Impact of Real-time, Electronic, Formative Feedback: Using InkSurvey as a Collegiate Learning Tool In Engineering Statistics

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Abstract

This paper describes the impact of InkSurvey in a college classroom, as a tool to formatively shape instruction. Tablet personal computers (PCs) were distributed and the InkSurvey software was used for the instruction of a Probability and Statistics Course for Engineers. Using InkSurvey, instructors are able to view student responses and use this information to alter instruction in real-time, immediately addressing students' learning needs. Data was collected from volunteers using the following methods: a pre and post concept inventory on statistics, a pre and post attitude survey, and an anonymous, end of the course, student assessment survey. The results of this study support that students' concept knowledge, as measured by the Statistics Concept Inventory, and the students' attitudes, as measured by the Attitudes Survey, both validated instruments, became more positive with respect to statistics over the course of a semester.

1. Introduction.

Todays' college students are accustomed to and comfortable with technology being integrated into all facets of their lives. Entering college students have interacted with technology since they were children, both through formal education and out of school experiences. College faculty who grew up during a different period may neglect technology as a resource, preferring traditional teaching methods, such as overheads and white boards. Yet, technology can provide advantages over these traditional methods, including the documentation of classroom instruction for later student review and the conversion of a passive classroom to an active one. Colleges and instructors are including technology in classrooms as a means of improving instruction, retention, and attitudes. Research is underway in an effort to identify the most effective pedagogical approaches (Probst, 2014). This article examines the impact of a method of embedding technology, viz. InkSurvey and Blackboard, on a daily basis, into the college level course for engineers in probability and statistics.

The sections that follow include an overview of how current students are likely to experience technology in the classroom before they enter college, and of college efforts to embed technology into instruction. This is followed by a review of the assumptions that inform college instruction and learning and how these assumptions can be supported through the use of the InkSurvey software and Blackboard. Next, the research methods used here and the results of these efforts are discussed. This article concludes with a description of the potential impact of this work for college level instruction.

1.1 College Students' Prior Experiences: Technology in Precollege Education

Ontario schools provide an example of the experiences that some students have with technology before entering college. Seventy nine percent of the kindergarten classrooms in Ontario reported the introduction and use of computer technology as part of the learning process (People for Education, 2014). In the U.S., as of 2003, 80% of kindergarten students reported using some type of computer and 32% reported the use of the internet; amongst high school students, 97% reported using the computer and 80% reported using the internet (National Center for Educational Statistics, 2005). In 2009, 97% of public schools in the U.S. reported the availability and use of the computers in the classroom (Gray, Thomas & Lewis, 2010). Many of the students included in the kindergarten sample in 2003 are now ready to enter college. Their then older peers, first through twelfth graders, may already be in college or have completed college. Pre-college students also report the use of hand-held and tablet PCs with pen-based entry to support the completion of comprehensive digital notes (Frolik, 2004; People for Education, 2014).

The details of how these machines are used during instruction are not clear. In Baltimore County Public Schools, through the support of HP, 120,000 PCs were distributed for teacher and student use in the fall of 2014 (Christensen, 2014). As more elementary and secondary schools embrace the use of technology as a natural component of instruction, more college students will expect technology to be integrated into the university experience. The use of traditional overheads and white boards, and the necessity of maintaining scrupulous notes, are likely to be confusing to students who have experienced a technology rich precollege education. As precollege instruction increases the use of technology in the classroom, colleges will be expected to respond in a similar manner.

1.2 Technology at the University

Many universities have responded to the anticipation of the arrival of technology savvy college students. Georgia Institute of Technology developed Classroom 2000 in the mid 1990s as an electronic resource to capture college level, classroom lectures (Abowd, 1998). This project continues today with a revised and period-appropriate name, eClass (Brotherton, 2001; Georgia Institute of Technology, 2014). eClass captures lectures by storing the instructor's audio and visual notes online for later review by the students. This approach makes it easier for students who attend class to maintain pace with the lecture while limiting the demand for note taking; students who miss class also have an online resource to assist them in making up the material. Various platforms are available to organize and post instructors' notes and videos, including purchased programs, such as Blackboard (Blackboard Learn, 2015), and free access versions, such as Moodle (2015). Often these platforms are coupled with other modes, such as YouTube, Smart Boards, etc., to provide students with more complete resources and information.

eTeach at the University of Wisconsin supports a different approach for transferring information from instructor to student, referred to as the "flipped classroom." The term "flipped classroom" has come to represent Moses and Litzkow's approach to instruction (2000; Anderson & Litzkow, 2008) in which students view online videotapes of a lecture before class. In class, the students participate in active problem solving. The classroom is called "flipped" because instruction occurs at home and homework is completed in class with the instructor available for questions. This flipped classroom approach to learning has been criticized by Bogost (2013) for being a "condensed" classroom or a classroom in which lectures are streamlined into morsels, and delivered in a manner that is similar to textbooks. Whether lecture is delivered in the classroom or via video at home, the learning process during the lecture is most likely passive. Students passively listen to an instructor either during class or while watching a video. The approach that is discussed in this article is different in that the students are actively engaged in lecture by responding to questions that the instructor posts on InkSurvey.

1.3 Assumptions of University Instruction

Reflecting on traditional instruction, online instruction, and the flipped classroom, several conclusions can be drawn as to the premises that underlie college learning environments regardless of whether technology is included:

- Lectures in some form continue to be necessary, whether they are delivered in person or by video. Lectures provide a method of introducing new material to students in an efficient manner.

- Students require active learning experiences, either in class or at home, in which they practice the process of applying their knowledge to problem solving situations.
- Active learning, or learning that engages students' interests and attention, is more effective for improving students' knowledge than is passive learning, or listening to instruction while taking notes.

The current article supports the addition of the following:

- Faculty are better able to support their students' learning needs when they have formative information concerning their students' knowledge base which can be used to dynamically adjust instruction to the learners' needs.

This final assumption separates the efforts described here from the previously described work. Most videos do not evaluate and adjust to the knowledge of the students who view them. When formative assessment information is available, faculty may change their instructional approach based on students' needs, creating a more efficient and effective learning environment.

These assumptions of learning lead to the model of instruction adapted to learning that appears in Figure 1. The first step in the process is student exposure to new material. This typically occurs through a lecture, which is viewed by students during class or before class via video. During the next phase, students participate in active learning, which usually includes problem-solving activities. Based on the student responses during active learning, the instructor can adjust and adapt instruction to match the students' learning needs. The cycle repeats throughout the learning process as new material is introduced. A shorter cycle is likely to result in a more efficient learning process, especially when the instructor has the information that is necessary to dynamically adapt to and address students' learning needs.

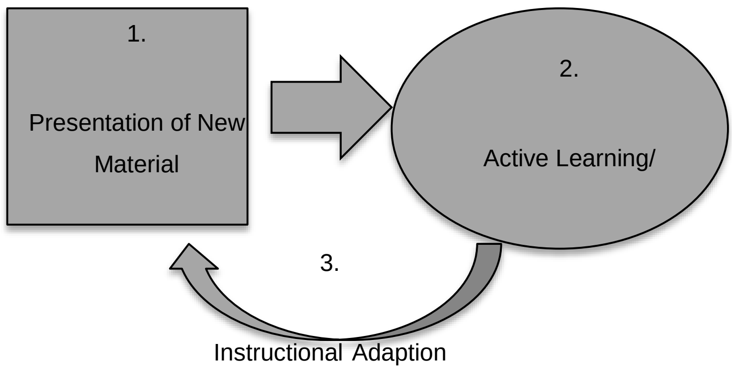

Figure 1. Model of instruction adapted to learning

1.4 InkSurvey Software

InkSurvey was developed at <Blind> under a HP Technology for Teaching grant with the purpose of supporting the formative assessment of students' understanding of lecture material while lecture was being delivered (Kowalski, Kowalski & Hoover, 2007). InkSurvey is web-based and permits the instructor to post questions to which students respond during lecture. Students can respond by typing or pen-based entry, as is more likely in probability and statistics. Other software, such as Classroom Presenter (Anderson et al., 2007), is available to support similar classroom purposes. InkSurvey was selected for use in this investigation rather than comparable software for the following reasons: i) InkSurvey was developed at <Blind>, providing local support for the software, and ii) InkSurvey is available via the internet without the requirement that additional software be downloaded to individual computers. Through InkSurvey, the students' classroom problem solving approaches are transformed into information that may be used immediately by the teacher to inform the direction of instruction. The cycle described in the previous section is reduced to a minimum length, allowing the teacher to acquire formative information from students multiple times during a single classroom event. Blackboard was used in this investigation to post an outline of the class notes, reducing note taking to a minimum.

1.5 Research Questions

The research questions that were investigated here are as follows:

1. As measured by the Statistics Concept Inventory, do students' concept understanding change from the beginning to end of a course that utilizes InkSurvey and Blackboard in the instruction of probability and statistics for engineers?
2. As measured by an attitudes survey, do students' attitudes with respect to probability and statistics improve following a course that utilizes InkSurvey and Blackboard in instruction?

3. Material and Methods

This section provides an overview of the course, instructor and its' students. Next, a description of the instructional and the assessment approach is provided.

3.1 Course, Instructor and Students

The data presented here was collected in the Spring of 2013 as part of the Probability and Statistics for engineers course at <Blind>. Probability and Statistics for engineers is a junior level course that is required for most engineering majors. The course textbook was "Statistics for Engineers and Scientists" (Navidi, 2010). The course instructor had 18 years of experience and had previously taught this course on seven occasions. On two prior occasions, this instructor had used InkSurvey and Blackboard jointly to support instructional learning. Additionally, this instructor had oversight of the initial implementation of InkSurvey in this course in 2011 (Blind). At the time of this investigation, she was already familiar and comfortable with the capabilities and use of the software in the classroom.

There were 38 students registered for this course. All students were majoring in science or engineering undergraduate degree programs at <Blind>. The students were not expected to have their own computers; rather, tablet computers were distributed to students who requested them at the start of the semester. Some students brought and used their own machines, including iPads and other hand held devices. All students had a machine that supported pen-based entry.

3.2 Instructional Approach

The primary approach to instruction used in this investigation was lecture. Lecture occurred twice per week, for one hour and fifteen minutes. An outline of each day's notes was created by the instructor in Word and posted in a PDF file on Blackboard for student access; registered students had the opportunity to download, print or review these notes before each class or during class. The online PDF notes are available upon request from the first author. The solutions to practice problems were omitted from the posted course notes. The students, using the InkSurvey software, completed these problems in class and submitted solutions anonymously to the instructor. The complete file of submitted responses appeared on the instructor's computer screen immediately following submission, and was reviewed by the instructor in real time by scrolling through responses.

The students were permitted to work individually or in pairs when completing in class problems, but were asked to submit individual responses. The instructor projected the online responses to a screen during class and discussed both correct and incorrect solutions. When necessary, the instructor used the student errors to identify material which needed to be discussed in greater depth. The instructor added follow-up problems when necessary or reduced the number of problems based on the students' submitted solutions. In other words, the use of the InkSurvey software resulted in the adaption of instruction in a dynamic manner based on student learning needs.

On average, the students completed a problem and submitted a solution through InkSurvey three times within a 90 minute instructional session. Approximately half of the attending class typically submitted a solution. Students had the option of writing anonymous questions to the instructor in place of a response if they were confused or required further information to complete a given problem. The instructor became proficient at quickly reviewing student responses and identifying correct and incorrect approaches.

2.3 Assessment Instruments

All students were invited to complete the online pre and post concept inventory and attitude survey during the first and last two weeks of class, respectively. Participation was voluntary and the instructor was not aware as to which students selected to participate. Both the concept inventory and the attitude survey were administered using the CiHub. Prior research supports each instruments' validity and reliability for use in the college classroom (Stone, Allen, Rhoads, Murphy, Shehab, & Shaha, 2003; Allen, 2006; Wise, 1985). The concept inventory contained 38 questions which directly addressed the material that was covered during the course, including probability, inference, and graphical representation of data (Allen, Reed-Rhodes, Terry, Murphy, & Stone, 2008). The survey was scored based on the number of correct answers.

The attitude survey was comprised of 29 statements about statistics, using both positive and negative phrasing (Wise, 2008). The survey was scored using a four-point Likert scale, ranging from 'Strongly Agree' to 'Strongly Disagree.' No neutral option was available, forcing students to determine whether they agreed or disagreed.

Student feedback concerning the use of the InkSurvey software was also collected as part of the end of the semester course evaluation. All feedback was anonymous. The course evaluation consisted of eleven statements addressing the effectiveness of the course and the instructor. Response categories ranged from "Strongly Agree" to "Strongly Disagree" and included a "Not Applicable" option. The survey further included three open-ended questions, in response to which students could provide unstructured comments concerning the course.

4. Results

4.1 Concept Inventory

Sixteen of the 38 registered students completed both the pre and post Probability and Statistics Concept Inventory. As Table 1 indicates, the majority of students' performances improved from pre to post-test with an average difference from pre to post of 12.2%. Only two students, student 3 and student 9, displayed either a decrease in performance or no change. Students average performance on the pretest was 47.7% and on the posttest 59.9%. The average posttest performance with student 3 and student 9 removed is 63.5%. Given that concept inventory was not created by the instructor, this level of performance on an externally developed assessment is acceptable (especially given the witnessed increase from the pretest as is described in the next paragraph).

Given the data is paired and the sample size is small, a probability plot was created across all students of the paired differences and trend line was fitted. This resulted in an $r^2 = 0.89$. Based on this, an assumption of normality is likely to be appropriate and a paired t-test was selected for analysis purposes. A one-tailed, paired t-test was completed and resulted in a statistically significant result, with $p = .001$. It can be concluded that students' average posttest scores were statically greater than their average pretest scores on the concept inventory. Students' average performances, as measured by the concept inventory, improved over the course of the semester at a statistically significant level.

Table 1. Summary of student knowledge of statistics course material.

	Pre-Test		Post-Test		Percent Difference
	Percent	Rank	Percent	Rank	
Student 1	47.4	Moderate	65.8	Moderate	18.4
Student 2	55.3	Moderate-high	71.1	High	15.8
Student 3	50	Low-moderate	23.7	Low	-26.3
Student 4	55.3	Moderate	60.5	Moderate-high	5.2
Student 5	65.8	Moderate	81.6	Moderate-high	15.8
Student 6	39.5	Low-moderate	63.2	Moderate	23.7
Student 7	34.2	Low	52.6	Low	18.4
Student 8	36.8	Low-moderate	44.7	Low-moderate	7.90
Student 9	65.8	Moderate	65.8	Moderate	0.0
Student 10	44.7	Low-moderate	73.7	Moderate-high	29.0
Student 11	36.8	Low-moderate	42.1	Moderate	5.3
Student 12	52.6	Moderate	65.8	Moderate-high	13.2
Student 13	34.2	Low	50.0	Moderate	15.8
Student 14	31.6	Low	34.2	Low	2.6
Student 15	57.9	Moderate-high	89.5	High	31.6
Student 16	55.3	Low-moderate	73.7	Moderate	18.4

4.2 Attitudes Survey

Sixteen of the 38 registered students also selected to complete the Attitudes Survey. Students' average responses for each statement that appeared on the attitudes survey are displayed in Table 2 and Table 3. Table 2 contains all of the positively phrased statements and Table 3 contains all the negatively phrased statements. As indicated in Table 2, on average, the students' responses were more positive with respect to their own need to learn statistics as a professional after the course than before the course. For the majority of the positively phrased statements, the average response across students increased. Only one statement out of fifteen displayed a decrease from pre to post assessment and one statement displayed, on average, a half-point gain from pre to post assessment.

Table 2. Summary of student attitudes toward statistics on positively phrased statements.

Positive Statements	Pre-Test Score	Post-Test Score
I feel that statistics will be useful to me in my profession.	3.2	3.2
A good researcher must have training in statistics.	3.2	3.5
Most people would benefit from taking a statistics course.	2.9	3.0
I would like to continue my statistical training in an advanced course.	2.2	2.3
Statistics will be useful to me in comparing the relative merits of different objects, methods, programs, etc.	3.1	3.1
Statistical training is relevant to my performance in my field of study.	2.9	3.0
Statistics is a worthwhile part of my professional training.	3.0	3.1
Statistics is an inseparable aspect of scientific research.	3.3	3.4
I am excited at the prospect of actually using statistics in my job.	2.6	2.7
My statistical training will help me better understand the research being done in my field of study.	3.0	3.1
One becomes a more effective consumer of research findings if one has some training in statistics.	3.3	3.3
Training in statistics makes for a more well-rounded professional experience.	3.2	3.3
*Statistical thinking can play a useful role in everyday life.	2.9	3.4
I feel that statistics should be required early in one's professional training.	2.9	3.1
#Statistical thinking will one day be as necessary for efficient citizenship as the ability to read and write.	2.3	2.1

Marks statements in which students' attitudes declined from pre to post assessment.

*Marks statements in which students' attitudes increased more than 0.5 on average from pre to post assessment.

The students' responses to the negatively phrased statements were reverse coded, so that a higher average indicated a positive attitude. This allows the reader to look across the table for increasing values from pre to post assessment in order to identify improved attitudes. Out of the fifteen statements, only two displayed a decrease in the students' attitudes toward statistics. Three of the statements, on average, displayed at least a half a point increase from pre to post assessment. These are marked.

Table 3. Summary of student attitudes toward statistics on negatively phrased statements.

Negative Statements	Pre-Test Score	Post-Test Score
*The thought of being enrolled in a statistics course makes me nervous.	2.0	2.5
#Statistics seems very mysterious to me.	2.5	2.4
I have difficulty seeing how statistics relates to my field of study.	2.0	2.2
*I see being enrolled in a statistics course as a very unpleasant experience.	2.1	2.7
Statistics is not really very useful because it tells us what we already know anyway.	1.8	2.1
*I wish that I could have avoided taking my statistics course.	2.2	2.7
Statistics is too math oriented to be of much use to me in the future.	1.8	1.9
I get upset at the thought of enrolling in another statistics course.	2.2	2.6
I feel intimidated when I have to deal with mathematical formulas.	1.7	1.8
Studying statistics is a waste of time.	1.8	2.0
Dealing with numbers makes me uneasy.	1.6	1.7
#Statistics is too complicated for me to use effectively.	2.0	1.8
Statistical training is not really useful for most professionals.	1.9	2.2
Statistics is not really very useful because it tells us what we already know anyway.	1.8	2.1
Statistical analysis is best left to the experts and should not be part of a lay professional's job.	2.0	2.1

Note: Categories were reverse coded, resulting in a higher number indicating a more positive attitude.
Marks statements in which students' attitudes declined from pre to post assessment.
*Marks statements in which students' attitudes increased more than 0.5 on average from pre to post assessment.

3.3 Course Evaluation

Eighteen students completed the end of the year course evaluation. The student responses to the selected response portion of the instrument are displayed in Table 4. As indicated by this table, the students' evaluations of this course were positive. None of the students indicated disagreement with any of the statements.

Table 4. Summary of student evaluations of probability and statistics course.

Statement	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree	Not Applicable
The teaching methods used in this course are effective for promoting student learning.	8	7	3	0	0	0
The instructor explains the material clearly.	7	9	2	0	0	0
The instructor is available during office hours.	7	9	2	0	0	1
The instructor creates an environment that fosters student involvement in the learning process.	10	7	1	0	0	0
The instructor demonstrates a positive attitude toward helping students.	9	8	1	0	0	0
The instructor facilitates student learning.	9	8	1	0	0	0
Graded work reflects the content of the course.	8	9	1	0	0	0
The stated grading policies for this course are fair.	8	9	1	0	0	0
The course goals are clearly stated.	5	12	1	0	0	0
The course goals are being met.	6	10	2	0	0	0
Overall, this instructor is effective.	6	10	1	0	0	0

The course evaluation also included three open-ended questions:

1. What aspects of instruction in this course do you find are effective for promoting your learning?
2. What recommendations would you make that would improve the instruction that you are receiving in this course?
3. If you have any additional comments, please write them in the space below.

Open-ended responses were coded for emergent themes. Some of the student responses to these open-ended questions pertained to the use of tablets and InkSurvey software during the class. These themes and the responses that fell within each are summarized below. Only one student expressed dislike for InkSurvey. Several students indicated that they liked InkSurvey and others indicated that they enjoyed the interactive examples provided in class. Negative comments included requests for more detailed explanations of the problems discussed in class; it is unclear as to whether these request were related or reflective of the use of the software in class.

Table 5. Student comments about the technology in the course.

Positive		Negative	
Comment	Number of Times Recorded	Comment	Number of Times Recorded
General liking of InkSurvey.	3	General dislike of InkSurvey.	1
Liked use of interactive example problems during lecture.	2	Requested more explanation of the solution to example problems.	3
Liked increased class involvement.	2	Found example problems too difficult to be helpful.	1
Liked lecture notes posted online.	1		

4. Discussion

The results of this investigation support the assertion that InkSurvey combined with Blackboard can be effectively used to support instruction in a college level engineering course on probability and statistics. The students' concept knowledge, as measured by the Concept Inventory, and the students' attitudes, as measured by the Attitudes Survey, became more positive with respect to statistics over the course of a semester. Although the first of these results would be anticipated (that students would learn the course material), prior research with respect to this same course, taught at the same university, and including the same instructor challenge this assertion.

In the spring 2011, a study was completed using InkSurvey across all Probability and Statistics courses offered at <Blind>. Out of five sections, four displayed no change or a decline in student performances as measured by the concept inventory from pre to post assessment. Only one instructor's students displayed a modest increase in students' performances and that was not the instructor who participated in the current investigation. The current instructor's students displayed no change in knowledge and a decrease in attitudes from pre to post assessment in 2011 investigation. Yet, the pedagogical approach used in 2011 by this instructor was similar, in fact almost identical, to that which was used in 2013. All course notes were posted on Blackboard and the students responded to approximately three questions per class through InkSurvey. In the 2011, implementation, however, Tablet PCs were distributed at the beginning of class and collected at the end of class. The cost of these machines prohibited the students from checking them out for the semester. By 2013, tablets with pen-based stylus and touch screens replaced the tablet PCs and were available at an affordable cost (~$150). These machines were loaned to the students for the semester.

In the article that was written concerning the 2011 implementation (2012), the researchers speculated that the implementation of pedagogical change, any pedagogical change, requires time for both the instructors and the students to adjust. The participating instructor has implemented this approach in three separate offerings of the course, with the current investigation being the third. As was reported here, the anticipated increase in performance was statistically captured in the respective instructor's course. Other factors that may impact the results of this investigation include a changing student population, with each year bringing students with greater technological experience, as well as changes in the technology that is used, such as movement from Tablet PCs to Touch Screen Tablets with Pen-based entry. Any or all of these factors could explain the differences that were witnessed here between the 2011 and 2013 findings.

This raises an important concern as technology is introduced and tested in the classroom. Technological pedagogical approaches that failed in the past may, due to changing students' skill bases and improvements in interface design, succeed in the future. As was argued by Probst (2012), students who have been raised with computers are likely to have different learning preferences from those who were raised without computers. These preferences are just beginning to display themselves at the college level. Additionally, as students receive more opportunities to use computers in the precollege classroom, they may demand the opportunity to use technology in the college classrooms. This next generation, or possibly the one that follows, may enter college not knowing how to take detailed hand-written notes. What was once a valuable skill may become outdated and replaced by online notes and video discussions. College professors need to prepare.

Some college instructors are responding to the learning needs and expectations of this generation of students by making better use of technology in the classroom. One trendy example is the implementation of the flipped classroom where faculty prepare a lecture online, the students watch this video at home, and during class the students complete reinforcement problems with the instructor's support. This method requires the creation and posting of videotapes online. Faculty may not know how to create and post a video, and some may be resistant to archiving their image online. InkSurvey combined with Blackboard offers a different to enriching the classroom through the use of technology. Instruction is documented through the availability of online notes and active learning and formative instruction are supported through InkSurvey.

4. Conclusion

In most college classrooms, traditional lectures continue to thrive. This article and the approaches describe here do not challenge the traditional methods; rather, this research supports the enhancement of traditional approaches through technology. Most faculty members know how to lecture and evaluate student responses. InkSurvey supports faculty members in using these skills in real time to improve student learning by shortening the instruction adapted to learning cycle. The feedback to the students is almost immediate as is the instructor's adaption of instruction to match student needs. As with any instructional change, there does appear to be a learning period of at least a semester in which the course instructor practices and learns the new methodology. As is discussed here, measurable change was detected in student performances and student attitudes during the third implementation of this approach.

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