Proceedings of the ASME 2011 International Design Engineering Technical Conferences & Computers and Information in Engineering Conference
IDETC/CIE 2011
August 29 – August 31, 2011, Washington, DC, USA

DETC2011-48310 (DRAFT)

USING WIKIS AS A FORMATIVE ASSESSEMENT TOOL FOR STUDENT ENGINEERING DESIGN TEAMS

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ABSTRACT

Due to its focus in project-based learning, design educators must provide individual coaching and mentoring of student teams as they progress through their design efforts. In order to increase the quantity and quality of design mentoring, the authors have implemented the use of Wiki websites as a medium for providing formative assessment for student design teams enrolled in a sophomore-level Mechanical Engineering design course. Wiki websites, which allow for easy creation and editing of interlinked webpages, were created for each design team in order to provide a virtual space for the creation, compilation, and editing of their design project report submissions. With access to each team's Wiki site, the mentor is able to observe each team's product design process unfold and provide feedback using an embedded commenting system. The public presentation of design reports also affords the facilitation of a peer-review of student work.

In this paper the authors present details of the implementation of a Wiki for preliminary assessment data for this tool. Results show that the students found the tool and the associated activities to be easy to use, helpful in developing better design reports and a contributing factor to their development of critical and analytical thinking skills. In addition, students who used the tool reported receiving more meaningful formative feedback from the instructor and reported giving more formative feedback to their peers when compared to other sections of the class that were not using the Wiki.

1. INTRODUCTION

1.1 Formative Assessment in Design Education

Widely considered to be the central or distinguishing activity of engineering, design has been a focus of research in engineering education (Simon, 1996). Research on engineering design thinking and learning has established that design is hard to learn and still harder to teach (Atman et al., 2008). Due to its focus in project-based learning, design instructors cannot simply "teach" design principles through lecture since the unique context of each design project prevents the canned delivery of common content. Instead, design educators must augment content delivery with individual coaching and mentoring of students as they progress through their design efforts (Dym et al., 2005).

As class size increases, it becomes more difficult for the mentor to coordinate meetings with each of the numerous design teams. As a result, assessment of student progress is often relegated to a few project report milestone submissions. This mode of assessment does not match well with the modes of learning and teaching engineering design. In this mode, feedback is provided long after the students have completed the task. As such, misunderstandings and misconceptions can linger well after the students have already moved on to the next design phase. Once the feedback is finally returned, students do not have an opportunity to adequately reflect on, and learn from, the feedback.

Formative assessment, on the other hand, informs both teachers and students about student learning at a point at which adjustments can be made. Research indicates that formative assessment is one of the most effective instructional techniques for supporting student learning (Black and Williams, 1998; Roselli & Brophy, 2006). As design education is not focused in the dissemination of domain knowledge from the teacher to the students, as is most traditional engineering instruction, it requires a means for formative assessment to provide immediate feedback to assist in scaffolding student learning.

1.2 Wikis as a Formative Assessment Tool

In order to increase the quantity and quality of mentoring, to provide additional formative assessment, and to provide an "individual course in a group setting" (Williams & Mistree, 2006), the authors have implemented the use of Wiki websites as a medium for providing formative assessment for student

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design teams enrolled in a sophomore-level Mechanical Engineering design course. Wiki websites, which allow for the creation and editing of interlinked webpages, were created for each design team in order to provide a virtual space for the creation, compilation, and editing of their design project report submissions.

In this paper, the authors describe the implementation of Wikis as tools for collaborative report creation in a sophomore-level design course. Previous uses of Wikis in engineering design classroom contexts are reviewed in Section 2. The strategy in which Wikis were implemented by the authors is described in Section 3. An assessment tool, a survey based on questions drawn from the National Survey of Student Engagement (NSSE), including questions from the optional writing component of the survey developed in 2008, is presented in Section 4. This assessment tool was given to students who used the Wiki to create their reports (the experimental group), as well as to those students who used traditional word processing programs (the control group). Preliminary comparative results of these two groups' responses are presented and discussed in Section 5. Conclusions and future work are offered in Section 6.

2. WIKIS IN DESIGN EDUCATION

Wiki websites allow for easy creation and editing of interlinked webpages via a web browser, and offer space for content sharing and automatic revision tracking. Thus, they are ideal for collaborative content development in classroom settings (Ellis & Cohen, 2009). As such, Wikis are becoming more and more prevalent in engineering classrooms as a means for students to collaboratively create course assignments (Tsai et al., 2011), lecture notes (Sarkar, 2009), exam revisions (Malik, 2010), and even textbooks (Hohne et al., 2007; Gehringer et al., 2010).

In design education, Wikis have been primarily examined as a means of facilitating collaboration amongst distributed design groups (Cajander et al., 2009). In this context, Wikis are primarily used as a means for file sharing, assignment preparation, and final document preparation (Koch et al., 2010). Walthall and coauthors studied Wikis' effects on design communication and concluded that they "provide a viable means for enhancing shared understanding, especially when frequent face-to-face communication is not feasible" (Walthall et al., 2009). Although not technically a Wiki, Finger et al.'s "Kiva" is a "digital engineering collaboratory" that provides students cyberinfrastructure for design collaboration while also providing an opportunity to track students' design process (Finger et al., 2006).

McGaughey and Michalek have implemented Wikis in their design course as an overall course management system. Through their experiences with the "Design Decisions Wiki," they anecdotally report that the use of the Wiki provides the following advantages: efficient information dissemination, improved course notes, enhanced ability to monitor student progress, improved team forming and scheduling, and collaborative writing for co-instruction (McGaughey & Michalek, 2008). It should be noted that in their work, McGaughey and Michalek do identify the Wiki's potential to improve both peer-to-peer and student-instructor interaction; however, no formal assessment is offered.

3. IMPLEMENTATION

3.1 Context

The use of Wikis as a means of providing formative assessment was piloted in a sophomore-level Mechanical Engineering design course at a large land-grant university. The course, entitled "Engineering Design and Economics," focuses in exposing students to engineering design and design methodologies at an early stage in their professional development. The course typically features a total enrollment of ~300 students.

In order to facilitate the hands-on experiences necessary for an introductory design course, several sections of the course are offered each semester. Typically, 8-10 sections are offered simultaneously, with each section having an enrollment of no more than 36 students. Fortunately, the presence of several offerings each semester provides an opportunity to create "control" and "experimental" student groups for assessment of curricular innovations.

Course goals include preparing students to work effectively in a team, to author and produce professional technical reports (complete with effective visuals), to plan a major engineering project, to formulate and use an economic quantitative financial model for decision making, to describe the design methodology behind a commercial product, and to discuss associated ethical, legal, societal, and safety issues. The Course Learning Statements (CLS) are presented to the students as:

- Define a problem, use multiple techniques to generate ideas, use the problem statement to identify solutions, select criteria and use them to evaluate solutions, determine the design details and prepare graphical representations.
- Prepare and present oral and written design reports.
- Use appropriate economic measures to select cost-effective solutions.
- Reverse engineer products and determine the engineering principles on which the product is based.
- Perform patent searches to establish the state of the art.
- Keep records of ideas that could be patentable concepts.
- Understand the Engineering Code of Ethics and how it can be used in decision making.

As course content is centered on the design process, the outcomes of the course are in-line with almost all of the ABET "a-k" learning objectives (system design, teaming, communication, understanding ethical responsibility, applying knowledge of math, science and engineering, and identifying, formulating, and solving engineering problems).

The 3-credit course is centered on active-learning opportunities that allow students to apply their engineering design learning. In its current form, classroom meetings follow

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a standard format: students are quizzed on assigned reading; the instructor leads a 10-15 minute discussion of the material; the students work in teams on an assigned in-class activity. The activities, which range from product dissections (IC engines, air compressors, electric drills, disposable cameras, etc.) to various speculative design scenarios, provide an opportunity for the instructor to perform individual mentoring and instruction. In addition to these in-class activities, students work in teams (typically 3 students per team) on an out-of-class semester design project wherein they create a novel consumer product.

Design instruction is organized to help students advance their understanding through progressive cognitive levels: knowledge is gained through text reading, comprehension is gained through the context and examples provided through in-class discussion, application is provided via hands-on in-class activities, and analysis and synthesis are provided through the semester-long design project experience.

Design reports serve as the students' major deliverables for their design project, and are the sole representation of their out-of-class design activities (and thus account for a major portion of their grade). There are three total milestone reports in the course, and they serve as the major tool for evaluating students' design process knowledge, as well as their progress towards other key learning outcomes (e.g., teaming and technical writing). In its traditional offering, student teams enrolled in this course have collaboratively composed their reports in a word processing program (e.g., Microsoft Word), which are then submitted at a predetermined due date. Although instructors return graded reports as quickly as possible, feedback is not offered until the students have already begun the next phase in their design process.

3.2 Wiki Reports

In order to provide an opportunity for formative assessment, and potentially a higher quality of design mentoring, the authors have implemented the use of Wiki websites to provide students a virtual space for the collaborative creation, compilation, and editing of their design report deliverables.

Using a modified version of the open-source "collaboration and learning environment" software, Sakai (Sakai Project, 2011), the authors created a Wiki site for each individual project team. The students used these sites as the central location for report preparation (e.g., file transfer, project progress descriptions, and communication). The use of the Wiki allowed teams to collaborate at a distance, as they provide users file-storage space for content sharing as well as automatic revision tracking and control.

With access to each team's Wiki site, the mentor is able to observe each team's product design process unfold. Using an on-line commenting system embedded within each page (similar to a blog), the instructor is able to provide "virtual" mentoring to students as they progress through their design efforts. As this feedback can occur at any time, and from any location, this feature provides an opportunity for significant increase in design project mentoring. In addition, the Wiki's automatic compilation of upload/download statistics allows the evaluation of individual contributions to the team project – something that cannot be done with traditional submission via a printed document.

In addition to the aforementioned technological benefits of using a Wiki (remote mentoring via commenting, revision tracking, file storage, collaborative content creation, site usage statistics), the Wiki might also better reflect students' preferred mode of communication. Previous research has shown that some student design teams in this course prefer to collaborate without face-to-face meetings – relying on shared OneNote sessions and IM chat sessions to complete their projects [4]. This also reflects professional practice: virtual teams are becoming more prevalent in the field as engineers increasingly work with others spread around the globe.

3.3 Peer Review

The commenting feature of the Wiki not only allows for the instructor to provide feedback – it also affords the facilitation of a peer-review procedure. Peer review engages students in metacognitive thinking and helps to create a learning community in the classroom as students see one another as resources for understanding.

In this implementation, student teams are paired together to review their groups' reports. To prevent students from being influenced by their peers' design innovations and decisions, access to each teams' Wikis is not given until the peer-review procedure start date - one week before the due date of the final draft. To complete the peer-review process, students log on to their partner team's page and use the built-in commenting feature to directly offer constructive criticism. (The Wiki's revision tracking feature assuages student fears of their peers accidentally changing their report's content.) Students are then able to take these comments into account for the preparation of their final report.

This peer-review procedure potentially provides advanced learning opportunities for students as they conduct critical analysis, educate their peers on course content, and reflect and improve on their own technical communication abilities. While the traditional use of paper-based reports does not preclude a peer-review process, the use of a Wiki makes the process collaborative. Students are able to provide feedback directly on their peers' reports and are thus able to leverage and speak directly to previous feedback. In addition, they are able to see how the instructor's prior feedback, which can serve as a model for them to follow (in both their feedback and in the creation of their own report). As students are able to provide this feedback from any location, at any time, it can be argued that the use of Wikis makes a peer-review process more efficient.

4. ASSESSMENT METHOD

4.1 Survey Instrument

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To assess the effectiveness of this approach, the authors surveyed students in several course sections: both students that used the Wiki report and peer-review procedure (experimental group) and those that used traditional report preparation techniques (control group).

To formulate survey questions, the authors drew from the National Survey of Student Engagement (NSSE), including the questions about writing developed in 2008 in collaboration with the Council of Writing Program Administrators (WPA) and included as an optional part of the survey (Anderson et al. 2010a). Analysis of results from two years of the survey (151 institutions, ~60,000 responses) identified correlations between specific types of writing activities and specific desirable learning outcomes (as self-reported by students). In particular, writing activities that involved interactive work (e.g. peer and teacher feedback), constructing mean (e.g. for specified audiences), and clear expectations correlated with the NSSE measures of deep learning (higher-order, integrative, and reflective) as well as with self-reported gains in practical, personal, and social development.

Using the NSSE findings as a guide, we selected several questions from the writing component (Table 1 and Table 2), several questions from the deep learning component (Table 3), and several questions from the self-reported learning gains (Table 4) components of NSSE that were deemed most relevant to students' work in the design course and the development of design reports. That is, questions from Tables 1 & 2 were selected for their alignment with the intended writing activities in the course, while Tables 3 and 4 were selected for their alignment with the desired learning gains. Findings reported from the WPA+NSSE study predict correlations between the two groups (Anderson 2010b).

The final survey instrument consisted of twenty four likert scale questions to be posed to the students, along with an open answer question and a consent question. Survey questions were designed to explore students' attitudes related to creating draft reports, the instructor's role, the influence of the report on cognitive activities, and development of professional skills (Tables 1-4, respectively).

Table 1. Survey questions related to creating report drafts

As you developed design reports, how frequently did you…	
#1	Talk with your instructor to develop your ideas before you started drafting your report?
#2	Talk with a classmate, friends, or family member to develop your ideas before you started drafting your report?
#3	Receive meaningful feedback from your instructor about a draft before turning in your final report?
#4	Receive meaningful feedback from a classmate before turning in your final report?
#5	Provided meaningful feedback to a classmate about a draft or outline the classmate has written?
5=Frequently; 4=Several Times; 3=A Few Times; 2=Once or Twice; 1=Never	

Table 2. Survey questions related to role of the instructor

The design report I submitted to the instructor...	
#6	Reflects the style and format of a professional engineering report.
Your instructor...	
#7	Provided clear instructions describing what he or she wanted you to do.
#8	Explained in advance what he or she wanted you to learn.
#9	Explained in advance the criteria he or she would use to grade your assignment.
5=Strongly Agree; 4=Agree; 3=Neutral; 2=Disagree; 1=Strongly Disagree	

Table 3. Survey questions related to influence of design report on cognitive activities

To what extent did the design reports for this course emphasize the following activities...	
#10	ANALYZING the basic elements of an idea, experience, or theory, such as examining a particular case or situation in depth and considering its components.
#11	SYNTHESIZING and organizing ideas, information, or experiences into new, more complex interpretations and relationships.
#12	MAKING JUDGMENTS about the value of information, arguments, or methods, such as examining how others gathered and interpreted data and assessing the soundness of their conclusions.
#13	APPLYING theories or concepts to practical problems or in new situations.
5=Very Strongly; 4=Strongly; 3=Moderately; 2=A Little; 1=Not at All	

Table 4. Survey questions related to reports' influence on skill development

My experience working on the design reports contributed to my knowledge, skills, and personal development in the following areas...	
#14	Acquiring job or work-related knowledge and skills.
#15	Working effectively with others.
#16	Using computing and information technology.
#17	Solving complex real-world problems.
#18	Writing clearly and effectively.
#19	Thinking critically and analytically.
5=Strongly Agree; 4=Agree; 3=Neutral; 2=Disagree; 1=Strongly Disagree	

In addition, five questions were formulated to specifically address Wiki use. These questions were only posed to the experimental group; the control groups received a shortened survey that included only the first nineteen likert statements. Like those in the control group, students in the experimental group created three total design reports in the class; however, their final two reports were created using the Wiki procedure. This mixed traditional/Wiki experience provided the

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experimental group students an opportunity to make direct comparisons between the two approaches.

Table 5. Survey questions related to Wiki usage

#20	Using the Wiki to write a report was difficult.
#21	It was easier to compile my team's report using the Wiki than MS Word.
#22	I felt uncomfortable making my report open to peer review.
#23	My team's report benefitted from the peer review process afforded by the Wiki.
#24	My understanding of course content (e.g., the design process) improved as a result of participating in the peer review process.
5=Strongly Agree; 4=Agree; 3=Neutral; 2=Disagree; 1=Strongly Disagree	

4.2 Participants

The survey instrument was administered to both the experimental and control groups at the end of the fall 2010 semester following their final report submission. The experimental participants were solicited from the single class section of the course that had been using the Wikis for their design reports. The control participants were solicited from several sections of the course that did not use the wikis to compile their design reports. It is important to note that there was not a common instructor for the two student groups.

The participants were solicited via e-mail to complete the survey online and both groups were given class credit for filling out the survey. A list of all students who completed the survey was passed on to the instructor for grading purposes, but no class instructors were given access to the survey data until final grades had been assigned for the semester. The last question on the survey allowed the students to opt out of participation in the research, and data from students who did not consent was removed before any analysis began. 17 valid responses for the experimental group and 101 valid responses from the control group were used as the data set for analysis.

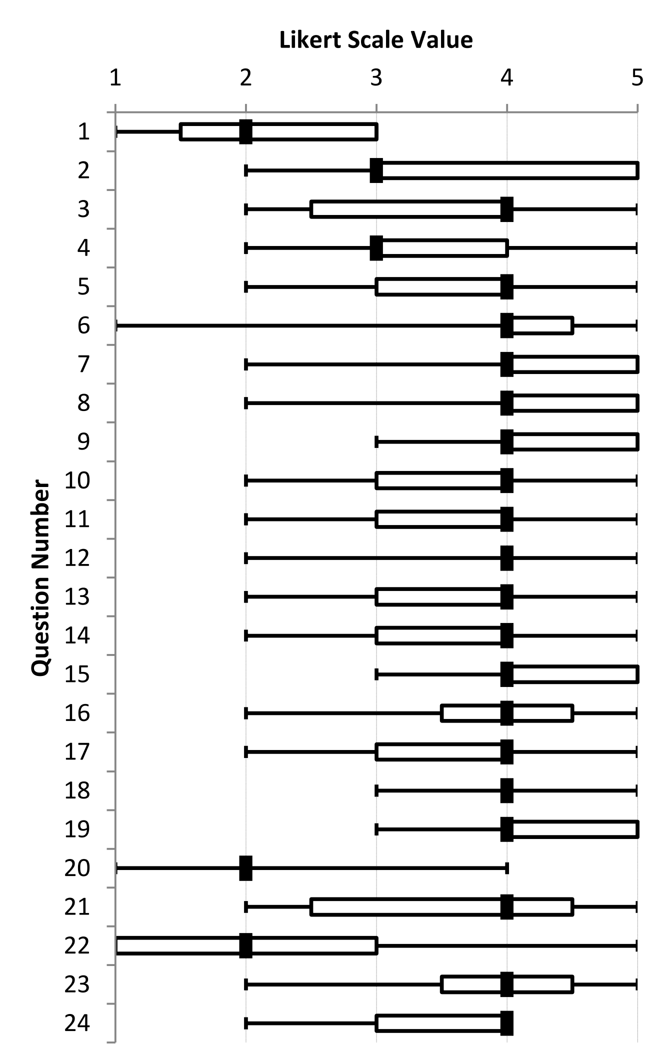
Further information regarding the administration of the assessment tool can be found gathered from the authors' institutional review board (IRB #10-1038).

5. RESULTS AND ANALYSIS

5.1 Wiki Group Results

A boxplot of the responses to the Likert scale questions is shown in Figure 1. The responses to most questions for both groups are positive, with the medians clustering at four. In particular, the responses to the last five questions show that 1) most students felt that the Wiki made the report easier to compile, 2) most students felt that their reports benefited from the peer review process and 3) most students felt that their understanding of the design process improved as a result participating in the peer review process. In addition, students did not find the Wiki to be difficult to use, and most students were not opposed to having their report open to peer review.

Figure 1. Boxplot of Survey Responses for the Wiki group



In addition to the Likert scale questions, students were asked to provide additional comments pertaining to the design report process. The collected quotes are a mix of positive and negative opinions that offer some more insight into the results. Some selected quotes are shared below. Though the students enjoyed using the Wiki and found the Wiki to make some parts of the compiling and review process easier, it had the potential to remove face to face group meetings from the design process. This may or may not be viewed as a problem since digital team communication is still occurring, but this replacement of face to face meetings was an unintended consequence of the Wikis that may warrant further investigation.

(S10) "Overall the wiki truly did make writing the reports easier in the sense that we as group members were all able to upload things to the wiki page so that everyone has the ability to use the resources. Peer review was also

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much easier than what could be accomplished through hard copies of the reports. There were some cumbersome components of the wikis, i.e. centering headings and making changes to tables and graphs, but all in all I enjoyed the wikis."

(S14) "The utilization of the Wiki on the design report had its ups and downs. I favored the peer review and compiling aspect of the wiki though. It was something new which I was pleased about. It was much easier than using word."

(S17) "The design report was easy to compile on the wiki, but also gave the team means to not meet together and work on the design report together. Although MS Word is hard to compile reports in, it allows more group work."

(S18) "The wiki has the potential of removing the teamwork aspect of the design process. Although my team met almost twice a week to stay up to date and work on our reports, it is my understanding that most teams very rarely met in person."

5.2 Comparison of Wiki and Non-Wiki Groups

In addition to the descriptive statistics above, the Likert scale responses of the control and experimental groups were compared to identify potential differences. To draw this comparison, a Shapiro-Wilk test of normality was first performed on the data. Though the data visually appeared to be normal, the non-continuous nature of the five point scale led almost all of the questions to fail the normality test. Because the data was not normal, and because measurements of medians are more appropriate than means for likert scale items, a Mann-Whitney U test was used to compare the medians. This non-parametric test is the most commonly used test to compare medians of two small and independent groups. Since the test does not rely on the data being normal, it further met the needs of the data analysis. Comparison data is presented in Table 2.

The results of the Mann –Whitney U test revealed only two statistically differences in the groups (highlighted in Table 2). The first difference noticed is that students in the Wiki group felt that they received meaningful feedback on their report from the instructor before turning in a final copy of the report (Question #3). This result indicates that the Wiki did indeed facilitate formative assessment in a more efficient manner than the traditional procedure. It is also important to note that the students found this feedback to be "meaningful" to the development of their report.

The second significant difference noticed is that students in the Wiki classroom felt that they were able to provide meaningful feedback to their peers (Question #5). With the peer review process present for the Wiki classroom, and not present for the Non-Wiki classroom, this is also not a surprising result.

Table 2. Results of comparison between control and experimental groups.

		Wiki Group Median	Wiki Group Mean	Non-Wiki Group Median	Non-Wiki Group Mean	Mann-Whitney P-Value
As you developed design reports, how frequently did you…	Talk with your instructor to develop your ideas before you started drafting your report?	2.00	2.12	2.00	2.26	0.7351
	Talk with a classmate, friends, or family member to develop your ideas before you started drafting your report?	3.00	3.59	4.00	3.55	0.9968
	Receive meaningful feedback from your instructor about a draft before turning in your final report?	4.00	3.47	2.00	2.40	0.0007
	Receive meaningful feedback from a classmate before turning in your final report?	3.00	3.24	3.00	3.06	0.5594
	Provided meaningful feedback to a classmate about a draft or outline the classmate has written?	4.00	3.65	3.00	2.85	0.0065
My experience working on the design reports contributed to my knowledge, skills, and personal development in the following areas…	Using computing and information technology.	4.00	3.94	4.00	3.60	0.1063
	Thinking critically and analytically.	4.00	4.24	4.00	3.93	0.1335

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Of interest is the mismatch with the Question #4. While students in the Wiki group feel they are giving more meaningful feedback than students in Non-Wiki classrooms, Wiki students do not feel that they are receiving more meaningful feedback from peers than their Non-Wiki counterparts.

It is also noted that some of the other questions had results that were close to being significant. Most notably, students felt that their experience in creating design reports using Wikis improved their ability to think critically and analytically and to use computing and information technology. With an experimental group of only seventeen students, it is very possible that there are other significant differences that are hidden by the small sample size. With a larger sample size, it may be possible to bring some of the more subtle differences to the surface.

6. CLOSURE

To improve the quantity and quality of design mentoring and formative assessment of students' written design reports, the authors have implemented a Wiki report system in a sophomore-level Mechanical Engineering design course. Wikis provide students a central location for collaborative report preparation with file storage and revision tracking features. In addition, the Wiki enables the instructor to observe each team's product design process unfold (instead of waiting for a final report) and provides an opportunity for formative assessment via an on-line commenting system embedded within each page. As this feedback can occur at any time, and from any location, this feature provides an opportunity for a significant increase in design project mentoring. Finally, the use of the Wiki afforded an opportunity for students to mentor each other through an efficient, collaborative peer-review process.

To assess this approach, two student groups (a control group who completed reports via traditional means, and an experimental group who used Wikis) were solicited to complete a survey. Statistically significant differences were found in the experimental group's attitudes related to receiving meaningful feedback from the instructor and providing meaningful feedback to their peers. In addition, students who used the Wiki tool were more likely to feel that they improved their ability to think critically and analytically, than those in the control group.

With this pilot assessment complete, and students' general positive attitudes towards the Wiki approach, the authors look to a formal assessment of the effects of the peer review process. The Wiki's revision-history feature allows the authors an opportunity to systematically analyze how students alter their reports from both their peers' review of their report and their review of their peers' reports.

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