Education

Peer Review in the Classroom

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Peer review or peer assessment is a process of evaluating work performance and products by peers. It is a vital part of professional life. For example, peer review is routinely used in two important phases of a research project: proposal evaluation and product assessment. Grant proposals are peer reviewed to ensure the quality, originality, and feasibility of the proposed work (Cole et al. 1982, Gaugler and Freckman 1990, Swift 1998). Research products such as papers for scientific journals are usually peer reviewed as well to enhance the quality of the journals, to maintain the integrity of the authors' work, and to provide accurate information for the scientific community (Waser et al. 1992, Bloom 1999). Despite the importance of peer review in scientific research (Cole et al. 1977, Kostoff 1997), few students receive formal training in reviewing proposals or manuscripts. Although some graduate students are exposed to the peer review process informally through their major professors, many graduate students and the vast majority of undergraduate students never have such experiences.

Yet the value of peer review in the classroom has been recognized for many years (Gaillet 1992). Researchers have found that effective peer review in the classroom stimulates learning and critical thinking (Herrington and Gadman 1991, Angelo and Cross 1993, Freeman 1994, Johnson et al. 1998). Traditionally, peer review is most often used in writing courses, in which students comment on each other's writing (Witbeck 1976, Jacobs 1987, Herrington and Gadman 1991). In science courses, however, peer review is much less frequently practiced (Sims 1989, Topping 1998), although Cunningham and Helms (1998) demonstrate how peer review can provide a powerful basis for making science education more authentic and inclusive. This lack of training in peer review is not in line with science education trends that emphasize learning by doing and rely increasingly on writing (Prothero 2000). Moreover, lack of training in peer review is very likely to hinder performance in the current and future scientific workplace, which often requires interdisciplinary teamwork and frequent evaluation of a peer's performance (Yuan 2000). Clearly, it makes sense to give students opportunities to learn and practice peer review skills in the classroom, and in this article we report on a peer review process that was developed in the classroom for university science majors.

Overview of the course

In 1996, we introduced a pilot peer review process in a graduate class, "Systems Modeling and Simulation," at Michigan State University (MSU). The main objectives of this course were to introduce modeling and simulation methods and to apply systems approaches and techniques to natural resource management, as well as to ecological and agricultural research. To achieve these objectives, each student developed a computer simulation model as a term project, in addition to attending lectures and participating in hands-on laboratory and discussion sessions. Students often focused on topics related to their research programs. Before developing a model, each student wrote a research proposal. After model development, the student wrote a draft project report. To gain appreciation for the peer review process used to evaluate proposals for funding agencies and manuscripts for scientific journals, each student reviewed two or three project proposals and draft reports written by other students. Overall, the students' comments on this pilot peer review process were very positive.

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Encouraged by the positive responses from students, we formalized the peer review process in the fall semester of 1998. The class consisted of 23 students from 11 different majors (computer science, crop and soil sciences, entomology, environmental biology, fisheries and wildlife, forestry, geography, mathematics, microbiology, resource development, and zoology). Sixteen of the students were in doctoral programs, five in master's programs, and two in undergraduate programs.

Peer review process in the classroom

Following a typical protocol for scientific research, students began by writing descriptions of their research problems, project goals, objectives, methods, hypotheses, feasibility, and expected results. They developed five-page proposals and submitted them to the instructor (Liu), who then assigned each proposal to three students to review. The criteria for matching reviewers with proposals included reviewers' expertise in the topics and their interests, skills, experience, and background. Because one reviewer might not be able to judge every aspect of a proposal, two other reviewers were selected to serve a complementary role. (Students completed a questionnaire about their backgrounds and research interests at the beginning of the semester; the results from the survey were used to help assign the proposals.) As a result, usually at least two of the three reviewers for a proposal had sufficient knowledge and experience to be considered "experts." The names of the reviewers were kept confidential unless the reviewers decided to reveal their identities. We used a number of criteria to review the proposals, including significance of research objectives, rigor of hypotheses, familiarity with literature, and feasibility of methods (box 1).

The instructor also reviewed the proposals and reviewers' comments to identify weak areas that the reviewers did not find and to advise the authors which of the reviewers' comments to incorporate into the development of their proposed models. For each project, some comments from all three reviewers were similar, though many were dissimilar, perhaps owing to the different disciplinary backgrounds of the reviewers. Most of the dissimilar comments were complementary, but a few were contradictory. In those contradictory cases, the instructor provided guidance about which comments should be ignored.

After the students developed their models and submitted their draft reports to the instructor, the original three reviewers of each proposal were then asked to review the resulting draft report. To parallel a typical peer review process for a scientific journal, each reviewer submitted the following to the instructor: a brief cover letter, a completed rating form, general and specific comments on each draft report, and comments written directly on each draft report. We gave the students detailed instructions for reviewing draft reports (box 2). The cover letter to the instructor gave a candid summary of the review. The rating form (box 3) offered numeric evaluations of projects (with scores from 1 through 5). Although the selection of numeric scores may be subjective, many journals use similar forms of numeric evaluations. Furthermore, numeric scores may be a more convenient way to compare different papers. Therefore, students should be aware of such forms and should practice the skills needed to give more objective evaluations.

To make the peer review process effective and efficient, we introduced specific guidelines for writing, reviewing, and revising proposals and draft reports in the classroom. For example, the guidelines for reviewing the draft reports included eight general areas (e.g., scientific soundness, originality and significance, degree to which conclusions were supported

Box 1. Guidelines for proposal review.

Purposes. The purposes of reviewing proposals are to (1) gain experience in peer-reviewing proposals for funding agencies such as the National Science Foundation, (2) learn others' work, and (3) provide critical and constructive suggestions and comments on others' proposals to help fellow students improve their proposals. Even if your specialty is not the same as the author's, your review can still be useful. General comments can provide a valuable and unique perspective.

Fairness and objectivity. If something in a proposal is flawed, criticize the "something," not the author. Harsh words in a review will cause the reader to doubt your objectivity; as a result, your criticisms may be rejected, even if they are correct! Comments directed to the author should convince the author that (1) you have read the entire proposal carefully, and (2) your criticisms are objective and are intended to help the author improve his or her proposal.

Anonymity. You may sign your review if you wish. If you choose to remain anonymous, please avoid comments to the author that might serve as clues to your identity.

Comments and suggestions. Please give the instructor two typed copies of your suggestions and comments on each proposal. If you wish to write some additional suggestions and comments on a proposal, please write them clearly and also give the instructor two copies of the proposal with your remarks. The instructor will distribute one copy of your comments to the author and use the other copy for evaluation.

Your review should include two parts: general comments regarding intellectual merits and scientific significance of the proposed project, and specific suggestions and comments on the proposal's strengths and weaknesses. Please use the following criteria: (1) significance of research objectives, (2) rigor of hypotheses, (3) familiarity with related work, (4) feasibility of methods (data availability and analysis, time requirement, etc.), (5) organization and clarity, and (6) others (e.g., presentation).

by the data, rationale of the assumptions) and 14 specific aspects (e.g., presentation style, methods) (box 2). Reviewers were instructed to be constructive, fair, and objective (e.g., criticizing the science, not the author, if they felt the research was flawed), and they were told that they could remain anonymous. To expose the students to how peer review is conducted in a scientific journal, the instructor showed the students the comments (positive and negative) reviewers made on one of his own papers (Liu et al. 1994) that had been published in a peer-reviewed scientific journal, his detailed responses to the reviewers' comments, and his letter to the journal editor.

Box 2. Guidelines for report review.

Purposes. The purposes of reviewing reports are similar to those of proposal review, except that you can gain experience in reviewing manuscripts for professional journals. As to anonymity as well as fairness and objectivity, please see "Guidelines for proposal review."

What to submit. Please submit your review in four parts: (1) a cover letter to the instructor, providing a candid summary of your opinion of the report; (2) the rating form; (3) comments for the author; and (4) the report with comments written on it. Please submit two copies of parts (2)–(4), because one copy will be distributed to the author and the other copy will be used by the instructor for evaluation.

Comments for the author. Please include both general and specific comments regarding the report's strengths and weaknesses, and emphasize your most significant points. General comments include (1) scientific soundness, (2) originality (if the model is an enhancement of an existing model, please comment on the originality of the improved sections), (3) degree to which conclusions are supported by the data, (4) appropriateness of the methods, (5) organization and clarity, (6) cohesiveness of argument, (7) length relative to the number of ideas and information, and (8) conciseness and writing style.

Please support your general comments with specific evidence. You may write directly on the report, but please also summarize your handwritten remarks in "Comments for the Author." Please comment on any of the following matters that significantly affected your judgment of the report:

Presentation. Does the report tell a cohesive story? Is a tightly reasoned argument evident throughout the report? Where does the report wander from its argument? Do the title, abstract, key words, introduction, and conclusions accurately and consistently reflect the major point(s) of the report? Is the writing concise, easy to follow, and interesting?

Assumptions. Are the rationales for the assumptions explained? Are the explanations reasonable and clear?

Model validation. If the model is not validated because of the lack of data, are there explanations regarding the reasons? Are there any explanations about potential ways to obtain such data?

Sensitivity analysis. Has any sensitivity analysis been done? Are the results reasonable? Are there any other parameters worth sensitivity analysis?

Scenario analysis. Has any scenario (management or experiment) been simulated and analyzed? Are there any other scenarios you think might be of interest?

Methods. Are they appropriate and described clearly enough so that the work could be replicated by someone else?

Data presentation. When results are stated in the text of the report, can you easily verify them by examining tables and figures? Are any of the results counterintuitive? Are tables and figures clearly labeled, well planned, too complex, necessary?

Statistical design and analysis. Are they appropriate and correct? Can the reader readily discern which measurements or observations are independent of other measurements or observations? Are replicates correctly identified? Are significance statements justified?

Errors. Please point out any errors in technique, fact, calculation, interpretation, or style. (For style, follow the CBE style manual, *Scientific Style and Format* [sixth edition], and ASTM Standard E380-92, "Standard Practice for Use of the International System of Units.")

Bugs. Please run the model to see if there are any bugs in the diagrams and equations. (Note: If the model is not programmed in STELLA but in a programming language that you do not know, you can ignore this issue.)

Documentation of the model. Is the User's Guide useful and easy to follow? Is the documentation for the model clear? Is it possible to rename some variables and flows so that they can be more clear, concise, and intuitive?

Citations. Are all (and only) pertinent references cited? Are they provided for all assertions of fact not supported by the data in the report?

Length. Which part(s) of the report should be expanded? condensed? deleted? (Please do not just advise an overall shortening by X%. Be specific!)

Overlap. Does this report include data or conclusions already published or in press? If so, please provide details.

Are there any other comments or suggestions?

Box 3. Rating form for report review.

Author's name ____________ Reviewer's name (optional) ____________

	Lowest				Highest
Originality of the research	1	2	3	4	5
Rationale of methods (e.g., assumptions)	1	2	3	4	5
Interpretation of results	1	2	3	4	5
Support of conclusions by results	1	2	3	4	5
Clarity of presentation	1	2	3	4	5
Ratio of information to length	1	2	3	4	5
Documentation of the model	1	2	3	4	5
Overall rating	1	2	3	4	5

As with the proposal review, the instructor reviewed and evaluated the draft reports and reviewers' comments (see examples of comments in box 4). In some cases, the instructor discovered subtle issues that the reviewers had not found and pointed these out to the authors. On several occasions, the instructor asked the authors to disregard comments that were inaccurate or inappropriate and advised the authors which contradictory comments should be ignored. Authors had to revise their reports based upon the instructor's and student reviewers' comments. At the end of the semester, final reports were submitted to the instructor for evaluation and grading. In addition, the authors included a cover letter to the instructor explaining, point by point, how they had dealt with the reviewers' comments and what changes had been made. If the authors disagreed with the reviewers' comments and suggestions, they had to state why.

Students' evaluation of the peer review process

To evaluate the merits and weaknesses of the peer review process in the classroom, we held a discussion session after the draft reports had been reviewed. The students were divided into four groups. Each group was composed of five or six students, one of whom was selected to take notes on the discussion and later orally present the results of the group discussion to the entire class. The students stated that the peer review process was a "good exercise for writing constructive criticisms" and that "they learned how to explain jargon terminology, learned about structures of the review process, and learned systems thinking in other fields." Reviewing the draft reports "allowed reviewers to obtain different ideas for data presentation," "helped [reviewers] to see strengths and weaknesses of our own papers," "forced idea synthesis," "helped point out holes and deficiencies and resolve detrimental issues," and gave students the opportunity to gain "perspectives on our own progress and quality of results." Although several students felt that "the reviewers from other disciplines could not help with specific methods or assumptions," the vast majority of students thought that "people outside of your discipline help clear up jargon and make it more understandable."

In MSU's official evaluation form ("Student Instructional Rating System"), which students filled out at the end of the semester, the comments on the peer review process were generally positive and quite consistent with the group comments mentioned above, which further confirmed the value of the peer review process. Among the individual comments were these statements: "I got a lot out of the peer review process. In fact, it may have been the most useful part of the course"; "The process showed me the way to the academic activities that I might encounter in the near future; I don't think I can learn these somewhere else"; and "The peer reviews were very helpful to enhance my learning of science and should be continued." One student felt that the "scribbled" comments on the draft report were more helpful than the separate typed comments, probably because the "scribbled" comments were written near the specific paragraphs or sentences of concern. In some cases, a reviewer's expertise did not match the topic of the author's project, and thus those reviewers could not provide specific comments on the methodologies and assumptions. Nevertheless, most students appreciated and recognized the value of the general comments made by "nonexperts" from different fields and perspectives.

As with other learning activities, peer review requires a fair amount of time and effort. Although the vast majority of students thought that the time needed to review another's work was well worth it, this time requirement must be explained at the beginning of the semester so that students can fit this activity into their schedules. Also, it should be emphasized that the peer review process is an integral part of the course and is included in the students' grade evaluation.

Implementation of the peer review process in other classes

In spring 1999, four faculty members at MSU and Yale University tested this peer review process in their classes, two at the undergraduate level and two at the graduate level. All classes adopted the guidelines for peer review developed from the "Systems Modeling and Simulation" class in 1998. In addition to providing written guidelines for all the classes, Liu also taught a special session on peer review in two of them, using examples of peer review for a special issue in the journal *Ecological Modelling* (Liu 2001) and for a book (Liu and Taylor 2002). The students found the peer review process very

Box 4. Examples of comments on content and copy or style on students' draft reports.

Content comments	Copy or style comments
Factual errors	Grammar errors
Illogical arguments	Spelling errors
Irrational assumptions	Missing words
Bugs in models	Inappropriate use of words
Statistical errors	Awkward sentence structure
Unclear goals and objectives	Typographic errors
Lack of testable hypotheses	Inappropriate order of paragraphs
Inappropriate interpretation of results	No figure legends
Weak conclusions	No figure numbers
Lack of discussion on model limitations	Low quality of figures
Incomplete critical components	Use of technical jargon
Lack of theoretical and empirical support	Same information in tables and figures

useful and educational (Millenbah et al. 2000), and overall, it was successful in all four classes.

In fall 2000, the peer review process was again implemented in the "Systems Modeling and Simulation" class at MSU, adhering to the same basic procedure as in 1998. There were a couple differences, however. First, the class size was larger (30 students versus 23 in 1998). Second, having learned from the 1998 experience, at the beginning of the semester, the instructor clearly stated the time needed for peer review. The use of the peer review process in the same course during three academic years (1996, 1998, 2000) has demonstrated similar positive outcomes.

In summary, practicing peer review skills in the classroom was very useful in several ways. First, by reviewing others' work, reviewers enhanced their critical thinking, which made their own work better. Second, reviewees benefited from the reviewers' comments, which improved their term projects and reports. Several students' term projects even resulted in peer-reviewed publications (e.g., Liu and Heins 1998, Conway et al. 1999, Xie et al. 1999, An et al. 2001). Third, because of the academic diversity of the students, the peer review process assisted the instructor in thoroughly and objectively evaluating those project topics outside his areas of expertise. At the same time, the diverse topics exposed students to research outside their respective fields and gave them an appreciation for the commonalities and topic-specific aspects of effective proposal and project writing. Fourth, the peer review process provided a foundation for students to evaluate a peer's work in a professional setting. A number of students indicated that the peer review process in the classroom had appropriately prepared them to review manuscripts for professional journals. Fifth, students realized that in the scientific community, reviewing a peer's product is a professional obligation and an aid to the advancement of science. The major challenge of teaching and practicing peer review in the classroom is the extra amount of time required. The benefits, however, significantly outweigh the time invested. Thus, we recommend that peer review be incorporated into more graduate and undergraduate courses.

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