Web-Based Peer Review: The Learner as both Adapter and Reviewer

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Abstract—**This study describes an effective web-based learning strategy, peer review, used by 143 computer science undergraduate students in an Operating Systems class at a Taiwanese university. Peer review, based on social constructivism, can be easily implemented via the authors' well-developed web-based peer review (WPR) system. Through peer review, the authors hope to form an authentic learning environment similar to an academic society in which a researcher submits a paper to a journal and receives reviews from society members before publication. Students using this learning strategy are expected to develop higher level thinking skills. The WPR system functioned in the following roles in this study: 1) an information distribution channel and management center for assignment submissions and peer review; 2) a forum for peer interaction and knowledge construction; and 3) storage for knowledge construction procedures. An evaluation of learning effects and students' perceptions about peer review during the spring of 1998 revealed that students not only performed better under peer review, but also displayed higher level thinking skills, i.e., critical thinking, planning, monitoring, and regulation. Students perceived peer review as an effective strategy that promoted their learning motivation. However, merely being an effective reviewer or an effective author may not excel in a peer review environment. The most effective individual appears to be the strategic adapter who effectively constructs a project, adjusts to peers' comments, and serves as a critical reviewer as well.**

Index Terms—**Constructivism, metacognition, peer review, web learning.**

I. INTRODUCTION

IN recent years, systems and learning theories have been developed for web-based learning in higher education [1]–[5], while the effectiveness of those implements have been empirically evaluated as well [1], [6]. However, higher level learning such as cognitive monitoring or critical thinking has received relatively little attention [7]. Most researchers concur that cooperative learning is the major approach when learning and teaching theories are distributed by the world wide web [4]. Generally, the cooperative learning approach utilizes the web as a media for information distribution and a channel for group interaction. Therefore, considerable attention has been paid to providing learning materials retrieved from the web and creating conducive environments to promote effective group interaction [4], [8].

Unlike cooperative learning that promotes cohesive teamwork, this study describes a web-based learning strategy, peer review, that values exchanging critical feedback among peers and modifying works according to peer feedback. This strategy is supported by a newly emerging trend of learning theory, social constructivism, promoted by researchers such as Novak [9], Resnick [10], and Rogoff [11]. Through peer review, an authentic learning environment can hopefully be fostered in which students actively construct knowledge similar to the manner in which scientists do. Peer review is used to model the journal publication process of an academic society. Each student takes the role of a researcher who hands in homework projects and simultaneously plays the role of a reviewer who comments on peers' projects. During the process, the teacher functions not merely as a knowledge giver, but rather like a journal editor. The instructional aim is to enhance learners' higher level thinking by mutually exchanging critiques among peers. Peer review is not just an economic replacement for teacher assessment because in this study the teacher evaluated each student's assignment after the peer review process.

The web-based peer-review (WPR) system, developed in 1998, was used to manage peer-review activities. Following the development of WPR, the learning effect of WPR process is being evaluated via current study. Also examined herein are students' perceptions about WPR, opportunities to execute higher level thinking, and observations concerning who performs better in WPR.

The rest of this paper is organized as follows. Section II introduces the major learning theories, constructivism and social constructivism underlining peer review. Section III and Section IV describe peer review and its anticipated learning gains. After the research questions are presented in Section V, Section VI summarizes the research methodology. Following a thorough discussion of the results of the empirical study in Section VII, conclusions and implications are drawn in Section VIII.

II. CONSTRUCTIVISM AND SOCIAL CONSTRUCTIVISM

Constructivism theory is highly promising for web-based learning, from which many new strategies are emerging. Constructivists, such as Novak [9] and Resnick [10], propose that the construction of new knowledge starts from one's observations of events through past experiences one already has. Learning something new involves changing the meaning of one's previous experiences. In other words, learning means to construct or modify ones' inner knowledge structure. During this process, learners actively acquire, not passively receive or

discover knowledge. Learning should be evaluated by revealing a learner's inner knowledge structures rather than measuring his/her behavioral performance. Therefore, web learning strategies in line with constructivism must focus on how computer networks support active knowledge construction of learners.

Social constructivism, a branch of constructivism [10]–[12], claims that although learning requires that an individual is responsible for developing one's own knowledge structure, learning a concept requires exchanging, sharing, and negotiation, as well as occasionally drawing on the expertise of more knowledgeable individuals. Learning involves both personal inner process and social aspect. Although many cognitive theorists have proposed models of inner learning process, social constructivism uniquely emphasizes the social aspect of learning [13]. This theory draws attention to the social context that individuals share or question other's ideas to construct and modify their own knowledge.

Following such a trend, the goal of teaching is to achieve shared meaning and active participation of all students. In addition to creating an authentic environment that closely resembles daily life circumstances with all kinds of challenges and social interactions, a teacher must motivate students' active knowledge construction. Moreover, teachers must be available to assist students when needed. Rather than authoritarian figures, teachers are more like knowledgeable "old-timers" who facilitate newcomers (students) in appropriate community-specific practices and resources [12]. This learning theory leads to acknowledge the effects of social interaction on facilitating learning. While classroom social interaction is not limited to teacher and students, peers interaction is the major concern for the current study.

III. PEER REVIEW

Peer review effectively allows academic societies to construct knowledge through social sharing and competition. In this study, an authentic peer review environment was formed in an undergraduate class made up of third-year computer science majors. According to social constructivism, students can hopefully achieve deep learning in such an authentic learning environment via social interaction.

Specifically, the undergraduate students in this study were asked to act as true researchers. Students worked independently and submitted homework in HTML format. The system then posted students' projects at a demonstration area and assigned several peer reviewers for each student. The reviewers rated and commented on other's homework. The submitters then had to make follow-up revisions to the original work in line with the comments received. After three rounds, the teacher graded homework based on the evaluations of the peer reviewers.

Under these circumstances, the teacher functions like a journal editor while the participating students function as either authors or reviewers. To receive high marks in such a class, a learner must play multiple roles: first as an effective author, then as a reviewer with critical thinking, and finally as an adapter who benefits from other reviewers' comments to make further improvement.
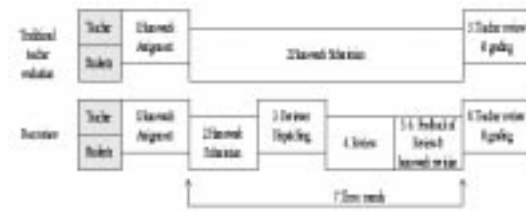

Fig. 1.   Comparison of peer review versus conventional teacher evaluation.

Related studies [14]–[18] have used peer review (or so called peer assessment, peer appraisal) in civil engineering, business, writing, and geography classes of higher education in several countries. Many peer assessment studies may only ask students to evaluate and comment on peers' works in a summative way, i.e., give a final grade for others' work. In such cases, less peer interaction occurs than in the current peer review. Therefore, less peer pressure is evoked for further knowledge modification and construction.

Some validity problems of peer review have not been resolved [19]. For instance, students may underrate their peers (to hurt their competitors) or overrate them (to raise all scores). Moreover, agreement between teacher evaluation and peer evaluation was not high enough to demonstrate the validity of peer review. However, preliminary results [15], [20]–[22] have shown favorable feedback from both students and teachers. While comparing cultural differences, Carson and Nelson [23] found that in peer review interaction, Chinese-speaking students' preference for group harmony prevented their critiquing peers' work. In general, peer review must be more closely examined to understand its overall effectiveness.

In sum, this study adopts the following eight steps for implementing peer review. In Fig. 1 peer review and conventional teacher evaluation are depicted to compare their procedures and the roles of teacher and students.

1) The teacher posts the homework assignment.
2) Each student prepares the homework in HTML format and uploads it to the WPR System.
3) The system randomly assigns six reviewers for each student.
4) Each reviewer rates and comments on others' assignments in the system.
5) The system distributes the ranks and comments back to each student and informs the teacher on the general status of the class.
6) The author must revise the original assignment in line with comments received.
7) Steps 2–6 are then repeated three more times.
8) The teacher gives 1) an assignment grade based on the six reviewers' grades and 2) a review grade about each reviewer's comment quality.

IV. ANTICIPATED LEARNING GAINS FROM PEER REVIEW: METACOGNITION

As widely anticipated, peer review promotes students' metacognition [7], [19], [24]. Metacognition has two separate, but related aspects: knowledge and regulation of an individual's

cognition. The knowledge aspect refers to knowing about one's own cognitive status (e.g., one's strengths, weaknesses, and study habits), knowing about tasks (i.e., difficulty and demands of a task), and knowing about learning strategies. The regulation aspect in contrast refers to the control of one's cognitive process, e.g., planning, monitoring of execution, self-checking of cognitive progress, and substituting a cognitive strategy if not effective [25], [26].

What do students achieve during the peer review process? In completing one's own project, a student may plan the contents and procedures to be shown in the project, then execute the plan. In reviewing peer homework, one must read, compare, or question ideas, suggest modification, or even reflect how well one's own work is compared with others. While processing these cognitive functions, one has to monitor the adequacy of cognitive functions adopted. If not adequate, or ineffective, one then must regulate cognitive functions accordingly.

Many students, particularly those with low motivation and achievement [25], are unwilling to do mindful works, such as executing higher level cognitive processes. Learners in the peer reviewer process receive review comments from peers, but not directly from the teacher as in the traditional process. Therefore, peer pressure, as a motivating factor, may push students to perform higher level cognitive functions [19].

V. RESEARCH QUESTIONS

This study examines the learning effect of and students' perceptions about peer review. Specific research questions are listed below.

1) Do computer science majors learn effectively through WPR?
2) Do students perceive to benefit from peer review and prefer using it? Do students express negative attitudes toward peer review?
3) Do students display metacognition skills during peer review?
4) Does the effective author or the critical thinking reviewer perform better in the final examination? Is an effective author always a good reviewer?

VI. RESEARCH METHODOLOGY

A. Participants and Course Contents

One hundred forty-three third-year computer science majors participated in the study. They were students enrolled in a mandatory course entitled Operating Systems in a research university in Northern Taiwan.

The course covered eight topics during 18 weeks of the spring semester in 1998, i.e., Introduction, Processes, Memory Management, File Systems, Input/Output, Deadlocks, Case Study 1: UNIX, and Case Study 2: MS-DOS. The assignment required students to select a topic from the above eight areas, read related articles and books, summarize the main ideas, and suggest future developments of the area.

B. Measurements

1) Achievement: Achievement was measured by three indexes: assignment, review, and final examination. The assignment score (ranging from 0 to 60), rated by the teacher based on peers' evaluations, was a combination of assignment performance in three rounds of peer review. The review score (ranging from 0 to 20), i.e., an indicator of each reviewer's comment quality, was rated by both the teacher and two teaching assistants. The final score (ranging from 0 to 100), based on multiple choice and essays in a standard paper-pencil test, was a summative evaluation of the students' achievement.

2) Perceived Satisfactory: The perceived satisfactory was measured by a questionnaire containing ten questions about the students' perception on learning effect and self-motivation in peer review as well as the adequacy of review criteria. Students were asked to rate their satisfactory on a five-point Likert scale, ranging from 1 = strongly agree to 5 = strongly disagree. A typical statement about the effectiveness of peer review is "I think peer review is an effective means of studying computer science courses." "The peer review process motivated me to do more work than other courses require" is a statement about motivation in peer review. A statement about review criteria states, "Our peer review criteria can give valuable information for both authors and reviewers." An open-ended question is attached to each statement to elicit free opinion or modification suggestions for peer review and the WPR system.

3) Metacognition: The teacher and a teaching assistant together read each reviewer's comments to see who and in which round a student demonstrates higher level thinking. The authors looked for qualitative evidence of several cognitive and metacognitive strategies, i.e., critical thinking, planning, monitoring, and regulation. Critical thinking refers to students' appropriate reasoning, questioning, and critical evaluation, when receiving new information or applying previous knowledge to new situations. Planning refers to a student's goal setting, task analysis, and retrieval of prior knowledge in the initial stage of a project. Monitoring refers to track attention while learning, self-testing, and questioning about the learning progress. Regulation refers to the fine-tuning and continuous adjustment of cognitive activities. A review comment containing keywords from any of these four kinds of higher level thinking was coded into an adequate category.

C. Web-Based Peer-Review System

The WPR system functioned in the following roles during the study: 1) as an information distribution channel and management center for assignment submission and peer review; 2) as a media for peer interaction and knowledge construction; and 3) as a storage center for knowledge construction procedures. In addition to formal interaction through the WPR system, teachers and students can post information in a Bulletin Board Service (BBS) designed for the course to express their opinions about the course and system.

Teachers can create a new course on the WPR system homepage by using a template form that can be modified according to the specific requirements of different courses (Fig. 2). Once a new course is created, a new directory with the course name
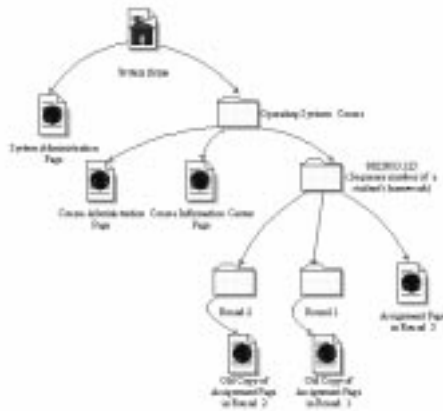
Fig. 2.   Homepage hierarchy of the WPR system.

TABLE   I
DESCRIPTIVE STATISTICS AND PAIRED *t* TEST OF COMPUTER SCIENCE
STUDENTS' ACHIEVEMENT IN THE OPERATING SYSTEMS CLASS

Achievement Indexs	Mean	Range	Standard Deviation	Paired t test	Skewness
Review	8.07	0~20	3.82	--	0.688
Assignment (with peer review)	91.90	0~415	4.12	10.428	-2.785
Final Examination (without peer review)	43.76	0~79	15.91	(p < .001)	-0.334

appears. Meanwhile, all other relevant homepages are automatically produced, and then some programs are linked to the new directory.

Through the course administration homepage, teachers and assistants can effectively manage the learning process, such as maintaining students record files, annoucing homework assignments, asking for peer evaluations, posting evaluation schedules, navigating students' homework, and browsing through the evaluation results.

Through the course information center, students can hand in and revise their assignments or review others' works. Students are asked to save their assignments in HTML format, and a common gateway interface (CGI) program is designed for users to upload homework to the website. The purpose is to ensure easy access to all uploaded assignments through the Internet. A user can upload more than one file to his or her directory and make his or her own linkage through the HTML tag. After uploading the assignment, the user must refer to a filename as an index for linkage. Because a blind evaluation is used to ensure fairness and willingness to critique, a serial number is attached to each assignement which is allocated to a particular directory. The system then duplicates each assignment to another directory before the evaluation of each round. Doing so keeps different assignment versions in various rounds intact for further analysis.

VII. RESULTS AND DISCUSSION

Research Question 1: *Do computer science majors learn effectively through WPR?*

The assignment score was achieved by a student under peer review, while the final score was gained by a student alone (without peer review). Comparing the assignment score and the final score revealed that students performed better with peer review (paired $t = 10.428$, $p < 0.001$, in Table I). However, this study has no control group, thereby making the causal effect of peer review uncertain. It is better to be conservative in claiming a positive learning effect of WPR and be aware that this result is exploratory in nature.

Question 2: *Do students perceive to benefit from peer review and prefer using it? Do students express negative attitudes toward peer review?*

The questionnaire analysis revealed that 64.71% (chi square $= 4.41$, df $= 1$, $p < 0.05$) of the participants viewed peer review as effective and that they benefited from using this learning strategy. Through open-ended questions, students reported that the benefit of peer review came from reading many peers' works, i.e., summaries of some important topics provided by peers, and obtaining critical insight from others' work during the review process. Many students mentioned that they compared their own work with peers' work and were more aware of their advantages and weaknesses than when in conventional teacher evaluation situations.

About 67.86% (chi square $= 7.14$, df $= 1$, $p < 0.05$) of the participants reported that they preferred using peer review. However, about 9% of the participants questioned the fairness of peer review and suggested decreasing the weight of peer review and increasing the weight of teacher evaluation in the total score of the course.

Regarding the review criteria, many students found that a total score with a global comment for an entire assignment might not offer sufficient information for further revision. Many students suggested using multiple review criteria, such as relevance of the project theme to the course content, appropriateness of text or explanation, richness of text or explanation, or appropriate linkages among relevant concepts.

Question 3: *Do students display metacognition skills during peer review?*

The qualitative analysis of metacognition indicated that 77% of reviewers displayed all four kinds of higher level thinking: planning, monitoring, regulation, and critical thinking. However, critical thinking and monitoring were more frequently used than planning and regulation.

Question 4: *Does the effective author or the critical thinking reviewer perform better in the final examination? Is an effective author always a good reviewer?*

Several correlation analyzes among the three indexes of achievement were performed. Results showed that multiple correlation among assignment, review, and final examination were significant ($R = 0.419$, $p < 0.01$), as shown in the overlapping areas among the three circles in Fig. 3. Notably, there was a significant high degree of association among the performances in assignment, review, and final examination.
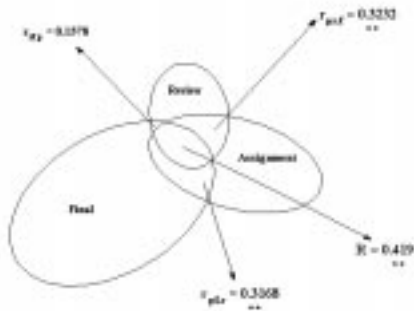
Fig. 3. Multiple correlation and partial correlations among assignment, review, and final examination. ($^{**}p < .01$).

TABLE II
FOUR CATEGORIES OF LEARNERS DIFFERENTIATED BY ASSIGNMENT AND REVIEW PERFORMANCE

		Assignment Score	
		High	Low
Review Score	High	Strategic Adapter	Effective Reviewer
	Low	Self-Centered Learner	Failure

There was a significant partial correlation ($r_{\mathrm{pr.f}} = 0.3232$, $p < 0.01$) between assignment and review when the influence of final examination was eliminated. Therefore, when the final score was held constant, this person was more likely to receive a high review score as well if he or she received a high assignment score. Besides, there was also a significant partial correlation ($r_{\mathrm{pf.r}} = 0.3168$, $p < .01$) between assignment and final examination when the influence of review was eliminated. Thus, when the review score was held constant, if one achieved a high assignment score, he or she had a higher likelihood of achieving a high final score as well.

However, the partial correlation ($r_{\mathrm{rf.p}} = 0.157$, $p = .06$) between review and final examination (while the influence of assignment was eliminated) was not significant. There was no clear association between review score and final score when the assignment score was held constant. In summary, the above correlation analysis reveals that merely being an effective reviewer may not gain a high grade in the final course evaluation. An effective reviewer must also be a quality author to ensure a high final score. However, effective authors are capable of making high quality comments in peer review.

Based on assignment and review performance, four categories of learners were identified specified in Table II. First, the person high in both assignment and review scores will excel the most in the WPR process. This person is referred to as a strategic adapter. Since the assignment score combines assignment performances of all three rounds of peer review, a high assignment scorer must be someone who can strategically adopt peers' critiques for self-improvement. Second, a reviewer who makes significant contributions to peers' works but cannot get a high assignment score is viewed as an effective reviewer. The above correlation results indicate that this study contained few effective reviewers. Those who received high assignment scores but cannot act as effective reviewers are known as self-centered learners. In this study, some computer science

students were self-centered. Finally, a failure is one who gets low assignment and review scores.

VIII. CONCLUSIONS AND IMPLICATIONS

While this study did not use an experimental design to compare achievement experimental and control groups, these findings are preliminary in nature. This study has demonstrated that peer review is an effective web-based learning strategy for computer science majors in universities that is parallel with findings of Falchikov [20], Freeman [21], and Topping [19]. During the peer review process, students displayed higher level thinking such as critical thinking, planning, monitoring, and regulation, similar to the results of Davis and Berrow [7]. Students also reported they were motivated to learn more through the peer review process. Finally, merely being an effective reviewer or an effective author may not succeed in a peer review environment. The one who excels the most is the strategic adapter who can effectively construct assignments, adjust to peers' comments and, at the same time, be a critical reviewer. The strategic adapter is similar to the self-regulated learner, defined by Schunk and Zimmerman [26], who can set personal educational goals and then generate thoughts, feelings, and actions to attain them.

Although the participants of this study were third-year computer science majors, it is believed that the peer review strategy is also effective for undergraduate students in related fields, such as computer, electrical, and electronics engineering. Based on the above findings, the authors conclude that the WPR system creates an authentic learning environment, as suggested by social constructivism.

Further study should examine the effectiveness of WPR in different fields, tasks (e.g., structured or ill-structured), as various evaluation tools (e.g., summative or formative), and in various formats (e.g., two rounds or three rounds). Finally, the authors encourage future research using experimental designs to confirm the causal effect of WPR. However, merely providing a learning-assisted system may not necessarily promote active knowledge construction. An effective learning strategy supported by the system is of priority concern.

Further study should also analyze the reasons some students cannot adapt well in peer review (failures in Table II). Teachers should not only closely monitor self-centered learners and effective reviewers, but also analyze what cognitive strategies they lack. In doing so, all computer science students can eventually be equipped to become strategic adapters, thus equipping them for challenges in the workplace as well.

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