Peer review in engineering education: speeding up learning, looking for a paradigm shift

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***Abstract* — This article presents an experience that aims at the improvement of written expression of students of Computer Engineering and Computer Science. While working to improve written expression, a greater objective is pursued: to promote the paradigm shift in learning, in such a way that students become responsible for their learning process. The practice of peer review in science is discussed. The potentiality of its application in learning is outlined, together with a detailed procedure for implementation. An account of results is presented and commented. The conclusion offers an appraisal of the experience, with recommendations for extension.**

***Index Terms* — Peer review, refereeing, scientific methodology, learning paradigms, scientific writing, distance learning.**

I. Introduction

This article presents an approach to the application of peer review in education. It is an initiative that aims at the improvement of written expression of students of Computer Engineering and Computer Science. Written expression does not receive a major emphasis in these courses *curricula*, although graduating students are requested to write a monograph.

In Brazil, where our experience is conducted, students enter university after being trained to repeat, hardly ever facing cognitive challenges that make them exercise and improve their analysis and synthesis skills, as well as their capacity for clear written expression. While working to improve written expression, a greater objective is pursued: to promote the paradigm shift in learning, in such a way that students become responsible for their learning process.

The application of peer review described here is part of the activities of a course on Databases. In addition to the study of database theory, students are invited to choose a topic and write a paper, with clear guidelines for topic selection, literature review, paper writing and formatting, and refereeing of other students' papers.

Database "text" and the scientific text are akin. Short, clear, and objective sentences are typical of high quality scientific text; a database model can be regarded as a set of statements with simple structure. For instance, fig. 1 shows a simple database model in which a relationship between the entities Department and Course can be read as two sentences: "A department offers zero, one, or several courses", and "A course is offered by exactly one department".

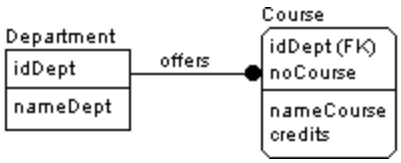

Fig. 1. A simple database model written in IDEF1X [1]

Designing a database can be considered a kind of writing task in which data structures and constraints are designed as business rules that take the form of simple sentences. Hence, the practice of scientific writing won't hurt the students' modeling skills. On the contrary, it may even help to speed up students' learning.

Another good reason for practicing peer review is work ethics. The ACM code of ethics and professional conduct [2], item 2.4, urges computer professionals to accept and provide appropriate professional review:

> "Quality professional work, especially in the computing profession, depends on professional reviewing and critiquing. Whenever appropriate, individual members should seek and utilize peer review as well as provide critical review of the work of others."

The next section discusses the peer review process as the quality system of science, especially in the computing area. Section III presents a brief debate about learning paradigms and the role of the peer review approach to learning. Section IV details a framework for the application of peer review in engineering education. Results of this framework's usage are reported in section V. Section VI, the Conclusion, summarizes the paper and discusses perspectives for the extension of this work, especially for distance learning.

II. Peer review in the appraisal of scientific articles

The observation of best practices among scientists led to the institution of peer review as the quality control system of the scientific community. It has been recognized that "scientific progress relies heavily on the peer review process" [3].

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The acceptance of a scientific work does not take into account arguments of authority, but rather the consensus of other scientists – the author's peers. This principle is used in the selection of articles for publication in journals and conferences. The referees for submitted articles are chosen by the editor of a journal or conference on the basis of their experience, reputation, and previous experience as referee.

It is important that a paper be well written, so it can be understood and used. This includes good language usage [4] and scientific merit [5]. Merit is judged in terms of the contribution a paper makes to the field it is devoted.

The contribution of a **research paper** is the presentation of new and relevant research results, or a new and insightful synthesis of existing results. A thorough, comprehensive **survey**, or an accessible and possibly partial **tutorial** on a field, are contributions, too [3].

The referee's work is not remunerated, but it is a professional duty. However, the referee should notify the editor, and perhaps return the paper, in the event of a conflict of interests. For instance, close friendship, or enmity directed toward the author are incompatible with an impartial review.

The referee's appraisal of a paper is documented in a referee report, usually divided in parts. Some journals, like IEEE Transactions of Knowledge and Data Engineering, publish their referee report forms online [6], where it is possible to see the report's structure.

A usual report presents, in first place, a brief recommendation for or against accepting the paper. Then, it summarizes the paper in a few sentences. This summary is for the editor's use and to ensure that the referee actually understands the paper [3].

The next report section evaluates merit and quality of the work, including legibility, methodology, and accuracy. The final section recommends for or against publication. The report should suggest improvements and list necessary changes if the recommendation is positive, or make clear why the recommendation is for rejection.

The report should be directed to the paper, not to the author. It should be objective; it is not meant to flatter or offend the author. The referee should read the paper without presumption about its correctness and compare it to an appropriate standard [3].

The peer review process establishes a collaboration among author, referee, and editor. It helps author and editor to improve the quality of published material, and also leads the referee to think about the nature and objective of article writing. In addition, it helps authors of rejected papers to become better authors and achieve quality standards. Smith [3] points out that "an author who feels insulted and ignores referee reports wastes an invaluable resource and the referees' time".

The peer review process has worked for the progress of science. The next section discusses the possible use of peer review for the progress of education.

III. Learning paradigms and the role of peer review in education

In the traditional learning paradigm, education is a permanent process of transference of knowledge. The professor teaches; the student has to be taught. The student learns in the classroom, there is no other learning space. This view subordinates education to an instruction process [7].

Piaget and Vygotsky are considered by [8] as the main theorists of a less limited understanding of education. According to their theories [9]-[10], the students can construct their knowledge. They are active and autonomous.

There might be a gain in the application of the peer review process in education. Researchers are active and autonomous, and the peer review process is dependent upon that kind of attitude. On the contrary, the students in the experience mentioned in this study do not show, according to the professor's perception, an attitude compatible with Piaget's and Vygotsky's ideas. Maybe they can be stimulated to assume a new attitude, if they come to understand the peer review process and its principles.

The successful application of peer review in the learning process of the students observed in this study can help to change their perception about scientific knowledge. They are not used to the mechanisms of science, and sometimes take "scientific truth" as unquestionable. This is a naive perception, perhaps imposed to them by an environment in which questioning is not usual, or not admissible.

The naive perception about science can be altered by the participation in a peer review process in which crucial aspects of the scientific activity are exercised. The students go through the necessary steps of scientific knowledge production and publication, and acquire the skill that may allow them to reconsider their way of thinking, based on common sense, to a broader approach, based on the understanding of the mechanics of science.

A summary of the expected effects of the application of peer review in learning, in terms of conceptual changes, is:

- Scientific knowledge is not a product of an individual mind, but a collective activity in which each author's ideas are appraised and enriched through a feedback process. The author's peers – researchers with similar interests – give the feedback.
- Scientific activity is essentially critic, refusing the argument of authority and focusing on the contribution of a proposition to the advance of knowledge.
- Scientific knowledge is not static or dogmatic. Science is in a continuous process of discussion and revision.
- The systematic ordering of ideas, the steps of scientific methodology, and objectivity and clearness in written expression are fundamental elements to be appropriated and exercised by the students.
- The core of the peer review approach to learning is the change, from passive and unquestioning receptor of information, to an active and critic member of a community that constructs knowledge.

These considerations are the starting point for the conception of a detailed procedure for the application of peer review in learning, presented next.

IV. Applying Peer Review in Engineering Education

In our experience, students are invited to work as authors of papers and reviewers of their peers' papers. Also, each student or group uses the feedback received to perform improvements in the original version of the paper, and then presents it in class.

The process simulates a scientific congress, including the publication of proceedings. The professor serves as organizing "committee" and president of the program committee. The students serve as authors and referees (members of the program committee). The Internet is the medium for call for papers and proceedings publication, distribution of papers for review and reviews back to the authors. Author and referee anonymity is preserved.

This is usually the student's first experience in publishing a refereed paper. The articles hardly offer any novel contribution. They are best classified as tutorials, rather than research papers, but this is adequate for the students' possibilities.

The whole process takes about twelve weeks. In each stage, students have specific needs for guidance and advising. The process is illustrated in fig. 2 as a list of numbered tasks, professor's and students' responsibilities, and the document flow.

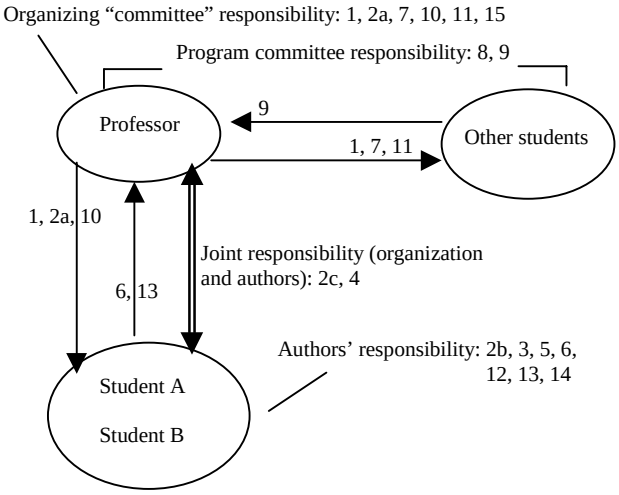

Fig. 2. Tasks, responsibilities, and document flow

The tasks and associated responsibilities and documents are:

1. Proposal: The professor publishes a call for papers (CFP) and a review form. The CFP defines guidelines for paper production and refereeing. The review form is for future use. This is indicated in fig. 2 by the number 1. It denotes that the publication is a professor's responsibility (in the role of organizing "committee"), and that the documents are sent to the students (in the roles of authors and members of the program committee).
2. Topic definition: (a) Topic suggestion: The professor presents topic suggestions, recommends research sources, and requests that the students form groups and look for topics. Suggestions and recommendations are sent via e-mail to authors, as shown in fig. 2, item 2a. (b) Topic selection: Authors form groups, look for topics and adequate bibliography, and select candidate topics. This subtask is the authors' duty, item 2b in figure 2. (c) Topic approval: The professor listens to authors' interests and gives advice on relevance, purpose, scope, and approach to the chosen topic. Topic approval aims at a challenging but feasible assignment. It is a joint responsibility of authors and organization (item 2c in fig. 2).
3. Draft: Each author group prepares a free-format draft paper for discussion. This is an authors' task (fig. 2, item 3). There is no need to request a formal submission, unless the professor feels that the students need strong guidance (if procrastination is a strong culture among students, for example).
4. Draft appraisal: Authors discuss the draft within the group, trying to build a first critique. They may discuss it also with the professor, for advice and guidance. This is a joint responsibility, shown as item 4 in fig. 2.
5. Writing: Each author group produces a full version of the paper. This is item 5 in fig. 2.
6. Paper submission: Each author group sends the original article via e-mail to the organizer (item 6 in fig. 2).
7. Paper allocation and distribution: The organizer assigns to each student a number (usually two, in our experience) of their peers' papers for refereeing. This assignment avoids self-refereeing. If there are enough referees, reciprocal refereeing is also avoided. Authorship is omitted, aiming at impersonal reviews. The number of times each paper is assigned for review is proportional to the number of its authors (twice this number, in our experience). This is an organizer's task, item 7 in fig. 2.
8. Peer review: Each student reads each paper assigned for his review, then writes a referee report using the form (item 8 in fig. 2) and guidelines previously received (see item 1). As president of the program committee, the professor may also review papers. However, this is unnecessary if the peer reviews are effective, i.e., if the referees have the necessary understanding about the task, and expend the appropriate amount of effort.
9. Review submission: Each referee submits the reports to the organizer, who acknowledges the receiving, as item 9 in fig. 2 indicates.
10. Review distribution: The notification to authors is made through the distribution of anonymous referee reports. The professor omits the authorship of reports. The

professor's review, if existent, is not anonymous. The distribution corresponds to item 10 in fig. 2.

11. Extended review feedback: Each referee receives copies of other reviews on the papers he reviewed. This is item 11 in fig. 2.
12. Feedback appropriation: The authors make corrections and improvements on the paper based on the referee reports received and their own judgment. Item 12 in fig. 2 represents feedback appropriation.
13. Final submission: Each author group submits the final version of the paper and receives acknowledgment from the organizer, as illustrated in fig. 2, item 13.
14. Presentation: All articles are presented in class, simulating technical sessions of a conference. The professor offers guidance on presentation techniques and gives feedback on the presentation, but the task is the authors' responsibility, as item 14 in fig. 2 shows.
15. Publication of proceedings: The organizer edits and publishes the proceedings with the final versions of the papers. Item 15 in fig. 2 designate this final task.

Evaluation of students' performance takes into account the quality of their work at various stages. The original submission, the referee reports submitted, and the final version are graded. The final version is where they demonstrate their capacity for feedback appropriation.

Presentations are also considered, but not graded. According to the professor's perception (based on the students' cheerful expressions), the mere participation as speaker and spectator is enough for a profitable experience, since students do not receive formal and proper preparation to become talkers. Vocal technique and body language, with their emotional implications, are challenging, important, and hard to work in the available time frame.

V. RESULTS

The peer-review procedure just described has been applied since 1997 in undergraduate courses on Databases. The first result was the recognition, by the professor, of the reach of the students' lack of preparedness for academic studies, in several cases including the simple ability to form phrases.

In many opportunities the students simply refused to do the work, renouncing to the grade, remaining secure in their traditional role: passive, apathetic, non-critic. The desired shift in the learning paradigm was not a result at this point, definitely. Despite that, in other opportunities the results were satisfactory. Digital versions of proceedings of some editions were published [11].

The peer-review process was applied also in graduate school. The first try, in a 45-hour *lato sensu* course, was turned into a book [12]. Later experiences, in *stricto sensu* courses, have been successful because the students are already used to present seminars and bring their experience to the classroom. Referee reports are frequently concordant. In many opportunities the students submitted their papers to conferences, sometimes with the professor as co-author. The proceedings of the 2000 school year were published [13].

The professor sought help in Psychology of Education to improve the results achieved at the undergraduate level. Since the beginning of the 2001 school year, the course on Databases has the assistance of a student in her curricular practice of Psychology of Education. The work is midway when this paper is being written, but it is possible that some change have already taken place.

In one of the latest experiences at the undergraduate level, students demonstrated frustration after knowing the grades for their papers' original versions. After a discussion about the reasons behind the poor grades, they seemed to recognize that the work was, indeed, poor. Then the discussion shifted to really important questions proposed by the students:

- What is Science, anyway?
- Can someone less graduated challenge a famous scientist?
- Can a famous scientist's article be rejected?

The **character** of their questions reveals the possibility that they begin to understand the principles behind the progress of science. Or, at least, they showed some inquietude related to the way science treats truth and authority – so differently from the experience they have. The professor, then, proposed other questions:

- What is the scientific method?
- Who validates scientific knowledge, and how?
- Does the peer review process being experienced have anything to do with the previous question?
- Can science solve all human problems?

Some of them showed an uneasy expression in regard of the third question above. Who validated the work of Einstein, Darwin, and other famous scientists? Is it possible that the criterion for approval of a new theory be what they just experimented with? Time will tell how much they progressed in their understanding of science. The inquietude demonstrated is, in the professor's perception, a hint that they may be using the opportunity to speed up the way how they learn.

VI. CONCLUSION

This paper presented a discussion and framework for the application of peer review in engineering education. A brief outline of learning paradigms was presented, with comments on the relation between learning paradigms and the cognitive aspects of peer review. A procedure for the implementation of peer review in classroom was detailed, and the results of its application were reported.

The results show that, although shifting the learning paradigm is an ambitious and difficult task, the approach is promising. The publication of proceedings has been an

incentive for the students. The assistance from Psychology of Education will continue, trying to understand the positive and negative aspects of the approach used so far, and looking for new ways to improve the experience.

A positive aspect of the peer review process is that it works only if the referees assume a responsible attitude, because "reading a paper as a referee is closer to what a teacher or professor does when grading a paper than what a scientist or engineer does when reading a published work" [3]. While a published paper carries with it the assumption of correctness, a submitted paper must be read with an open mind, with no previous assumption about its quality.

The peer review approach can be applied not only to the writing of articles, but also to other tasks. For instance, analysis and programming assignments can use the approach to expand student's acquaintance about the professional reviewing and critiquing skills that their future profession demands [2].

One area in which the peer review process is particularly promising is distance learning. However the experience reported here was conducted in a traditional classroom, the whole process may run through the Internet. If the students understand how it works and resources are offered in digital form (especially digital libraries), the possibilities of success are high. Even the presentation sessions may be carried out (using videoconference, for instance).

A serious limitation of the approach is the heavy amount of bureaucracy it generates. This work is burdened on the organizer, as section IV indicates. Some of the functional requirements of a software interface for peer review application in learning are: website configuration, CFP and review form publication, student data input, paper submission, referee allocation support, authorship omission, acknowledgment of reception, and author notification.

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Ms. Bento is a student of Psychology at UNIVALI at Biguaçu-SC, Brazil. She is assisting the first author in undergraduate courses on Databases as a specialist in Psychology of Education, under the supervising of prof. Maria do Rosário Stotz.

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