Collaborative Learning Using Wiki Web Sites for Computer Science Undergraduate Education: A Case Study

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***Abstract*—This paper proposes a collaborative approach to enhancing the student learning experience based on Web 2.0 principles. Specifically, wiki Web sites are used by students for collaboration and for publication of course assignments, which are then shared with the class. Web 2.0 principles include: the Web as platform, harnessing collective intelligence, data are the next Intel Inside, and rich user experiences. Based on a case study in a junior-level undergraduate class, this paper studies a set of six factors with comprehensive grading and evaluation criteria that are critical to make this approach successful. The six factors are knowledge base, motivation, research, social aspects, presentation, and feedback and support. The data collected show that most of the students who participated feel that this approach is exciting and rewarding, and that even some undergraduate students are able to produce original and innovative concepts. The data also show other interesting phenomena with respect to motivation, undergraduate research, and social aspects. Finally, the paper proposes a methodology of conducting a wiki project in a university class using a cyclic constant improvement process.**

***Index Terms*—Collaborative learning, social networking, Web 2.0, wiki.**

I. Introduction

ONE recent trend in education is the application of social computing and Web 2.0, as evidenced by several initiatives in the U.S. and Europe [1]–[3]. These initiatives raise many open research questions and identify various opportunities. This paper addresses some of these questions and opportunities by integrating Web 2.0 activities into the classroom by presenting a process for a class assignment that includes the identification of critical success factors for its application. This process was tested through a case study using the assignment in the junior-level course CSE360: *Introduction to Software Engineering*. Data from surveys and student grades indicate that the critical factors presented in the case study have enhanced the educational experience and improved student performance.

These factors ensure that Web 2.0 is leveraged to create a Web-based education infrastructure that does the following:

- allows the collective intelligence experiences and creativity of its multiple users to be harnessed;
- enables continuous personalized learning;
- promotes learning experiences and rich user experiences that can integrate local, remote, and virtual elements.

The following Web 2.0 principles and design patterns played a central role in the study of this paper.

1) The Web as Platform [4]: Web 2.0 treats the Web as the platform, in contrast to the conventional practice of treating desktop computers as the platform. A Web-based computing platform implies that instead of focusing on computer-based education, attention should be focused on Web-based education. For education, the Web is a platform for many activities, including: 1) knowledge publication, dissemination, and sharing; 2) reference literature and other learning materials; 3) assessments; 4) communication and collaboration among teaching staff and students. An emerging Web-based platform trend can be seen in the amount of educational materials (such as videos, audios, presentation slides, learning objects, papers, and textbooks) currently available via the Web. Students can also take examinations via the Web and work on joint projects using Web-based collaboration tools such as *Google Docs*. However, the Web will not be the only platform for education as students can still learn via regular class instruction and other means.

2) Harnessing Collective Intelligence [4]: In Web 2.0, users can be active contributors rather than just passive observers. The materials developed by active users may have significant innovation and economic value. This collective intelligence has been demonstrated in drug development, mining exploration, e-commerce, and encyclopedias. Wikipedia is an outstanding example, with more than 75 000 active contributors as of April 2009 [5].

This collective intelligence can be used for both instructors and students to create education materials that can have great value. Furthermore, those who participate in creating the material benefit from this process. The collective intelligence of instructors, teaching assistants, and students can be used for creating and publishing subject area knowledge, instruction materials, instruction methods and tools, educational standards and curricula, assessment materials, and student performance assessment and for the evaluation of education materials. Using

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the Web as the platform, collective collaboration can be done in both space and time. Users can rank and review items. Items that are used in conjunction with each other can be tracked and used for suggestions. Temporal aspects (time of day, month, or year) can be tracked as well.

Students can also actively contribute to the learning process and content development. This participation follows the theme of *learning by sharing and contribution*. With the Web, students can even collaborate with people unknown to them on certain topics, as with Wikipedia, where people who do not know each other can collaborate to write encyclopedia materials.

3) Rich User Experiences [4]: By using the Web, students can have a rich user experience in education, which includes viewing and listening to lectures; reading presentation slides, papers, and education materials; taking examinations; and collaborating with fellow students.

4) Data Are the Next Intel Inside [4]: Data are important in Web 2.0. As more people use a Web site, more data are generated, and data become more accurate. Education materials will have similar characteristics. The more people participate in education material development, the better the quality of material will be, and the more education materials will become available.

The paper is organized as follows. Section II discusses related work. Section III outlines the design of the class project, including the class design factors, the wiki-based project process, and grading criteria that make this type of project assignment successful. Section IV describes a case study and presents data collected during the study. Section V evaluates the case study with respect to Web 2.0 principles, current research e-learning questions, and opportunities for action. Section VI presents a process for instituting learning activities that incorporate wiki Web sites, and Section VII concludes the paper.

II. Related Work

Many studies indicate that Web 2.0 is the future of education, as discussed below. This section examines visions and issues in applying Web 2.0 to education.

Cyberlearning, the use of the Web for learning, has received much attention lately, including a 2008 NSF report [2], which identifies key research questions and opportunities for action.

The term e-learning 2.0 was proposed in 2005 by Downes in recognition of the fact that computer-based learning (e-learning 1.0) will be transformed by Web 2.0, and that this transformation will be more of a social change than a technological change [6].

EDCOMP [7] is a Web-based computer simulator with a graphical user interface used for computer architecture and organization instruction. Students found the rich user experience provided by EDCOMP to be instructive and easy to use. Instructors reported that students who used EDCOMP were better prepared and had deeper understanding of the concepts.

The Ecole de Polytechnique Fédérale de Lausanne (EPFL), Switzerland, introduced a Web-based experimentation environment to perform laboratory experiments in automatic control, biomechanics, and fluid mechanics. The study found that the key component in this environment was a Web-based collaboration tool, eJournal, a Web service that enables the collection and sharing of notes and experimental results with both peers and teaching assistants [8].

A 2006 case study by Grant on using wikis in classrooms described a process for using wikis as a tool for a collaborative team project [9]. The study described social issues related to this activity, such as how students resolve disagreements about content. The study concluded that wiki software can be a useful tool for education and also noted that problems arising from social and cultural practices can hinder its usefulness.

These three studies show the value of using Web 2.0 principles in education.

In [10], a study of social software and learning that looked at moving from e-learning to c-learning is presented, where c-learning is community, collaborative, and/or communicative learning. The paper defined key attributes of social software for learning including communication between people, providing, gathering, and sharing resources, delivering collaborative collecting and indexing of information allowing syndication and assisting in the personalization of priorities, knowledge aggregation, and creation of new knowledge, and delivering to platforms for creators, recipients, and context. The paper proposed several questions, two of which will be addressed in this paper.

"How can we recognize and validate the learning that some young people already achieve through using social software?" and *"What actions have to be taken to enable learner choice and voice that make the use of social software in the education system an available option? What barriers have to be removed?"*

A JISC report [11] described and cataloged Web 2.0 technology's importance to education, including blogs, wikis, tagging, social bookmarking, folksonomies, multimedia sharing, audio blogging, podcasting, RSS, social networks, aggregation services, data mash-ups, tracking and filtering content, collaborating, browser-based office-style software, and crowd sourcing.

An EU report [3] discussed objectives, activities, pedagogical issues, and barriers in using Web 2.0 for education in Europe. The report also cited many case studies and tools used. One example is "Welker's wikinomics" [12], in which a wiki tool is used in secondary education where youth contribute their comments about a blog in a wiki Web site after having once learned the relevant materials in the classroom.

Service-oriented computing is often associated with Web 2.0, where software services are published and discovered and then composed into applications [13]–[16]. Another interesting fact is that STEM knowledge can be embedded in service specifications, and thus young people can learn service-oriented computing while refreshing their STEM knowledge [17]–[19].

III. Class Design With Wiki

Some of the Web 2.0 principles are not new to education. Collaboration has been a standard part of university education. Another Web 2.0 concept, sharing, has been advocated in software engineering for many years. Many software engineering concepts, such as open source [20], design patterns [21], and object-oriented frameworks [22], all support sharing.

There are constraints and regulations that need to be considered when incorporating Web 2.0 principles in a classroom, which can be physical, social, administrative, or other.

1) Physical Constraints: In typical university classes, students still attend lectures and laboratory sessions regularly on campus. While online classes are available, most students still

attend classes in person. Thus, Web 2.0 must be practiced within this physical constraint. The use of Web 2.0 should increase student's active participation, both physically and via the Web.

2) Social Constraints: One important feature of Web 2.0 and social networking is that the people involved should be civil to each other in the cyber world. However, a social cyber world is not possible without a social physical world in the classroom. Specifically, students will not be happy if the instructor simply sends out instructions via the Web while keeping students isolated and lonely in the physical space.

3) Administrative Constraints: Web 2.0 does not change the existing course and accreditation requirements. Thus, the application of Web 2.0 can only be used to enhance the existing instructions, rather than changing the course content. For example, many courses at universities are subjected to ABET accreditation requirements [23], and the course must still meet these requirements when Web 2.0 is introduced.

4) Quality of Published Work: While the wiki approach encourages students to publish their work for sharing, the quality and value of materials published are important. The wiki Web sites developed must have educational value to both students and external viewers. The materials must be correct and presented in a logical manner. Otherwise, the students will not benefit from the application of Web 2.0.

5) Technical Support: Students need to know how to use the wiki software to publish their work. Initial technical support can be provided so that students have a resource for getting specific questions answered. As students become proficient, they also become a support resource for each other. Finally, collaboration tools (such as a wiki) can be used to maintain answers to frequently asked questions and tips on how to use the technology.

6) Grading Criteria: The grading criteria must be fair and may be extended to assess understanding of the new dimension in learning.

7) Student Peer Evaluation: Students are asked to rate each other's finished products. This evaluation has many benefits. When students evaluate their peers, they learn about the content and style of their peers' work. By rating others' efforts, students gain experience in trying to be fair, objective, and impartial. Ranking and rating are important to many Web 2.0 applications. By learning about ranking and rating, students become better net-citizens.

A. Pilot and Case Study Selections

The first experiment using Web 2.0 in education at Arizona State University, Tempe, took place during the Fall 2008 semester in CSE 494/598, a senior/graduate class on service-oriented computing. Students created blogs and published articles about service-oriented architecture (SOA) topics. In general, students were excited about this approach. Some of the Web sites had several hundred hits or more within two days of publication. This level of interest was surprising. Many of the hits could be attributed to friends and families of the students. Some topics were apparently interesting enough for search engines to index them, where they were discovered and visited by those interested in the Web site's topics.

At the end of semester, most students indicated that publishing their research on the Web was an excellent way of instruction.

The success of the pilot study provided evidence that this approach had merit for a seminar-type class at the senior/graduate levels. It was not clear that this approach would be suitable at the undergraduate level, where students have less experience and knowledge in related topics, and classes need to have better structure than a seminar class. The work reported in this paper selected an undergraduate class, CSE360: Introduction to Software Engineering, as the subject for a case study. CSE 360 is a required junior-level course for Computer Science and Engineering majors.

B. Class Design Factors

This paper identifies six learning factors relevant for wiki Web site development in an undergraduate class. A table with a detailed description of these factors is available at *http://asusrl.eas.asu.edu/cse360/Factor.htm*. Briefly, these factors are the following.

- **Knowledge base**: Students should contribute relevant and useful materials pertinent to the class. Fellow students and instructors should find these materials useful, educational, and even entertaining. Knowledge may include principles, practices, technologies, history, photographs, and graphs. The key evaluation criteria are *relevancy* and *correctness* of contents.
- **Motivation**: Motivation for the class comes from the students' own interest in the material, their receiving good grades for the assignments, and recognition from their classmates, friends, teachers, and family. Students are allowed to choose relevant topics for their projects. This choice provides for a sense of ownership, which also adds to student motivation.
- **Research** (harnessing collective intelligence): Students should be able to conduct semi-independent research in an undergraduate class, seeking materials beyond those taught in the lectures and textbooks. Students should also select those materials that are most useful to the class. Students are provided with an initial set of suggested topics, or they can, with the instructor's approval, choose a topic of interest to them. They can seek guidance from the teaching assistants and instructors during their research. Once they have their initial Web site completed, they will be given feedback by the instructor and fellow students so that they can improve their Web sites.
- **Social aspects**: Students should be involved in this project in a socially friendly manner. This socialization is accomplished by having the students work in teams. Furthermore, the students need to perform peer evaluations of the materials developed by other teams. To encourage peer evaluation and collaboration, students need to cast their votes on the best Web site developed. The best Web sites will receive a grading bonus.
- **Presentation**: Students should organize the materials on their Web sites in a logical manner; furthermore, students should be able to present their Web sites in front of fellow students in the classroom.
- **Feedback and support**: Bidirectional feedback occurs between the teaching team and students. The teaching team provides feedback and suggestions to students as they perform research and assemble their wiki projects. Students

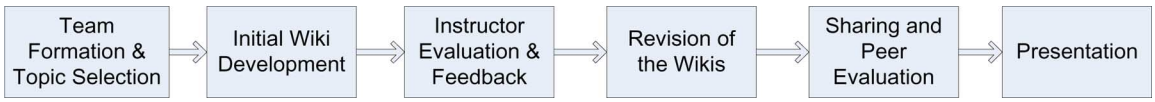

Fig. 1. Project design for the course.

also provide feedback on the difficulties and issues encountered. Furthermore, students provide feedback to fellow students by peer evaluation and ranking of the wiki Web sites. The student evaluation of the teaching team includes assessment of the effectiveness of the wiki Web sites for education and of the various activities and elements of the wiki projects including presentation, Web site design, and technical support.

C. Class Design

The catalog description of the class is "software life cycle models; project management, team development environments, and methodologies; software architectures; quality assurance and standards; legal, ethical issues." The course has three objectives based on ABET requirements [23].

- Students will develop an understanding of software engineering topics, including basic software engineering approaches supporting requirements, design, coding, testing, maintenance, and quality assurance.
- Students will become aware of national and international standards. Students employ a disciplined process for acquiring requirements, developing software architecture, and reasoning about the correctness of software programs while adhering to a code of ethics.
- Students will learn to work in a team setting where project planning and tracking is used as a basis to support systematic software development, software inspection, software product documentation, and oral presentation.

Note the importance of documentation, oral presentation, and collaborative learning via team development stated in the objectives. The overall process for a collaborative assignment is shown in Fig. 1.

Students were exposed to Web 2.0 at the beginning of the class by being assigned reading on this topic as homework. They were also told that they would develop a wiki in the middle of the semester. This preliminary exposure helps to establish a mindset for students and helps to prepare for the wiki project. A brief description of each step in the progress of the case study follows:

1) Team Formation and Topic Selection: A shared spreadsheet was created on Google Docs so the students could network and form teams. The students formed 25 teams of three members each. The instructor provided a list of more than 30 topics relevant to software engineering. Among the 25 teams, 21 chose from this list, while the other teams chose their own topics. The project topics can be found at *http://wiki.asu.edu/cse360*.

2) Initial Wiki Development: Students were given two weeks to search on the Web to learn about their chosen topic, understand those materials and their content, and share their learning by creating a preliminary wiki. By sharing this Web site, students demonstrate their mastery of the material. It is important for students to list the Web sites visited as well as papers or books read to produce the content. Note that neither the instructor nor the teaching assistants were involved in selecting reference materials. They did, however, assist students to find references if they requested help.

3) Instructor Evaluation and Feedback: There was significant variance in wiki Web sites with respect to their accuracy. Most (more than 85%) of the initial wiki Web sites contain either incorrect or insufficient information, or even conceptual mistakes. In fact, most wiki Web sites can be considered preliminary or tentative. The instructor read each Web site and provided individual comments to each Web site. The comments were passed to team members confidentially. To encourage students to improve their Web sites, the initial Web sites were graded only on the basis of whether students turned in the assignment on a timely basis.

4) Revision of the Wikis: Students were given one week to revise their Web sites based on the instructor feedback. Twenty-four of the 25 teams were able to complete their Web sites and incorporate the feedback. The completed Web sites can be seen at http://wiki.asu.edu/cse360.

5) Sharing and Peer Evaluation: The 24 completed Web sites contained relevant and useful information related to the course, and most of the material was correct. Students also evaluated the Web sites produced by others and voted on the best Web sites. Students voted on the top three Web sites according the following criteria: a) most innovative concepts introduced; b) most useful education materials; and c) best Web site design.

6) Presentation: Oral presentations are important as they reveal how well the team has mastered the materials and how well they worked collaboratively. From oral presentations, it is apparent that while most sites were the result of team efforts, a few were the results of a group of individuals who each just worked exclusively on their particular parts without having bothered to learn and review the materials provided by teammates. Furthermore, an inability to answer questions during oral presentation shows that they might not have carried out their studies thoroughly.

D. Web Support for Collaboration

To be better prepared for Web 2.0, this class used the Web extensively for a variety of activities.

1) Identifying Partners in a Community: In this case study, a shared Google spreadsheet was used to track team formation. The spreadsheet also allowed teams to track each other. Each team described their topic and provided a link to a wiki that contained their project work. This method of team formation provides the means for a student to make an informed choice of team members and avoids the situation where students on a team do not share common interests.

2) Enable Personalized Learning: Students have different interests, and the instructor should encourage students to explore and pursue their interests on the topics related to the class. For

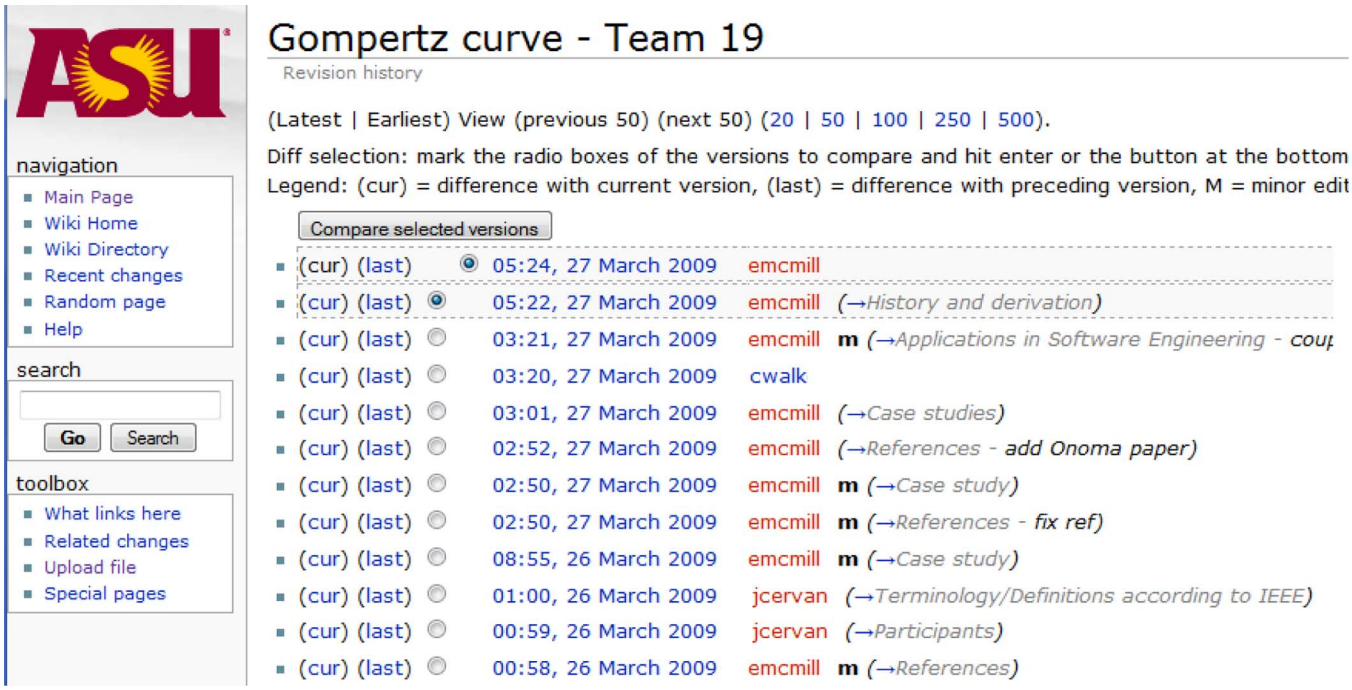

Fig. 2. Progress tracking.

example, a team of electrical engineering students may be interested in embedded system software design, and a team of practicing software engineers may be interested in project management. As students have different interests, the broad spectrum of topics covered by the wiki Web sites enriches the class in terms of both materials and presentation styles.

3) Peer Evaluation: In this project, evaluation was not simply confined to being between the instructor and students. It was also performed by students on each other. Students rated the work of the other students through voting and peer evaluation. Interactions that are both online and offline could thus occur.

4) Communication: Interactions between students and the instructor could be through face-to-face meetings or through online communications such as forums, social networks, e-mail, and online instant chatting. Through the online forum, the students were able to help each other to solve a problem, in addition to having an option of asking for the instructor's assistance.

5) Progress Tracking: The wiki software automatically tracks the changes. Thus, the instructing team could see the progress of each project. Fig. 2 shows an example of tracking progress.

6) Sharing Interesting Web Finds: Students were encouraged to send links on blogs, papers, and videos related to the class materials for sharing.

E. Grading and Evaluation Criteria

Fair grading was an important issue for this project. Unfortunately, each wiki Web site is unique. This uniqueness can make it difficult to provide an objective evaluation. The grading criteria must also reflect the six success factors identified in Section III-B. The fair evaluation and grading criteria are shown in Table I. Note that the evaluation criteria cover both teaching and learning efforts.

IV. Evaluation of the Case Study

A. Class Structural Data

The class used for this case study had 70 students, an instructor, a teaching assistant, and a grader. The 70 students were divided into 25 teams of two or three students. Twenty-four teams successfully completed the wiki assignment. The survey response was above 70%, with 51 students participating. The URL *http://wiki.asu.edu/cse360* contains an index of the wiki sites created by the students.

B. Student Survey Results

Student surveys were used to determine how well the class design factors were implemented in this case study. A summary of the results is shown in Table II. The detailed survey data are available at *http://asusrl.eas.asu.edu/cse360/Data.htm.*

C. Effects of Collaboration and Feedback on Grades

The paper collected data to determine whether the effort (estimated by the number of changes made to a site) that students spent incorporating feedback had an effect on the correctness of their Web site. The paper states the following two hypotheses.

H_0: The number of edits made to a Web site has no effect on the grade received.

H_1: The number of edits made to a Web site has a positive impact on the grade that the Web site receives.

Fig. 3 shows a scatter plot of the Web site grades as a function of the number of edits made to the Web site. Note that the grade scale ranges from 0–100 plus up to a 20-point bonus. The highest possible score is 120.

The Pearson correlation on these two sets of data shows a correlation coefficient of 0.35. While a trend is visible, it is not statistically significant to the 0.01 level. However, the trend is statistically significant at 0.08. In other words, the number of

TABLE I
FAIR GRADING AND EVALUATION CRITERIA FOR WIKI PROJECTS

Factors	Criteria	Instructor/TA contribution or evaluation	Student contribution or evaluation
Knowledge Base	Relevancy	Grading.	Provide relevant materials, peer evaluation, voting, and survey.
	Correctness	Grading.	Provide correct information, peer evaluation, and survey.
	References and links	Check whether the references and links are correct. Supply appropriate references if limited references.	Search and provide references.
	Length	Direct measurement.	Provide sufficient materials for publishing.
Motivation	Fair and comprehensive grading criteria	Publish criteria beforehand.	Student survey.
	Importance of publishing and sharing	Lecture on Web 2.0 principles.	Student survey.
	Recognition and Rewards	Grade bonus or certificate for outstanding perform-ance based on instructor evaluation.	Peer evaluation of other student sites. Grade bonus or other award is given to outstanding sites based on peer review.
Research	Innovation	Grading.	Search for new materials beyond textbooks and lecture notes, peer evaluation, survey, and voting.
Social Aspects	Peer evaluation by other teams	Announce peer evaluation process and criteria beforehand.	Participate and collaborate, peer evaluation and survey.
	Peer evaluation by team members	Announce peer evaluation process and criteria beforehand.	Participate and collaborate, peer evaluation, survey.
Presentation	User friendliness	Grading.	Organize materials logically, peer evaluation, voting, survey.
	Oral presentation	Grading.	Peer evaluation, voting, survey.
Feedback and Support	Usefulness of feedback	Read each wiki website and provide individualized comments.	Student survey of instructor feedback.
	Response to feedback	Examining if websites are updated according to comments.	Student updates wiki websites based on comments.

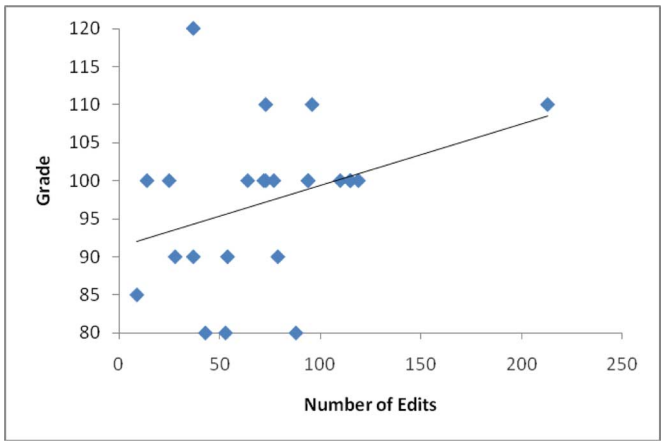

Fig. 3. Number of changes and grade for the homework.

edits is proportional to the grade at 92% confidence, but not at the 99% level. Thus, the paper cannot accept or reject either hypothesis based on the data available.

1) Length: Most of the good Web sites were of reasonable length, while short Web sites often reflect lack of dedication to the project. The paper tests this hypothesis by measuring the size of each Web site and states the following two hypotheses.

H_0: The number of words in the Web site has no effect on the grade received.

H_1: The number of words contained within a Web site has a positive impact on the grade that the Web site receives.

Fig. 4 shows the relationship between the number of words in each wiki Web site and the resulting project grade.

The relationship between the size of a Web site (as measured by the number of words of content in the site) and the grade that Web site receives shows a positive correlation. This paper calculates a Pearson correlation coefficient of 0.71, which is statistically significant to at the 0.01 level. Thus, the paper can reject H_0 and accept H_1. In other words, with 99% confidence, the size of the Web site is proportional the grade.

D. Student Comments

Students also made comments about this wiki project. One of comments was the following:

TABLE II
SUMMARY OF SURVEY RESULTS

Factor	Survey Results	Analysis	Factor Satisfied
Correctness of knowledge base	96% correct or mostly correct	Resulting wiki websites' contents were correct	Yes
Fair and comprehensive grading criteria	70% - very good or good	Overwhelming majority felt grading was fair.	Yes
Motivation – Importance of publishing and sharing	61% liked 1st wiki assignment very much or pretty much 55% liked 2nd wiki assignment very much or pretty much 72% thought this wiki project a very good or good idea for this class. 76% thought this wiki a very good or good idea for education for other classes such as English, business of economic classes.	Highly positive responses (majority of students like both assignments), and the students indicated that wiki-based assignments are a good idea for this class, other computer science classes, and even non-computer science classes.	Yes
Motivation – student learning	68% learned very much or pretty much by constructing your own wiki website. 57% -- learned very much or pretty much by reading classmates wiki websites.	Majority of students reported that the learned a lot from these assignments.	Yes
Research motivation and difficulties	73% very much or pretty much liked research as a part of class. 18% found research to be difficult or challenging.	Majority of students liked the research aspect of the class, only 18% found research to be especially difficult or challenging.	Yes
Motivation – stimulation of thinking	65% found the instructor's approach stimulated thinking.	Majority of students were stimulated by the instructor's approach.	Yes
Social Aspects – peer review	40% liked to evaluate other websites by casting votes. 98% found peer evaluation to be a great or an OK idea.	Only 40% of the students like to grade other students, but almost everyone either thinks it is a great idea or they are at least OK with it.	Mixed
Social – teamwork	80% found teamwork to be excellent or good.	Teamwork present except in some isolated instances	Yes
Social – learning from each other	66% learned very much or pretty much from their teammates during this wiki project.	Students learned from each other.	Yes
Peer evaluation of sites	84% thought that these wiki websites were mostly or somewhat organized in a logical manner. 90% thought the wiki websites were mostly or somewhat easy to navigate and the links were valid.	The websites are of good quality.	Yes
Instructor Feedback	Is instructor feedback useful? 49% -- Definitely 49% -- Neutral 2% -- No	About half the class was neutral to the feedback, but only one person was negative.	Mixed
Response to feedback	85% of the initial websites contained serious problems with content. 100% of the completed sites received a grade of 80% or better after incorporation of feedback.	Revisions according to the feedback are very important.	Yes

"*Just an idea: rather than just oral presentations on the wiki, have each group do an open discussion where they briefly present to the class and then the class discusses their work and gives feedback. Then, have another assignment similar to assignment 4 were the group modifies and add to their website based on the feedback received from the class*." This suggests an interesting way of presenting the wiki Web sites.

Overall, most comments were related to technical support, particularly related to the wiki software used. The second most common comment types were related to students' difficulty in finding reference materials using the Web search engines such as Google.

E. Issues Encountered and Lessons Learned

1) Potential for Cheating and Vandalism: One issue is that some mischievous students may vandalize a classmate's Web sites intentionally by deleting useful contents or adding irrelevant or false materials, as the wiki Web sites are not policed even though they are tracked. They may also intentionally engage in vote fraud by voting a below-average Web site as being

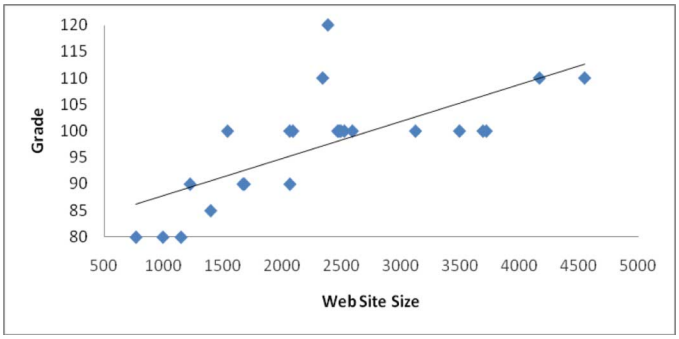

Fig. 4. Length of the wiki page and the grade.

outstanding, or an outstanding Web site as being below average. However, the very fact that the wiki Web sites are tracked and previous versions can be restored encouraged students to act in a responsible manner. A student who intentionally vandalizes a Web site does so at a risk of being caught and disciplined, and the effects of the vandalism acts can easily be undone. This class did not encounter any "vote fraud" problems either. The class was operated in a socially friendly environment, and all the students were serious about the course materials. However, vandalism is always a potential risk.

2) Difficulties in Locating Research Materials: Some students had difficulties finding relevant material using Web search engines such as Google as they did not understand that they may need to use alternative keywords to find appropriate references.

3) Strong Technical Support is Needed: Students need access to a reliable wiki platform for this type of project. Arizona State University provides working wiki software for all students to use. However, even some computer science undergraduate students found the wiki software difficult to use. For example, at least five groups reported having problems of uploading photographs to the wiki Web site. The teaching assistant was kept busy helping students just before assignment due dates.

4) Undergraduate Student Research Capabilities and Motivation: While many undergraduate students were excited about this wiki project, some did not show enthusiasm. Some of them were overloaded with other classes or commitments, and others did not show any interest in trying something new, particularly related to research.

5) Quality Needs Constant Improvement: Students need to learn that quality needs constant improvement. Such a need can be evidenced by the initial Web site created for the first assignment. While most contained useful and interesting materials, many references and links were missing, and the quality and quantity of the contents required significant improvement.

V. Evaluation With Respect to Web 2.0 and Research Questions

This case study produced interesting information with respect to the use of Web 2.0 as an educational tool as well as answering recently posed research questions and suggesting opportunities for action on the topic of cyberlearning.

A. Web 2.0 as an Educational Tool

1) The Web as Platform: In this case study, students used the Web as a platform for research and discovery of new materials, sharing by publishing their knowledge, and participating in evaluation of other Web sites provided by classmates. While the Web is not the only platform for education, it is a good supplement to the regular lectures, office hours, and e-mails. Note also that there are more questions asked via e-mails than in visits during office hours.

2) Harnessing Collective Intelligence: Students performed research on a topic related to the class and shared relevant materials with readers. About 60% of the materials presented in those Web sites can be an excellent education resource if this class were to be taught again in the future.

3) Rich User Experiences: The Web sites created have significantly enhanced students' learning experiences. Furthermore, in addition to regular lectures with PowerPoint slides and guest lectures, textbooks, and e-mails, students also watched videos, searched on the Web, and conducted actual software inspection as a part of team projects in the class. This class also hosted two students with vision disabilities for whom audio and video taping of the lecture was performed.

4) Data Are the Next Intel Inside: The case study had two phases: initial wiki Web site development and revision after receiving comments. The revision clearly showed that the wiki Web site materials improved significantly as predicted by this Web 2.0 principle. As more users were involved and more materials contributed, the contents of these Web sites became better and more valuable.

B. Research Questions

The NSF task force on cyberlearning posed several research questions on the topic of cyberlearning [2]. This case study has information that is relevant to some of these questions.

- *"How can we leverage the best of cyberlearning advances in the universities and industry to attract and prepare a new, diverse generation of leaders?"*

The wiki Web sites are developed in teams. The team members need to collaborate with each other in topic selection, performing research and analysis, organizing and creating content, preparing and presenting Web site material to the assembled class, and answering questions in a Q&A session. Each team will rotate team leaders every two weeks to ensure each member can have a chance to lead. This exercise prepares students for leadership in the new cyber world including cyberlearning.

- *"How can we merge innovations and create community resources?"*

This paper suggests that innovations can be used to create education resources that supplement regular lectures and textbooks. The Web sites created can be accumulated for the next term, and the students can create more wiki Web sites. In this way, a community for this class can be created. After several years of operation, a large database of wiki Web sites will be available. In addition, topics can be solicited from a larger community than that of the class. Academic departments, community, and industry can contribute topics of interest that teams can investigate using this type of learning activity. Arizona State University currently uses this strategy effectively for topics of senior capstone projects.

- *"How can we encourage collaborative development and enhancement of innovations created by others? What are appropriate criteria and standards?"*

This paper addresses several motivational factors that affect collaborative development in the context of undergraduate class (see Section III-A). Further motivational factors need to be developed for learning in other context such as high school classes or informal education.

- *"What are effective ways to establish the educational validity of innovative approaches to instruction?"*

This paper used a variety of ways of validating student's learning, including the following:

- instructor evaluation of wiki Web site for content correctness and organization;
- peer evaluation by students including viewing wiki Web sites and attending oral presentation in class;
- checking validity of references and links by the instructing team;
- measuring wiki Web site length and the number of edits performed by teams;
- oral presentation to demonstrate the mastery of knowledge;
- extensive student survey on various aspects of this project.
- *"What actions have to be taken to enable learner choice and voice that makes the use of social software in the education system an available option? What barriers have to be removed?"*

There is no free lunch; applying Web 2.0 in education systems will require significant planning and effort. This paper suggests six factors, each with individual actions that provide support for a successful project. These actions are designed to ensure the following.

- The social software must be available with adequate technical support.
- Baseline knowledge must be available to evaluate the wiki Web sites.
- Instructors and teaching assistants must have time to read and evaluate wiki Web sites carefully to provide individualized comments to ensure that quality products will be produced.
- *"How can we recognize and validate the learning that some young people already achieves through using social software"*

Since universities currently recognize learning only by examinations, including regular examinations, oral defense, or written reports, student learning via social software still need to write reports and take examinations to get university credits.

- *"What actions have to be taken to enable learner choice and voices that makes the use of social software in the education system an available option? What barriers have to be removed?"*

Education materials shared must be of high quality to be useful, even if these are developed by students. Otherwise, incorrect or imprecise information will be disseminated by students, and then taken as accurate by other users. The quality of wiki Web sites can be ensured through rigorous verification and validation by instructors and also partially through student peer evaluation.

The studies indicate that students learn most by the process of developing the wiki Web sites, rather than from the contents of wiki Web sites developed by others. Thus, it is important that students are involved in research, organizing and creating materials, rather than being passive observers in reading Web sites created by fellow students or by the public. This finding is a clear indication that Web 2.0 principles, specifically harnessing collective intelligence, works for education.

C. Opportunities for Action

The NSF also presented several opportunities for action to support cyberlearning [2]. Two of the opportunities were pursued in this case study.

- *"advance seamless cyberlearning (which incorporates elements in and out of the classroom and class time)"*

The strategy of using Web sites developed by the students successfully incorporates outside elements and time spent outside the classroom with traditional teaching. Students collaborate outside the classroom to develop the Web site material. Students can incorporate materials from many sources within their Web sites. The presentation of their material to the class results in the incorporation of these outside elements into the classroom.

- *"promote open educational resources"*

The Web sites created were published as open educational resources.

VI. Methodology for Conducting a Wiki Project in a University Class

This section presents a 10-step process that can be used to prepare a successful wiki project. The overall process is shown in Fig. 5. It is cyclical and incorporates principles of continuous improvement. The detailed description of this process can be found at http://asusrl.eas.asu.edu/cse360/TenSteps.htm.

VII. Conclusion

Recently, many reports have appeared on the application of Web 2.0 to education—for example, the comprehensive report from Europe [3]. The report indicated that the wiki approach develops new ways of learning, improves collaboration, improves learning results, and increases self-directed learning activities/skills; the approach also involves accessing information, delivering information, creating and sharing knowledge, collaborating and interacting, and using a wiki tool in a learning environment. However, the report considered the wiki approach to be suitable only for *informal* education [3, p. 33].

This paper agrees with all the objectives and activities as stated in [3]. However, this paper uses the wiki approach in *formal* education, particularly at the university undergraduate level. Furthermore, the wiki approach presented in this paper also increases motivation and participation, improves peer support for learning, improves accessibility of learning, improves learning results, and increases self-directed learning activities/skills. These objectives are applicable to social computing, but the report did not consider that the wiki approach can achieve these objectives. The six factors proposed here address these issues, including motivation (factor 2), peer support (factors 2, 4, and 6), accessibility (on the Web), learning results (all six factors), and increasing self-directed learning (factor 3).

The report also mentioned key pedagogical innovations about social computing such as personalized learning (motivation, self-directed learning skills, reflection, and meta cognition) and networking and collaboration. This paper addressed these issues via the six factors as well as addressing many other

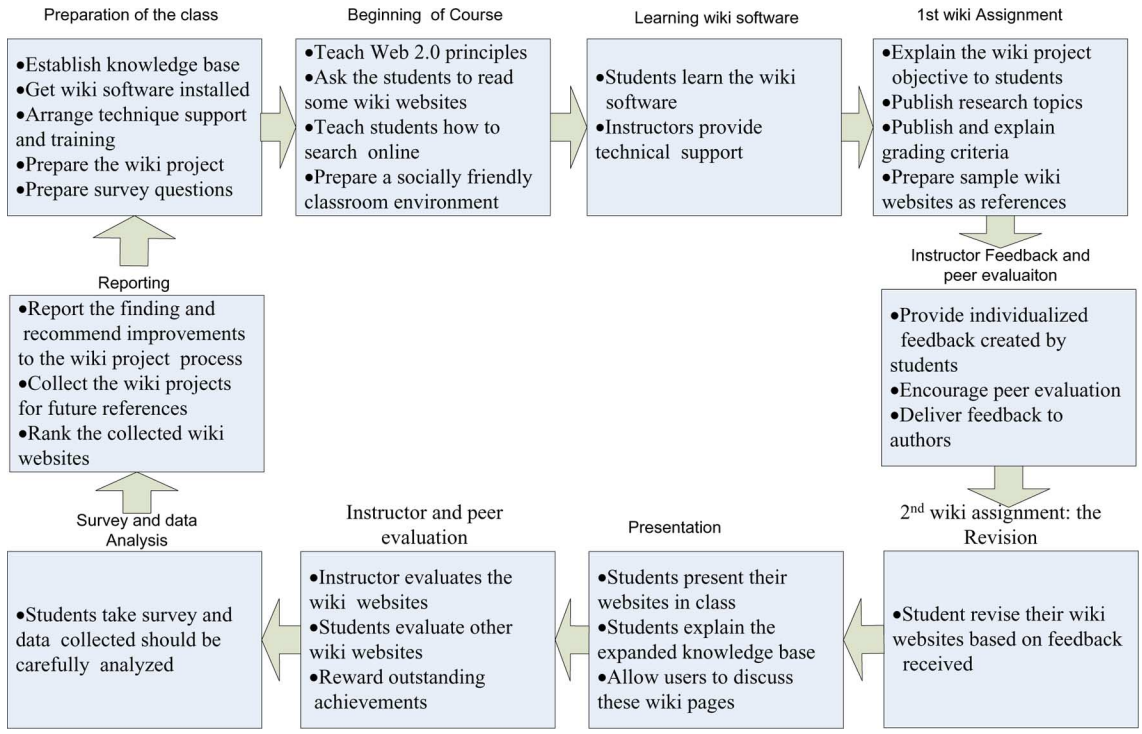

Fig. 5. Ten steps for the undergraduate class using wiki software.

issues related to using the wiki approach in an undergraduate class with an existing assessment already in place. The use of wiki does not invalidate these existing assessments. Rather, it enhances the assessment process and learning results. These issues have not been addressed in the literature.

A critical component of the proposed six factors is *quality*. Quality is necessary for the knowledge base (relevancy, correctness, references and links, length, and logical organization), for the presentations (both Web site presentations and oral presentations) and for the instructor feedback. While most of Web 2.0-for-education reports emphasize sharing and collaboration, few of them emphasize the quality of final products, either by evaluating the correctness and presentation or by including processes to attain quality. This paper proposed several rigorous processes to ensure the quality of wiki Web sites produced. Social computing indeed increases and promotes sharing and collaboration. However, if the quality of work is compromised, inferior or false information may be shared and disseminated and be treated as "collective intelligence." In this case study, incorrect information was detected, and thus the concern over quality is critical, particularly if the wiki Web sites will be open to the general public.

This paper also defined a framework for the assignment and created a 10-step process that can be used to create successful wiki-based assignments. These elements were tested using a case study with Web 2.0 technology in an undergraduate computer science class. The results indicated that Web 2.0 is indeed useful for education, and that students do gain knowledge and experience with this approach. However, there are pitfalls and issues not mentioned in the literature that must be considered, including the following:

- ensuring that only quality materials are published;
- motivating students to perform research, to publish their findings, and to collaborate in teams and in the cyber world; and
- educating students in the impartial evaluation and rating of material published by their peers.

These issues became apparent when conducting the case study. This approach requires significant time and effort, which is often not mentioned in the literature.

Web 2.0 is indeed a new and exciting approach for education. Careful planning, evaluation, and execution will be critical to make Web-based projects successful. This study has demonstrated that by applying the six factors to an assignment, the assignment is transformed into one that accomplished the original educational goals and adds a new dimension to the students' education—understanding and using Web 2.0 technologies.

The case study also discovered some unexpected situations.

- Students are not comfortable with evaluating other students' work, especially if their evaluation can affect their standing. More than 60% of the students were either neutral on or disliked this aspect of the project. This student discomfort has been noticed in other studies [24]. There are proposed measures that can be incorporated to make students more comfortable [25]. These measures will be incorporated in a future class.
- Students were split on how much they learned by reading other students' wiki pages. They reported that they learned more by working on their own wiki pages.
- While the relationship between the number of times students edited their Web site and the grade their Web site received showed a visible trend, it was only statistically significant at a level of 0.08. This lack of statistical significance may have been due to generous grading. Further

investigation is needed to validate whether this trend exists, how strong it is, and if better measures of collaboration are available.

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