new activity, new faculty should critically assess whether the activity supports their efforts for tenure and to what extent it adds to their existing workload. While it is difficult to quantify time spent mentoring graduate students to read the literature via traditional mentoring techniques, the author has felt that Journal Club streamlined these efforts considerably. This structured forum enabled efficient dissemination of literature-review strategies to multiple students at one time while simultaneously following up on their progress. The administrative details relating to grading added a small amount of time, but this was offset by improved attitudes and efficiency of gleaning important information from the articles. In addition, the structured forum promoted documenting the important concepts (via Dossier and EndNote)[21, 22] and stimulated creative ideas.

## ASSESSMENT

A survey was designed and conducted of the students enrolled in the Journal Club class from Fall 2008 through Fall 2009. The 13-question survey was approved by MSU's Institutional Review Board (IRB) for the protection of human subjects.[25] Students all signed consent forms giving permission for their data to be included. The survey was designed to test the hypothesis that the students would gain confidence and experience with literature review in the Journal Club class.

The full survey is included in Appendix A. It should be noted that student perceptions are valuable factors to consider, as student performance can be negatively affected by negative perceptions.[26]

Students enrolled in the class were asked to complete the survey at four points in time: 1. Beginning of the Fall 2008 semester, 2. End of the Fall 2008 semester, 3. End of the Spring 2009 semester, and 4. End of the Fall 2009 semester. Journal Club was not conducted during the summer months due to conference and travel schedules of the professor and students. Course enrollments from Spring 2008 through Fall 2009 are included in Table 1. Tracking of individual graduate students was straightforward due to retention of those students. Undergraduates' involvement in Journal Club and research varied each semester due to graduations, course loads, and progress in the lab.

The first five questions were asked to determine how the students self-rated their backgrounds. The topics included Q1) experience conducting literature searches, Q2) confidence obtaining good profile of published work on a specific research topic, Q3) experience reading and understanding archival journal articles, Q4) familiarity with electrokinetics (a primary subject in this research group), and Q5) familiarity with microdevices (a foundational knowledge utilized in this research group). The remaining eight questions asked the students to self-rate their skills in a variety of areas including Q6) experience facilitating a discussion in a group, Q7) confidence guiding participants through content and keeping them participating in content discussions, Q8) experience adapting techniques described in articles in own research, Q9) experience critiquing techniques and conclusions asserted in the literature, Q10) experience compiling a survey of the literature, organizing it logically, and presenting it to others to show progression of knowledge and missing information, Q11) experience analyzing raw data to determine trends and dependencies, Q12) experience writing research articles. Lastly, the students were given the opportunity to openly comment on any of the survey questions or to provide general feedback (Q13). The data obtained from these surveys are outlined below.

To judge growth over time, the three graduate students who participated continuously in Journal Club from Spring 2008 to present were tracked. Their average responses for

**TABLE 1**
**Graduate and undergraduate student enrollment in the Journal Club course in 2008 and 2009. Total graduate students are a sum of Post M.S. and Direct-Admit Ph.D. These students are concurrently classified as either New or Continuing.**

| | Spring 2008 | Fall 2008 | Spring 2009 | Fall 2009 |
|---|---|---|---|---|
| **Graduate Students** | 3 | 4 | 4 | 4 |
| Post M.S. | 2 | 2 | 2 | 2 |
| Direct-Admit Ph.D. | 1 | 2 | 2 | 2 |
| New | - | 1 | - | - |
| Continuing | 3 | 3 | 4 | 4 |
| **Undergraduate Students** | 3 | 2 | 2 | 4 |
| New | 2 | 1 | - | 3 |
| Continuing | 1 | 1 | 2 | 1 |

each question are shown in Figure 2. In the survey conducted just prior to Fall 2008, these students rated themselves around 3.5 overall on the five-point scale allowed for all questions. This jumped to 4.22 at the end of Fall 2008, then dropped to 4.13 at the end of Spring 2009 and increased again to 4.32 at the end of Fall 2009. What is interesting about this fluctuation is that it was student dependent. One student steadily increased in self-rated experience and confidence, a second student peaked in Spring 2009, and the third student self-rated themselves substantially lower in Spring 2009. As shown in Figure 2, however, an increase over time occurs for almost all questions. In general, the self-rated background questions showed greater increases than the skills questions.

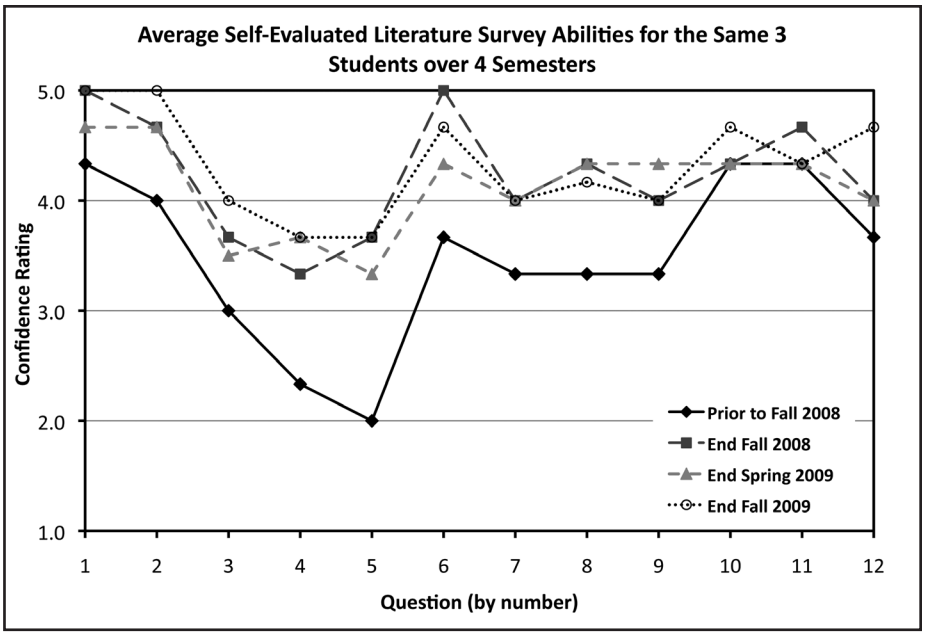


***Figure 2.*** *Tabulated responses at four points in time for graduate students (Prior to Fall 2008 = black diamonds, End Fall 2008 = dark gray squares, End Spring 2009 = light gray triangles, End Fall 2009 = open circles). Average responses for each question are determined from the same three graduate students who were enrolled continuously in Journal Club from Spring 2008.*

A similar analysis was conducted for two undergraduates who were enrolled in Journal Club during Fall 2008 and Spring 2009 (Figure 3). Both completed the survey prior to Fall 2008, although only one had been enrolled in Journal Club in Spring 2008. Substantial increases are noted (changes from 1 to over 4), likely due to the novice nature of undergraduates engaging in research for the first time. A majority of the students' self-rated background and skills increased over the two semesters. Questions 3 and 4 dealt with experience reading journal articles and familiarity with electrokinetics and both of these saw a half-point decline in undergraduates, but the same trend was not observed with the graduate students. Interestingly, while question 7 on guiding participants through discussions on content showed stagnation with graduate students after the first semester, an inversion was seen in the undergraduates' confidence from Fall 2008 to Spring 2009. The students lead a discussion twice during a semester and if that student led the discussion on a particularly difficult article, this might account for a drop in confidence.

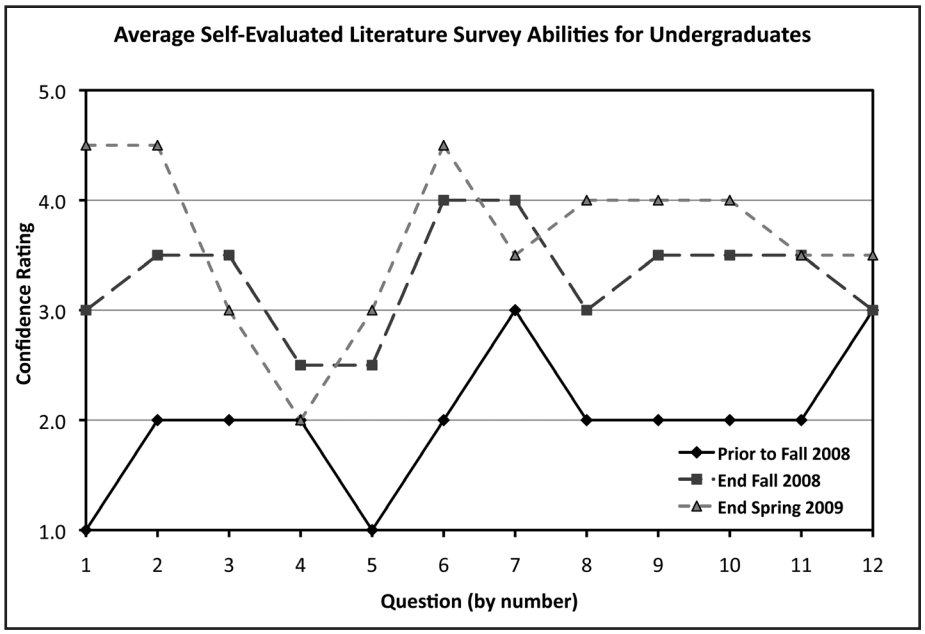


***Figure 3.*** *Tabulated responses at three points in time for undergraduates enrolled in Journal Club (Prior to Fall 2008 = black diamonds, End Fall 2008 = dark gray squares, End Spring 2009 = light gray triangles). Average responses for each question are determined from the same two undergraduate students.*

The changes over time for the types of graduate students shown in Table 1 were determined by comparing the first survey completed by the student to their survey in Fall 2009.

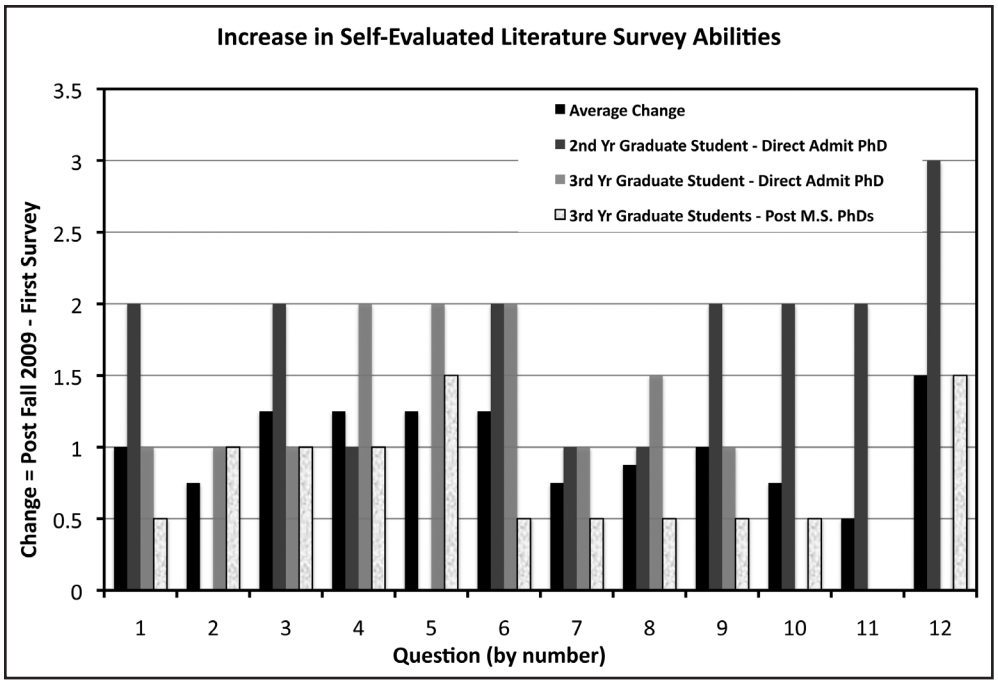


***Figure 4.*** *Average changes over the time period the graduate students were enrolled in the course. The changes are grouped by student experience. The first bar (black) shows the average change over all students. The second bar (dark gray) shows the increase for a 2nd year (as of Fall 2009) direct-admit Ph.D. student, the third bar (light gray) shows the increase for a 3rd year direct-admit Ph.D. student, while the fourth and last bar (textured) shows the increase for two post-M.S. Ph.D. students.*

This is depicted in Figure 4 for each of the 12 scored questions. All changes are positive (*i.e.*, greater in Fall 2009 than prior survey) showing the impact that an activity such as Journal Club has on the growth and maturation of research students. It is interesting that regardless of the background and research experience of the students, a positive impact and growth was observed.

## CONCLUSIONS

This manuscript outlines a strategy to keep all members of a research group abreast of the technical literature in their field. The goal of such a Journal Club is to counteract literature lethargy and to train student researchers (M.S., Ph.D., and REU) how to effectively learn from and critique articles.

The purpose and importance of the peer-review process is included in the Journal Club and seemed beneficial for all participants. Portions of an example class syllabus are provided and resources on leading discussions are given. Learning objectives are enumerated and included such skills as learning to critically review the literature and to write archival journal articles. Rubrics are described that could be used for grading purposes or as guidelines from which to provide feedback to the student after facilitating a discussion. Experiential advice is included that yielded the most efficient and effective learning experience for the students and the professor. The author briefly reviews the technical and credential-building merits of developing a literature review course, which include increased publishing productivity, accrued teaching credentials, and increased student confidence in his / her research area and in research skills. Assessment of the students enrolled in the course over a two-year period shows this increase in self-rated technical background, discussion facilitation, and literature suavity.

In conclusion, student involvement in literature discussions teaches critical thinking, increases technical vocabulary, guides poster / presentation quality, increases technical knowledge, bolsters confidence, and aids in optimizing research experiments. Additional benefits include peer-to-peer mentoring and streamlined professor-to-research student mentoring. Outcomes of the Journal Club activity have also included increased student knowledge of the literature, decreased apprehension in younger students toward understanding technical publications, and increases in publications within the research group.

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## APPENDIX A: COURSE SKILLS AND ATTITUDE ASSESSMENT

This survey is to assess your current familiarity and skill-level with regards to a) searching the literature for relevant published work related to your research project as well as b) reading articles and extracting important information to understand the work that was done and how to apply it to your own research.

### Background

*1. I have experience conducting literature searches.*

*a. Strongly agree*

*b. Agree*

*c. Neutral*

*d. Disagree*

*e. Strongly disagree*

*2. I am confident that I can obtain a good profile of published work (past and present) on a specific research topic.*

*a. Strongly agree*

*b. Agree*

*c. Neutral*

*d. Disagree*

*e. Strongly disagree*

*3. Please rate your experience at reading archival journal articles.*

*a. Very proficient (can read / skim it once and understand all)*

*b. Proficient (can read closely once and understand all)*

*c. Sufficient (can understand most after rereading closely)*

*d. Inefficient (can understand some after rereading closely)*

*e. Very inefficient (understand little after much rereading)*

*4. Please rate your familiarity with electrokinetics.*

*a. Expert*

*b. Master*

*c. Apprentice*

*d. Novice*

*e. Completely unfamiliar*

*5. Please rate your familiarity with microdevices.*

*a. Expert*

*b. Master*

*c. Apprentice*

*d. Novice*

*e. Completely unfamiliar*

### Skills

*6. I have experience facilitating a discussion in a group.*

*a. Strongly agree*

*b. Agree*

*c. Neutral*

*d. Disagree*

*e. Strongly disagree*

*7. I am confident that I can guide participants through specific content in a research article and keep them interactively participating in content discussions.*

*a. Strongly agree (all participants provide full sentence statements about concepts)*

*b. Agree (most participants contribute statements about content)*

*c. Neutral (most participants will provide short feedback)*

*d. Disagree (some participants provide some feedback)*

*e. Strongly disagree (participants say little, nod or agree when appropriate)*

*8. I have experience adapting techniques described in articles in my own research.*

*a. Strongly agree (I do this regularly without guidance from anyone)*

*b. Agree (I recognize opportunities for this and need to discuss with others)*

*c. Neutral (I recognize relations when others point them out to me)*

*d. Disagree (I rarely see how literature is related to my project)*

*e. Strongly disagree (articles are from a different planet than my project)*

*9. I have experience critiquing techniques and conclusions asserted in the literature.*

*a. Strongly agree (regularly recognize trends and limitations, others rarely recognize things I didn't already see)*

*b. Agree (regularly recognize trends & limitations, learn from other's insights)*

*c. Neutral (sometimes recognize limitations, learn from other's insights)*

*d. Disagree (Rarely recognize trends & limitations, rarely follow other's insights)*

*e. Strongly disagree (I feel lost)*

*10. I have experience compiling a survey of the literature on a subject, organizing it logically, and presenting it to others in a manner that shows progression of knowledge and suggests what information is missing.*

*a. Strongly agree (I can do this independent of guidance)*

*b. Agree (Can do some independent, need some guidance)*

*c. Neutral (Need guidance, can follow instructions)*

*d. Disagree (Need guidance, sometimes need repeat to follow instructions)*

*e. Strongly disagree (please don't make me do this!)*

*11. I have experience analyzing raw data (list of numbers) to determine trends and dependencies.*

*a. Strongly agree (I can do this independent of guidance)*

*b. Agree (Can do some independent, need some guidance)*

*c. Neutral (Need guidance, can follow instructions)*

*d. Disagree (Need guidance, sometimes repeat guidance to follow instructions)*

*e. Strongly disagree (please don't make me do this!)*

*12. I have experience writing research articles that combine the skills from 7 through 11.*

*a. Strongly agree (I can do this independent of guidance)*

*b. Agree (Can structure a complete first draft, need guidance refining to final draft)*

*c. Neutral (Need guidance structuring first draft, guidance refining to final draft)*

*d. Disagree (Need guidance on some sections and guidance on first through final drafts)*

*e. Strongly disagree (Need guidance on each section and step by step approach)*

*13. Please comment on anything that influenced your answers to 1 through 12 here:*

*(i.e., for #1, have you previously learned to read research articles in another course / educational experience?)* ❐