Using Wiki to Promote Collaborative Learning in Statistics Education

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Please, grant me the serenity to accept the pages I cannot edit,
The courage to edit the pages I can, And the wisdom to know the difference.
("The Wiki Prayer", Lamb, 2004)

1. INTRODUCTION

Technology is changing faster than at any time in its history. It is transforming the way people communicate and collaborate, the way people consume information and participate in the World Wide Web, and potentially the way people teach and learn. One of the interesting shifts that is currently happening is a shift between using technology to support the individual to using technology to support interactions and relationships between individuals. With that shift, we keep discovering new tools and social behaviors for helping us help each other, which is the very essence of collaborative learning.

In this article, we focus on the educational potential of one such new collaboration medium, in the context of statistics education. The medium is Ward Cunningham's WikiWikiWeb (or concisely – Wiki; Leuf & Cunningham 2001). The term Wiki refers to a Website that allows all users to add, remove, edit and change content, typically without the need for registration, and to the software (Wiki engine, such as *MediaWiki*, http://www.mediawiki.org) that facilitates the operation of a Wiki Website. In Wiki, users are writers, editors and contributors, rather than just readers or consumers, and jointly form a democratic community of collaboration. The implementation of Wiki in classrooms is rather straightforward since the technology is simple, user-friendly and inexpensive. The ease of operation and interaction makes Wiki an effective tool for mass collaborative authoring, which can best be seen in action through the popular free international encyclopedia, Wikipedia (http://wikipedia.org). According to Alexa (http://www.alexa.com), Wikipedia is one of the top ten most visited sites on the Web (July 2007). Wikis (and Blogs) are considered by some experts as the signal of the arrival of Web 2.0, the second-generation Web and Web-based communities (e.g., Godwin-Jones 2003).

The use of Wiki in educational implementations is rapidly increasing, and more and more scientific publications and conferences are devoted to the topic. Typical educational uses of Wiki include in-class collaboration, group projects outside of class, networks of collaboration for learning from peers, peer and teacher feedback and review, and assessment and management of team performance. With the right guidance of a teacher, these collaborative activities can turn a classroom into a caring, supportive learning community and change the individual focus of traditional instruction to one of collaboration and shared construction of knowledge (c.f. Mejias 2006).

Our goal in this article is to briefly present the theory and technique of Wiki, and demonstrate how it can facilitate collaborative learning and bring about instructional change to improve student learning of statistics. Three fundamental assumptions form the basis of this article. Firstly, statistics is a collaborative discipline and therefore culturally compatible with Wiki as a collaborative learning tool. Secondly, collaboration can improve the learning of each individual in the statistics classroom as well as the whole class. Thirdly, Wiki is an appropriate and powerful tool to help improve statistics classrooms through collaboration and communication.

In this article, we further introduce Wiki and provide a detailed context for Wiki-based collaboration (Section 3). In the literature review (Section 4) we discuss the challenge of implementing a new medium in education, and the need for cultural compatibility between a discipline and the technology used in the teaching of that discipline. This is followed by a presentation of statistics as a collaborative discipline and collaboration as an essential and productive way to enhance the learning of statistics. Next, this background sets the stage for proposing ways to prepare a new Wiki-based course (Section 5); and several uses of Wiki in statistics classrooms, including collaborative writing, discussion and review, glossaries, statistical projects, self-reflective journals, and assessment are presented (Section 6).

This article is not meant to be a step-by-step tutorial but rather a call for consideration and further study of Wikis in statistics classrooms. However we briefly discuss some issues of application and include some advice to teachers on how to use Wikis (Section 7 and 8). Many resources (e.g., books, tutorial, Websites) are available nowadays that provide detailed instructions on how to use Wikis, how to get a Wiki, what the options are, issues of security in Wikis, good examples of Wikis in classrooms, etc. (e.g., Leuf & Cunningham 2001; Richardson 2006; Wikiversity, http://en.wikiversity.org).

In sum, this article attempts to make a convincing case for the use of Wiki to support collaborative learning experiences for students in the statistics classroom.

2. THE STUDY

The particular uses of Wiki proposed in this article are based on current literature and practical experiences and insights gained as an instructor and researcher of several Wiki-based graduate courses in the recently founded *Educational Technologies Graduate Program* at the University of Haifa (Israel). One course (proposed to school teachers) deals with practical issues of teaching statistics. The other is a graduate seminar that brings the research in statistics education to teachers and prospective researchers. Ongoing collaborative research with colleagues and graduate students accompanies the teaching in the Wiki-based classrooms and aims at designing and analyzing appropriate instructional activities as well as constructing a theoretical framework. This is an exploratory study to study the ways in which Wiki-based communities can support learning through student active participation, collaboration, communication, and sense of agency and responsibility.

3. WHAT IS WIKI?

Wiki means "quick" or "informal" in the Hawaiian language. The WikiWikiWeb concept, most often called simply "a Wiki", originated with Ward Cunningham, who called it "*the simplest online database that could possibly work*" (Leuf & Cunningham 2001, p. 15). His reasoning was simple: The quickest way to create a Website is to ask all visitors to be authors. Wiki is easy and quick to edit and change and users are encouraged to become involved and contribute their knowledge. The word Wiki is sometimes interpreted as the acronym for "What I Know Is", which describes the knowledge contribution, storage, and exchange functions of Wikis.

Wikis are collaborative Websites with "open editing." That is, the information on a Wiki can be created and edited by any and all users. Once users visit Wikis, they can read and, if they wish, edit or change the text by using a regular Web-browser (without any extra add-ons, or need to know any computer language) to re-write, re-organize, or update the structure and content of the site. Users can also discuss any issue through a "discussion page" that accompanies each Wiki page. Therefore, in Wikis, readers are writers, and readers and writers jointly form a community of collaboration. Allowing everyday users to create and edit any page in a Website is exciting and revolutionary in that it encourages democratic use of the Web, promotes content discussion and compositions by all users, and questions traditional beliefs about acceptable sources of knowledge and about copyrights. The idea that under the right circumstances large groups of people are smarter than an elite few has been explored recently in interesting books (e.g., Bonabeau, Dorigo, & Theraulaz 1999; Surowiecki 2004). On the other hand the open philosophy of most

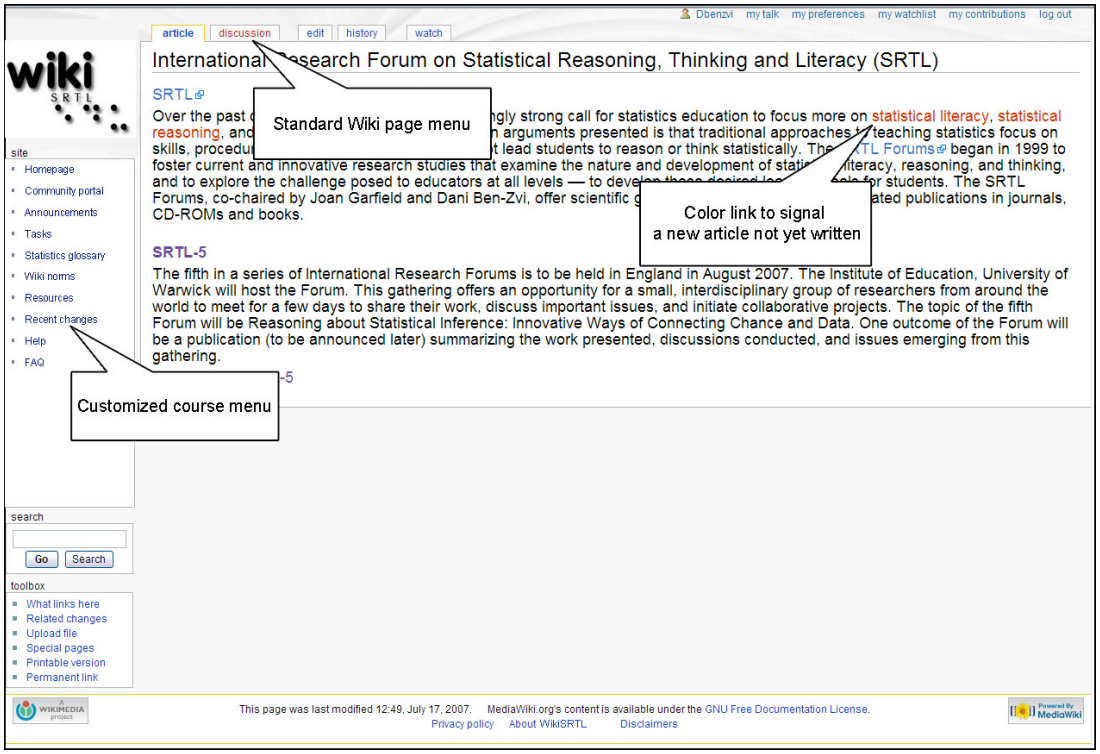

Figure 1: A screenshot of a statistics course page in a Wiki Website. This page is translated from Hebrew, the original language of this Website, see http://wikisrtl.edu.haifa.ac.il.

Wikis—of allowing anyone to edit content—does not ensure that editors are well-meaning. Wiki's approach is to make damage easy to undo rather than to prevent damage.

Wiki is unusual among group communication technologies (such as email and discussion group) in that it allows the *organization* of contributions to be edited in addition to the content itself. Wiki promotes meaningful topic associations between different pages by making page link creation almost intuitively easy and by showing whether an intended target page exist or not. This in turn affects the way new knowledge is treated and constructed in a Wiki community. Unknown terms can be simply linked to a new, not yet written page, which will result in a unique color link, inviting other members of the community to fill in the missing piece of information. A Wiki is therefore a freely expandable collection of Web pages interlinked in meaningful ways that are continuously formed by the users.

As a result of these features, a Wiki is not a carefully crafted site for casual visitors. Instead, it seeks to involve the visitor in an ongoing process of creation, discussion and collaboration that thereby constantly changes the Website landscape (Leuf & Cunningham 2001, p. 16). No one will argue that one of the extraordinary stories of the Internet age is that of Wikipedia, a free online encyclopedia that anyone can edit. This radical and rapidly growing publication, which includes millions of entries, is now a much-used resource. But it is also controversial: if anyone can edit entries, how do users know if Wikipedia is as accurate as established sources such as Encyclopedia Britannica? Several recent cases have highlighted the potential problems. One Wikipedia article was revealed as falsely suggesting that a former assistant to US Senator Robert Kennedy may have been involved in his assassination. However, a peer review comparison of Wikipedia and Britannica's coverage of science suggests that such high-profile examples are the exception rather than the rule. The exercise revealed numerous errors in both encyclopedias, but among 42 entries tested, the difference in accuracy was not particularly great: the average science entry in Wikipedia contained around four inaccuracies; Britannica, about three (Giles 2005).

In light of its virtues and shortcomings, it is inevitable to question the potential of this unusual collaboration space in education. It is necessary to discuss the rationale and purposes to use Wiki for collaborative learning in statistics education. In the following literature review we shall provide preliminary coverage of these questions.

4. LITERATURE REVIEW

4.1 Integrating New Media into Courses

Media – the channels through which we forge and communicate meaning – affect us as individuals and as a society. This effect is frequently not predicted by its creator; typically, it is only understood in hindsight (McLuhan 1964). Since a new medium can change how we relate and interact to ideas, to others, and to ourselves, it has the potential to become a tool in creating powerful new learning environments (Turkle,1995; Rick &

Lamberty 2005). Unfortunately, realizing that potential is often challenging (Bolter & Grusin 1999).

Before the characteristics, applications and implications of a new medium are fully understood, significant use in diverse contexts and extended evolution of the medium itself are required. These complex and long processes are exemplified in the development stories of radio, television, telephone, computers, and the World Wide Web. Furthermore, when it comes to implementing a new medium in education, greater demands are placed on teachers and students in accommodating it and learning how to best use it for teaching, learning and communication.

In this article, we describe one new medium, Wiki, which has promising potential to support collaborative learning. Wiki has been successfully used in other domains, such as the business world and online encyclopedias, but still has to establish its added value in education. As with other new media, realizing that potential is far from trivial. Adopters such as teachers and students need the freedom to innovate, experiment, and design. Researchers need to collect and analyze data, reflect and suggest revisions. The more educational contexts and uses the medium is applied to, the more likely it is that the true affordances of the new medium will emerge.

4.2 Cultural Compatibility

In a series of studies by Rick & Guzdial (2006), they developed, implemented and studied CoWeb, a version of Wiki designed to support collaborative learning. In general, the results of situating CoWeb across the academic landscape of Georgia Tech (a polytechnical university in the United States) since 1998 were mostly positive. In architecture classes, for example, CoWeb enabled faculty to better serve more students in a design-based course. In English composition, a comparative study demonstrated significant learning benefits without incurring disproportionate costs. Yet, situating CoWeb was not always successful. In many science, technology, engineering, and mathematics classes, students actively resisted collaboration.

The researchers interpret these results by claiming that compatibility between the classroom culture, the discipline culture and the medium used is important for computer-supported collaborative learning to be effective (see also van Aalst and Chan 2001). In architecture, both the culture of the field and the culture of the classroom are compatible with collaboration (e.g., common focus on group design tasks). In English composition, the culture of the field is not necessarily collaborative, but the culture of the classrooms is. In science, technology, engineering, and mathematics classes, Rick & Guzdial (2006) claim that the culture of the field and the culture of the classroom are only partially compatible with collaboration. However, collaboration can be successfully designed into the classroom culture. Rick & Guzdial (2006) explicitly designed a class on introductory computing to take advantage of the collaborative possibilities that Wiki affords, in which Wiki played an essential role in allowing that change of the culture happen.

Is statistics considered a collaborative discipline? In the next section, we portray statistics as a collaborative subject, and therefore one that can easily accommodate collaborative learning and collaborative technology.

4.3 Collaboration in Statistics

Most statistical work is collaborative. Statisticians need to be able to work smoothly on teams and to communicate effectively with their collaborators, who may have little or no background in statistics. This is true across academe, business and industry, where statisticians offer statistical consulting for various projects in different disciplines. In this role, they provide guidance in thinking about and making decisions regarding the statistical aspects of research projects at various stages including design, data collection as well as data analysis. In a significant collaboration, the statistician collaborates on the overall problem (not just the statistical questions) as an equal researcher, sharing responsibility for project success or failure, as well as for publication and patenting.

Since we believe statistics instruction ought to resemble statistical practice, even for non-statistics majors, students should learn about and experience collaboration, teamwork, and develop their communication skills as part of their learning (see Garfield & Ben-Zvi, in press). This assertion is backed by Ross (1995) who claims regarding statistics students that, "the most important thing I would like to see is people emerging from graduate school understanding that they are going to play on a team, and knowing how to communicate in that team setting" (p. 7). Nearly all graduate and even undergraduate programs in statistics today prepare their students to be statistical consultants, and some also prepare their students in communication skills, realizing statistical practice requires high level skills in teamwork, collaboration, and communication. Collaboration in statistics classrooms is important also because it is associated with a host of positive outcomes (e.g., Johnson, Johnson, & Smith 1991). In the following section we briefly present the case for this use of collaboration.

4.4 Collaboration in the Statistics Classroom

Educators, psychologists, and statisticians have all called for students to have opportunities to work together as they learn statistics (e.g., Garfield 1993; Hogg 1992; Lovett & Greenhouse 2002). The recent Guidelines for Assessment and Instruction in Statistics Education (GAISE, Franklin & Garfield 2006), which have been endorsed by the American Statistical Association, also call for active and group learning, even in large classes. Although there appears to be a consensus that collaborative learning should be a part of every statistics class in some way, many faculty have resisted incorporating collaborative learning in their classes (Garfield, Hogg, Schau, & Whittinghill 2002).

Collaborative learning is an important and beneficial way for students to successfully learn statistics if used in a carefully structured way supported by appropriate technology (Johnson, Johnson, & Smith 1991). However, to use this instructional method well, simply putting students in groups to learn is not enough. Instead we want to structure and promote collaboration among students. To accomplish that, the instructors need to learn about, understand and believe in collaborative learning. They also need to be aware of and use research-based guidelines for structuring and monitoring groups.

Peer learning – the instructional use of small groups – includes cooperative and collaborative learning, peer tutoring, cross-age tutoring, and other teaching strategies aimed at structuring the way students interact with each other as they learn (O'Donnell 2006). *Collaborative learning* is used in this article as an umbrella term for all forms of

peer learning in which students work together to maximize their own and each other's learning (Johnson, Johnson, & Holubec 1998).

Extensive research indicates that collaborative learning is associated with a host of positive outcomes, including higher achievement, greater effort to learn, more positive relationships among students, and more positive attitudes toward subject matter (e.g., Johnson & Johnson 1989; Rohrbeck, Ginsburg-Block, Fantuzzo, & Miller 2003; Roseth, Fang, Johnson, & Johnson 2006; Slavin 1995).

In statistics education in particular, researchers emphasize the influence of collaborative learning on statistical reasoning and thinking (e.g., Chick & Watson 2002; Courtney, Courtney, & Nicholson 1994; Perkins & Saris 2001; Potthast 1999). Several studies have documented positive effects of using collaborative learning in teaching college level statistics (e.g., Giraud 1997; Keeler & Steinhorst 1995), even in large classes (see Magel 1998).

Collaborative learning groups can provide statistics teachers with a "window" into students' minds by making hidden thinking processes overt and subject to observation and commentary. Groups can be used to see how and what students are learning, communicating, and doing with their statistical knowledge. Collaborative learning can be supported by collaborative technologies such as Wiki, which is introduced next.

4.5 Educational Wikis

Wiki technology is increasingly explored as a means of supporting collaborative learning activities. The flexibility of Wiki's open architecture, the social and democratic aspects of authoring shared spaces and texts, and the potential to expand functionalities through the design of metadata holds enormous appeal for schools and universities. Common uses of Wikis encourage community building among students and thus change the individual focus of traditional instruction to one of collaboration and a shared construction of knowledge (c.f., Mejias 2006).

Perhaps the most comprehensive application and study of Wiki in learning situations is the CoWeb project, a version of Wiki designed to support collaborative learning at college level that has been mentioned above (Rick & Guzdial 2006). The researchers report that CoWeb supported collaborative learning, particularly in disciplines where open-ended discussion and reflection through writing are valued. In many cases, students were able to concentrate on content (rather than looks) to achieve better results. In other cases, teachers and students were able to go beyond adopting the medium to inventing new uses to serve their needs (Guzdial, Rick, & Kehoe 2001).

Another study investigated how Wiki might help student teams share information and resources while learning to design (Grierson, Nicol, Littlejohn, & Wodehouse 2004). A version of Wiki called TikiWiki (http://tikiwiki.org) was configured so that teams could structure their design resources using Wiki pages and share them using two search strategies – browsing the Wiki pages or using keywords. The results showed that the structuring of information supported learning and that teams preferred to search the Wiki structures rather than use keywords.

Wiki is used and studied at all levels of education, even in primary school. A case study in the course of five semesters since 2002 (Désilets & Paquet 2005) shows that teams of two to five students (grade 4-6) are able to use Wiki for the purpose of collaborative Web-based storytelling. The authors provide a detailed "recipe" and guidelines to allow teachers to use Wiki for this type of activity in their own classroom as well as a number of valuable insights into the collaborative process that children undergo when using Wiki. It also suggests that Wiki could be enhanced by the addition of graphical capabilities.

Perhaps the most common pedagogical application of Wikis in education is to support writing instruction (Lamb 2004), but results are not always positive. For example, in an empirical study of using Wiki in freshman-level English as a second language (ESL), students practiced English writing on a Wiki website (Wang, Lu, Yang, Hu, Chiou, Chiang, & Hsu 2005). Their finding of a significant, but inverse, relation between students' editing usage and academic performance challenges some idealistic hypotheses that Wiki technology is "naturally beneficial" to learning. These researchers believe that building an instructive or constructive instructional model with Wiki in a rigorous manner requires more empirical evidence.

In the following sections we address practical considerations and offer several suggestions of how Wiki could be utilized in a statistics course. We start by presenting necessary steps to be taken before a new course starts.

5. PREPARING A NEW WIKI-BASED COURSE

Before a new course starts, a Wiki Website has to be established on a Wiki server. This is a simple operation that can be typically done via the university IT personal. The instructor's role at this stage is to (a) provide the content of the homepage, (b) choose relevant items for the navigation menu, and (c) decide on the participation policy. The home page typically includes the course goals, content, schedule, main tasks, assessment, etc. It also has a short description of the Wiki-based learning environment including links to a "What is Wiki?" page, a "sand box" – a Wiki writing training page, and help page. It is also recommended to leave room for a "banner" that enables the teacher and students to post messages to appear at the top of every page, creating a course-wide forum for news, ideas, and community building.

The standard Wiki navigation menu (horizontal side menu) can be easily changed to fit the instructional needs of a specific course. For example, in courses I teach, the following menu items are typically used (see Figure 1):

- *Homepage*, a return link to the course homepage at any stage. The homepage is the default first page that shows up when the Website is loaded.
- *Community*, a list of all the students in the course that is linked to their personal pages. Personal pages are automatically created when a student registers to the Wiki Website. These personal pages can be used to keep personal reflective journals (see details below). Group-projects can also be linked here to students' names.
- *Announcements*, a page dedicated to the instructor's messages to the students, and possibly also to students' announcements.

- *Tasks*, a list of links to class or homework tasks ordered chronologically (the newest at the top).
- *Glossary*, a list of annotated concepts created by students throughout the course (see details below).
- *Wiki norms*, a collection of classroom norms generated during the course to make clear the agreed participation praxis (e.g., "don't edit a page while it is used by another student", "It is OK to edit someone else's contribution").
- *Help*, a collection of guidelines to help students in using Wiki.
- *Resources*, a collection of hot links to relevant Websites, journals and books, conferences, etc.

Additional standard menu items in Wiki include links to a list of "Recent Changes" in the Website, search engine, as well as various tools that help using, navigating, editing and printing pages. These tools are important since the amount of information that accumulates during a course is enormous (typically hundreds or even thousands of pages), and without them it impossible to follow the ongoing knowledge construction process. Finally, in preparing for the course, a participation policy has to be decided by the instructor, whether anyone (including an outsider) is allowed to edit content according to the open philosophy of Wiki, or whether participation is limited. I tend to leave the course Website open to anyone, but ask for registration before participation, to avoid anonymous contributions. So far we have had no damage to our courses' Websites. Most students tend to have good intentions, and vandalism is rare. Moreover, we had several enjoyable cases of meaningful contributions by faculty and students from other universities, who found our discussions stimulating, and shared their thoughts and knowledge with us. We turn now to describing several examples of successful implementation of Wiki in statistics classrooms.

6. PROPOSED USES OF WIKI IN STATISTICS CLASSROOMS

We suggest that Wiki can support collaborative learning environments that foster and extend in-class collaboration, facilitate work on group projects outside of class, build networks of collaboration for learning from peers and constructing shared knowledge, foster peer feedback, and assess and manage team performance. In the following examples some of these features are demonstrated. Moreover, Wiki can be used for class management tasks such as distributing information and materials and communications with students. We start with these simple uses followed by more advanced activities.

6.1 Class Management and Information Distribution

Wiki can support many simple class management tasks. With Wiki**,** communicating with students is simple and informal and can be tailored to the specific needs of the instructor. The instructor can easily and quickly distribute information to students between classes, make last-minute changes and cancel class meetings. In many cases, students add their own announcements in the same page (remember that students can change any page in the Wiki Website!), or in a separate students' personal announcements page.

In addition, instructors can use Wiki to circulate course materials to students**,** hand out syllabus, add readings at the last minute, provide access to supplementary material, and distribute links to graphics, videos, and audio materials. The organization and content of this information can be designed and changed easily.

Students can be asked to work together to create a *Resources* page that points to useful Web references related to the topics of the course and post annotated URLs for others to use. In this activity, the teacher has to define the kinds of resources needed, make use of these external resources in the activities of the class (to make sense for the students), and perhaps offer credit for contributing.

A collaborative *Questions and Answers Collection* can be created to include questions that people frequently ask on a topic, and the best answers to those questions (provided by the teacher or by the students). Doing this activity collaboratively makes sense: The question gets asked once, and the answers can be improved during the course of time. The questions and answers can be listed all on a single page, or only the questions are listed on a single page and there are separate pages for each answer. The teacher sets up the basic structure, can post some exemplary questions (perhaps asked in class or in office hours) and start answering them to catalyze the process and leverage the value of student's good questions and answers.

Wiki can also be used for handing-in homework. Students' sharing their assigned homework on the Wiki lets everyone see what peers are doing and creates material for reflection, discussion and later linking. Teachers need to be aware that by requiring posting of homework, students make public their work to the entire Internet, unless access restrictions to the course Wiki are set so that only students can get into it. Students however generally like handing-in assignments this way and find this convenient and useful.

6.2 Collaborative Writing

To extend their statistical knowledge, students can be challenged to write collaborative documents in Wiki in response to questions or puzzles that have multiple solutions and where it is not stated which solution approach to follow. Collaborative writing in Wiki has advantages over traditional collaborative writing in classes. In Wiki, students have to read each others' pieces and truly collaborate to complete the paper instead of just pasting individual pieces together, sometimes without even reading the other pieces. Collaborative writing in Wiki occurs in pages that everyone can edit from anywhere, and there is only one version that always resides in a globally accessible space, instead of individual versions that reside on each student's computer. Moreover, incompatibilities between different word-processors are avoided and the Wiki "Recent Changes" page identifies when, where and by whom the page has been edited and draws students' attention to the ongoing editing.

This high level of collaboration has to be supported by classroom social norms that tolerate student mistakes, welcome feedback, promote revisions, encourage responsibility, value high-quality writing, and appreciate help from peers and teachers. Creating a sense of a community is a complex challenge for the teacher and students. For example, in the beginning, students in our Wiki classes mostly added new pieces of their

own, and were reluctant to “interfere with other people businesses.” Some of them even considered it rude and expected the teacher to be the only authority that provided corrections in the body of the text. Whole-group discussions about class social norms helped students to gradually get over these hesitations and start exploring a review–discuss–suggest–revise process in their writings to synthesize individual contributions and improve group’s products.

Part of the teacher's responsibility in collaborative writing (and other collaborative activities) is to organize small groups by assigning students to topics, creating pages for each team, and allowing the students to simply edit these pages. The responsibility of assigning groups can be turned over to the students by creating the topic (or puzzle) pages and putting in “sign up” numbers (e.g., three numbers for three slots). Students sign their names next to the numbers for the topic that they want to write on.

6.3 A Collaborative Glossary

One benefit of collaborative activities is the practice students get communicating in the statistical language (Franklin & Garfield 2006). Understanding and using the basic language and tools of statistics, knowing what rudimentary statistical terms mean, are part of students’ evolving statistical literacy (Rumsey 2002). One activity in this direction is generating a *collaborative glossary* of statistical terms. It involves students in identifying key statistical ideas, defining and explaining important concepts, talking and writing in statistical language, debating meanings, reaching consensus, providing illuminating examples, and making links among statistical concepts. In our courses, this activity got students to collaborate on something of joint usefulness, a resource for future students to extend (or correct), and thereby generated meaningful discussion and understanding.

Since statistics classes have a rich vocabulary, this activity could be used in many places throughout the course, and could become part of extra credit given to students. As more topics are met, new terms are added. The teacher can provide a list of key concepts, or can ask the students to come up with their lists. The teacher can assign terms to each group or let the groups choose which terms they want to write on. The teacher has to provide several good examples of glossary items, to help students understand the expected length and depth of the task. A page template can be provided in advance that details glossary page sections, e.g., concept title, definition, uses, examples, links to Web resources and related concepts. In our classes, students tended to work on this task on their own, although it was presented as a collaborative task. The teacher’s encouragement helped students to collaborate, but more useful was the students' discovery that teamwork results in higher-quality items. Setting up this activity is simple: Pages need to be created for the glossaries (perhaps one page per concept).

6.4 Discussion and Review

There are many opportunities during the statistics course that call for reviewing and discussing a reading piece. For example, students prepare for class by reading a few pages in a textbook. The students are given some study questions to guide their reading and note taking. Thus, their introduction to new content takes place outside of class, as

they read the material, practice some examples, and jot down notes. This preliminary exposure to statistical language and technique can be supported by collaborative discussion in Wiki in which students raise questions regarding the reading portion, request clarifications, and make connections (e.g. create hyperlinks to glossary items and related Websites). Such a collaborative discussion can better prepare them to come to class, as well as help the teacher identify difficulties, misconceptions, and questions of interest.

Activities that involve reading, reviewing and analyzing some text posted on the Wiki by the teacher can be used in different ways during the course. The advantage of using Wiki is that the discussion by the students is closely anchored to the original text. Students can use the discussion page, which accompanies every Wiki page, to discuss issues related to the posted text. They can also identify issues that they want to explore in the given text, and hyperlink them to new pages in which they extend the phrase or idea, by explaining it, providing examples, linking to other concepts, etc. This type of collaboration led in our classes to more extended and still on-topic discussion than in electronic collaboration spaces like newsgroups or WebCT.

Collaborative discussion and review activities are quite easy to set up in Wiki. The discussion topic is typically an assignment or homework definition provided by the teacher, with a commentary page linked to it. Just about any class that has interesting things to talk about can use collaboration to focus and prolong student discussion. Examples include:

- Answer homework questions;
- Collaboratively analyze data, or other textual material that call for statistical judgments;
- Review media clips that include data-based arguments and graphs, annotate them, criticize them, change them, and suggest corrections; and
- Post solutions, questions, or critiques of other solutions of problems like those that can be expected to be on a Midterm or Final examination (e.g., taken from previous exams).

6.5 Collaborative Statistical Projects

In addition to quizzes, homework and exams, many statistics teachers use student's statistical projects as a form of conceptual learning and authentic assessment. These projects vary in structure, but typically allow students to collaborate with peers and professionals in posing or selecting a problem, gathering or accessing appropriate data to answer the problem, analyzing the data, and writing up the results in a technical report and/or presentation (Chance 2000; Starkings 1997).

In Wiki students can write up their projects in a way useful to their own group work and peers, as well as future students. Instead of posting just their final report, students are asked to present the process that led to this report, such as considerations used in formulating their research question, choosing sampling method, data gathering, etc. By publicly exposing the statistical investigation process, students can get timely feedback from other students and the teacher instead of just at the endpoint. Students use this

project library of previous classes to improve their projects, by looking at lots of different cases, gaining insight into research ideas that they might not get just from seeing a few cases in class and in the book. Examples of projects are interesting if they include corrections, description of the research process, strengths/weaknesses analyses of the project, etc.

The teacher has to create a project page to which all projects are linked, and to organize this page to indicate what the cases are about and optionally what the better ones are. The teacher provides ongoing feedback on the process. This conveys to the students that the teacher actually reads and values the projects. Students in our classes learned to value posting "half-baked ideas" in the Wiki in order to discuss them and get feedback. They also learned the important role of revisions and communication in the statistical investigation process.

6.6 Reflective Learning Journals (Diaries)

Students are asked to self-reflect on their learning in a Wiki personal page. (A personal Web-page is automatically generated as soon as a student registers to the Wiki Website.) They are asked to do so soon after class, when their memories are still fresh. They can write about their learning experiences, understandings, concerns and difficulties, activities they (dis-) liked or found more (or less) useful, or report on their group's work. These journal entries are a valuable resource for the student that help develop metacognitive abilities by reflecting on and monitoring his/her learning processes (Schoenfeld 1992). It is also valuable to the teacher – to reflect on students' (mis-) understandings and attitudes, as well as for other students – to relate to their peer's experiences. Student self-reflection is also intended to increase student responsibility to her/his learning. To set up this activity the teacher has only to link these personal diaries to a "*Community*" page that lists all students in class.

In the first lesson, these individual pages can be used by students to introduce themselves to the group by posting on it information about themselves (e.g., a picture). This can help in creating a sense of community in which learners know each other better. In our classes, in which several community building activities took place, students reported that this 'sense of community' promoted their motivation, participation, risk-taking (e.g., in posting "half-baked" ideas, in initiating new pages), and contribution. Some of the students reported a sense of ownership of the collaborative space, and initiated new ideas and discussion.

6.7 Assessment

Many of the Wiki-based activities that are presented above can be used as formal and informal opportunities for student assessment, self-reflection, and feedback to the instructor. For example, to assess student statistical literacy, use student interpretations and critique of articles and graphs in a newspaper, or a glossary activity. To assess student statistical reasoning, use short essay writing, or solving collaboratively open-ended statistical problems. To assess statistical thinking, use a collaborative statistical project (Garfield & Ben-Zvi, in press). Student written journals (personal diaries) include valuable information on student learning and on the instructional materials and methods.

Wiki allows the instructor to provide constructive and timely feedback, with clear indications of how to improve performance, and adhere to the task requirements and expectations. This feedback becomes part of the Wiki page or the adjacent discussion page, and can be utilized by students in later tasks.

The teacher can use the Wiki's "My Contribution" page (lists all pages that were edited or created by any registered user) to evaluate each student's contribution to the collaborative activities and discussions. (This specific recommendation is hard to follow, since the numbers of individuals' contributions is enormous, and we therefore plan to develop techniques and perhaps software tools that will assist us in tracking contributions more efficiently.) It is important for the teacher to consider how to combine these assessment tools throughout the course to make sure that, as a collection, the assessment tasks cover the most important goals for the course, that the action/feedback from the different components inform each other, and that no undue burden is placed on the instructor or the students. It is crucial to consider this assessment component while a course is designed and to clearly lay out the goals and purposes of the assessments as part of the course syllabus.

7. PRACTICAL CONSIDERATIONS/LIMITATIONS

Adoption on a massive scale of Wiki-based courses is possible since the application is fairly unsophisticated (low bandwidth, no special hardware) technology (Zimring, Khan, Craig, ul Haq, & Guzdial 2001). Wiki is usually a cross-platform and lightweight server application that can be run on virtually any hardware, so even an older server can easily support many classes. Student access to Internet-enabled computers is essential for Wiki use; there is usually no need to incur any additional infrastructure costs as universities' campuses are already wired for Internet connectivity. Unlike Wiki, many other efforts to implement technology in learning focused on expensive software and new hardware that make widespread adoption of the technology impractical.

The most substantial cost is teacher time. Yet, computer-supported collaborative learning has the potential to actually decrease that cost (Barab & Squire 2004, p. 11). By engaging students in collaboration, the large numbers in classes can be leveraged to create greater opportunities for discussion, reflection, and (consequently) learning and assessment. Because the increased opportunity for learning is coming from the students themselves, the cost for the teacher does not need to rise any further than simply providing oversight for the process (Rick & Guzdial 2006).

8. SUMMARY

In this article, we concentrated on understanding the potential of one new medium—Wiki—in statistics classrooms. We portrayed statistics as a collaborative discipline and therefore compatible with Wiki as a collaborative medium. We have suggested that collaboration in the statistics classroom can improve learning of individuals in the group as well as the whole class. We presented a set of recommended instructional activities in which Wiki can become a powerful tool in supporting statistics learning through collaboration and communication. These suggested instructional ideas

are designed to utilize the essence of Wiki—relative simplicity, empowered learners, bottom-up organization.

The needs met by Wikis—easy authoring of Web content, open access, unrestricted collaboration—are not being satisfied by other available ICT tools. (Information and Communication Technology (ICT) deals with the use of electronic computers, electronic communication and computer software to convert, store, protect, process, transmit and retrieve information.) Therefore, it is clear that Wiki (and other emergent technologies) are filling a gaping void in existing teaching and learning practices. However realizing the Wiki potential in statistics education is far from trivial. Effective utilization requires thoughtful and deliberate planning as well as creativity and enthusiasm. Serious use and extended practice is necessary to properly understand the potential of the new medium (Bolter & Grusin 1999; McLuhan 1964). Adopters need the freedom to innovate. The more contexts and uses the medium is applied to, the more likely it is that the true affordances of the new medium will emerge.

Wikis are beginning to enter into practice across the academe and grow in popularity, but what remains unknown is whether educators, institutions, and developers will join the innovative, sometimes revolutionary practices.

It is our hope that, through this article, others will better understand the Wiki's potential to support collaborative learning, and as a result will be better equipped to realize that potential to address their own teaching or learning goals. It's also our hope that more studies will take place in years to come that will provide information on appropriate uses of Wiki to improve student collaborative learning of statistics.

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