Teaching Statistics Online: A Decade's Review of the Literature About What Works

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Abstract

A statistics course can be a very challenging subject to teach. To enhance learning, today's modern course in statistics might incorporate many different aspects of technology. Due to advances in technology, teaching statistics online has also become a popular course option. Although researchers are studying how to deliver statistics courses in this new technological environment, there is still much to learn about how to effectively implement these online courses. The purpose of this paper is to report the results of an extensive review of the literature conducted across several disciplines from the last decade in an effort to summarize, identify, and understand overall trends and themes in online instruction. A summary of effective practices that might be useful to teachers teaching statistics online concludes this paper.

1. Introduction

Today, technology is used more than ever before in education, primarily to supplement and/or enhance teaching and learning. In fact, as technology has advanced, many traditional colleges and universities are now also offering courses and complete degree-programs in a wide variety of disciplines online or at a distance (Council for Higher Education Accreditation 2002). This alternative form of course delivery is a fast-growing trend and has the potential to change and revolutionize teaching and learning at every level of education, perhaps forever.

One challenge from a statistics education perspective is the lack of empirical results, discussion, and research about teaching and learning in an online statistics course. Particular questions of

interest include: What theoretical framework best informs how students learn statistics at a distance? How is instruction "best" delivered? Which type of technologies appear to be most helpful for learning specific statistics concepts online? How does student-to-student interaction and student-to-teacher interaction take place? Is there an optimal course design? Although there are researchers who are studying how to deliver statistics courses in this new technological environment (i.e., Harrington, 1999; Chao and Davis, 2000; Kennedy and McCallister, 2000, 2001; Speed and Hardin, 2001; Stephenson, 2001; Yablon and Katz, 2001; Zhang 2002; Pan, 2003; Utts, Sommer, Acredolo, Maher, and Matthews, 2003; Brown and Kulikowich, 2004; Grandzol, 2004; McLaren, 2004; Suanpang, Petocz, and Kalceff, 2004; Ward, 2004; Dutton and Dutton, 2005; Mills and Xu, 2005-2006; Rynearson and Kerr, 2005; Sloboda, 2005; Summers, Waigandt, and Whittaker, 2005; Kartha, 2006; Kreiner, 2006; Tudor, 2006; Everson and Garfield, 2008; Johnson, Dasgupta, Zhang, and Evans, 2009), there is still much to learn about how to effectively implement these courses and what practices are best.

2. Purpose

The purpose of this paper is to report the results of an extensive review of the literature in several disciplines from the last decade in an effort to summarize, identify, and understand overall trends and themes in online instruction. In addition, a summary of findings and recommendations that might be useful to teachers teaching statistics online or at a distance is also discussed.

For the studies reported in this review, a variety of terms were used to describe their approach to online teaching or teaching at a distance. Some of these terms included:

- "teaching statistics online"
- "statistics through the medium of the internet"
- "teaching statistics via distance"
- "teaching in a blended learning environment"
- "programmed instruction/distance learning"
- "a hybrid statistics course"
- "hybrid internet-based course" and
- "web-based or "web-assisted" instruction.

In addition, a review in the literature of defined terms used to describe teaching online revealed similar, but vague or indistinguishable definitions. For example, according to the Council for Higher Education Accreditation (2001, p. 3), the term "distance learning" refers to "any application of electronic technology to teaching and learning". It was also defined as "any kind of education activity in which students are separated from faculty members and their peers" (Council for Higher Education Accreditation , 2001, p. 3). Another common term known as "electronic learning" or "e-learning" also has its roots in distance education and has been defined in many different ways in the literature. Ong, Lai, and Wang (2004) broadly defined it as "instructional content or a learning experience delivered or enabled by electronic technologies" (2004, p.1).

The term "online learning" or "online education" is another commonly used term to describe all or some of the learning activities mentioned above. The National Education Association (2005)

defined "online education" as encompassing a number of different guidelines, some of which might include:

- A planned course of instruction conducted primarily online.
- Students and teachers separated in time and place but they meet face-to-face on occasion.
- Asynchronous or synchronous communication is utilized.
- Use of one or more of the following technologies: computer, internet access, telephone, and some type of course or learning management system (i.e., e-learning, Blackboard, etc.).

Given the variety of terms and definitions that were found in the literature related to teaching statistics online, it makes sense to provide an operational definition for "online teaching" for the studies summarized in this paper. For the purposes of this review, studies that met the NEA (2005) definition as well as studies in which students learned statistics exclusively online (i.e., class meetings are not required) are included in this review. In addition, although an effort was made to identify all studies meeting the above criteria during the last decade, studies or papers that were published in peer-reviewed journals or other peer-reviewed outlets are the primary focus. Other (unpublished) related papers that did not meet the criteria defined here that have contributed to the literature in this field are cited when appropriate.

The next section describes the results from an extensive review of the literature from the last decade (i.e., 1999-2009). The search was conducted using the following search terms: ["Online" and "Teaching" and "statistics"] and ["distance" and "teaching" and "statistics"] using numerous subject databases included in the appendix (See Appendix). The review begins below with a table of key elements from each study grouped by years, along with a brief overview and/or unique characteristics from each study. Summary comments by the authors follow for each group of studies. Suggestions about future work in the field conclude this paper.

3. The Literature

3.1 Years: 1999 to 2002

Table 1: Review Period 1999-2002

Study by Year	O/H	A/S	Technology Used	Audience	Empirical Study?	Interaction
Speed and Hardin (2001)	H	Both	TMIM, streaming videos, audio/video clips, animated tutorials, electronic whiteboard, Telephone. Netmeeting, Word, Powerpoint, Mathlab, SAS, SPSS.	Mixed, graduate-level	No	Minimal, no formal discussions.
Zhang (2002)	O	A?	WebCT, MINITAB, Workshop teaching materials designed by Rossman & Chance (2000).	Introductory	No	Minimal, no formal discussions. Email, chat, bulletin boards.
Katz and Yablon (2002)	H	Both	Internet-based course with audio-visual presentations, simulations.	Introductory students in education and social work.	Qualitative findings revealed online students reported same satisfaction level as traditional students.	Email and chat sessions.

? – Unclear or Not Reported
O/H – Online (0)/Hybrid (H)
A/S – Asynchronous (A)/Synchronous (S)

In 2001, Speed and Hardin described their graduate level regression analysis course in which they taught students at both local (live and web-assisted) and distance (live and web-based) sites. The authors reported planning and delivering their course by following a pedagogical model advocated by Boettcher and Conrad (1999), which they later revised to form the model DECAL:

- **D**uplicating the Class
- **E**xcellent Quality
- **C**ustomized and accessible
- **A**ctive and
- **L**ifestyle-fitted

Their goal was to duplicate the live classroom experience for their distance students and establish the same degree of quality for the distance students that their local students received. They developed technology-mediated instructional materials (TMIM), which utilized streaming videos, audio and video clips of the instructor working through problems, and animated tutorials on how to run statistical software programs. Live conferencing using Netmeeting and phone calls were two other forms of technology they reported using. The authors reported the following disadvantages:

- Significant programming requirements and its associated costs on the front end.
- Burden on the instructor in terms of investment time.
- Inability to communicate mathematics in "real-time."
- Problems presenting mathematics formulas on the internet.

Similarly, Zhang (2002) described disadvantages with delivering their online elementary-level statistics course but many advantages were reported as well. The "workshop" teaching materials developed by Rossman and Chance (2001), in which students explore learning by working on a sequence of activities using real data sets in Minitab, provided the basis for the course. The advantages stated by the author were:

- Ability to view materials online at any time.
- Ease of calculation of statistics with technology.
- Convenience of communication through email.
- Greater flexibility in administering exams and distributing homework.

Disadvantages reported were:

- Lack of face-to-face interactions.
- Inability to motivate students and/or identify students needing help immediately.
- The need for students to have certain technical skills.

The author reported several recommendations for future courses: 1) Provide all materials on a CD in addition to materials on the website, 2) Videotape lectures for future courses, 3) Plan to be available to students via telephone, email, and chat, and 4) Be flexible with students in acclimating to the technology.

Encouraging findings were reported for students in Katz and Yablon's (2002) mandatory internet-based Introduction to Statistics course compared to students in their lecture-based

course. Initial results revealed that students in their internet course had lower expectations of learning statistics than did students enrolled in their traditional course. However, at the end of the semester, results of their qualitative analyses revealed that:

- Students in their internet course were "satisfied that the course provided them with a sound basis in statistics" (Katz and Yablon 2002, p. 72), despite students having low expectations and expressing doubts about whether they could learn statistics online.

Because students in the internet course became increasingly more confident with the technology used in the course as the course progressed, their anxiety levels decreased. As a result, the internet-based students' level of satisfaction was similar to that of students enrolled in the traditional course by the end of the course. Thus, the authors concluded that either course format could deliver favorable results for students.

3.2 Summary Comments: 1999 to 2002

Speed and Hardin (2001) represent two of many educators who have helped to pave the way and provide an initial framework for teaching and learning statistics in this new technological environment (i.e., Harrington, 1999; Stephenson, 2001; Smith and Ferguson, 2002). In doing so, the authors and Zhang (2002) reported technology challenges as well as the need for specialized technical skills for both teachers and students. In addition, there were problems related to: 1) file size for streaming videos, 2) speed (i.e., slow dial-up connections), and 3) internet availability (i.e., intermittent access). As a result, many of these problems adversely affected their online teaching and learning environments.

Today, many of these problems have been resolved for most users due to broadband digital connections and other user-friendly interfaces. What has also changed since the beginning of this decade is the different types of software that can now be used to communicate statistically online. In 2010, we are able to use statistical language and symbols in many different applications, including whiteboards in course management systems (i.e., WebCT or eLearning). Microsoft Word and Wordperfect have improved and increased their statistics symbol selections, while other software programs such as MathLab and StatLab have contributed to helping students learn and communicate statistics from a distance.

Finally, it is clear that the level of interaction among the students and the instructor in these earlier studies was not what can be experienced today. In fact, what we have learned from teaching over the past decade is that active discussions in the online statistics course can help to facilitate the learning process, motivate students to finish the course, and allow students to feel more connected to their learning experiences (Harrington, 1999; Pan, 2003; McLaren, 2004; Dutton and Dutton, 2005; Mills and Xu, 2005-2006; Kartha, 2006; Kreiner, 2006; Everson and Garfield, 2008; Groth, 2008).

3.3 Years: 2003 to 2004

Table 2: Review Period 2003-2004

Study by Year	O/H	A/S	Technology Used	Audience	Empirical Study?	Interaction
Utts et al. (2003)	H	A	CyberStats	Elementary	No performance differences on academic measures, controlling for GPA, classification, and gender. Students in hybrid course less satisfied with their course experiences.	Minimal, no formal discussions online. Met once per week.
Pan (2003)	H	Both	Blackboard using Internet "tools" and WWW, E-lectures.	Graduate elementary	No	Threaded asynchronous discussions and synchronous live chats.
Grandzol (2004)	H	A	Blackboard using computer-mediated (internet), phone calls, email, chat.	Graduate elementary	Results inconclusive on academic measures. Improved technology-based communication and decision-making skills for online students but they were dissatisfied with Blackboard-delivered exams.	Discussion forums and chat rooms.
Suanpang et al. (2004)	Both	Both	Blackboard 5, MSN, Yahoo Messenger, telephone.	Undergraduate -level? business statistics.	Students in online classes reported more positive attitudes toward statistics (i.e., statistically significant) than students in the traditional courses.	Discussion and group areas.

O/H – Online (0)/Hybrid (H)
A/S – Asynchronous (A)/Synchronous (S)

Utts et al. (2003) compared students enrolled in a "hybrid" (i.e., a blend of face-to-face and online) elementary statistics course to those enrolled in a traditional offering. In their hybrid course, students were required to learn the material on their own using web-based materials (i.e., CyberStats). They met once a week for 80 minutes and during the first 20-30 minutes, a quiz was administered. During the remaining time, the instructor provided an overview of the material that would be covered for the upcoming week and demonstrated interactive materials on the web. The traditional offering met three times a week for a one-hour lecture and once a week for a one-hour discussion section. The authors reported that while a significant amount of time was devoted to answering email (i.e., disadvantage), they felt as though the hybrid course was a useful alternative to the traditional class (i.e., advantage). Other conclusions and recommendations from their study included:

- Provide weekly meetings to keep students on track.
- Administer short weekly quizzes to motivate students to work on the materials, otherwise students tend to fall behind.
- Provide a textbook for the course in addition to the online material.
- Use class time to review materials that the students studied and covered the previous week.

Pan (2003) and Grandzol (2004) both found teaching an online statistics course to MBA students challenging. Similarly, Suanpang et al. (2004) also investigated student attitudes for online and lecture-based students in their business statistics courses (See Table 2). Grandzol (2004) reported following the guidelines suggested by Phipps, Wellman, and Merisotis (1998), in addition to the seven benchmarks specified by the Institute of Higher Education (2000) for the implementation of his online Statistical Analysis and Design course. His students were required to attend two on-campus sessions in order to orient everyone to the course (i.e., become familiar with Blackboard, demonstrate statistical software, etc.). They were required to make mandatory discussion board postings, attend at least one hour of online chat, and participate in a variety of activities to improve learning (i.e., homework problems, reports, tutorials, read supplemental materials, etc.). Similarly, students in Pan's (2003) course were required to visit the campus in the beginning for an orientation and at the end of the term for their final examination. They listened to e-lectures in Blackboard and participated in threaded discussions and real-time chats. Pan (2003) reported the following advantages:

- It can be a convenient teaching and learning environment for both students and the teacher.
- The evaluation of the course can be conducted in a timely fashion.
- Advances in technology (i.e., broadband connection) can improve online interactions.

Suanpang et al. (2004) reported the following disadvantages:

- Technology problems such as slow speeds, computers "hanging up" and a lack of basic skills for some students were significant challenges.

- Some students did not have computers at home which limited their accessibility.

The authors provided the following conclusions and recommendations for others teaching in this format:

- Create as many opportunities for online students to interact as possible, as this appears to promote student learning (Grandzol, 2004).
- Use qualitative methods to further assist in providing additional information in terms of measuring and evaluating student learning outcomes (Grandzol, 2004).
- Web-based courses appear to be particularly suited for students who are highly-motivated (Pan, 2003).
- A theoretical framework should be implemented that addresses instructional strategies and the delivery of the media (Suanpang et al., 2004).

Table 3: Review Period 2004

Study by Year	O/H	A/S	Technology Used	Audience	Empirical Study?	Interaction
Ward (2004)	H	A	Tools from a course Webpage, PowerPoint, applet demonstrations, course content modules, phone, email.	Elementary	No significant differences in academic performances. Significant difference in the 'extra credit' grade with the hybrid students being less likely to submit for extra credit. Students in hybrid course had more positive attitudes.	Office hours via internet chat.
McLaren (2004)	O	A	Course website via internet, postal mail, fax, email, phone.	Intermediate	No significant difference in terms of academic performance. Significant difference in persistence between the online and traditional classes.	? Daily instruction was "traditional" for online course.
Brown & Kulikowich (2004)	H	A	PictureTele Technology for distance ed group, PowerPoint, SPSS, cameras, TVs, audio/videos.	Graduate students, introductory level.	No significant differences on: final exam, self-regulatory habits and study behaviors, self-ratings of prerequisite knowledge, statistical anxiety, and course evaluation ratings.	None? "Traditional" distance education course, with some class meetings.

O/H – Online (0)/Hybrid (H)
A/S – Asynchronous (A)/Synchronous (S)

Ward (2004) found no differences in students' academic performance between a hybrid and traditional offering for first-year business administration and music business majors in her elementary statistics course. The traditional course met three times a week for fifty minutes. Class time was utilized for lectures, computer lab activities, collaborative problem-solving sessions, tests, quizzes, answering questions, interactive worksheets, and calculator activities. These students were given lab exercises, worksheets, and problem sets identical to documents available to students in the hybrid offering. The hybrid course met once a week for seventy-five minutes and the students had identical activities as the traditional students. The students in the hybrid course were required to have learned the material before class time using the textbook and were expected to have accessed and familiarized themselves with "tools" from the course web page. Applets, suggested readings, and PowerPoint reviews were made available for students in both courses. At the end of her study, Ward (2004) noted the following:

- The hybrid students appeared to take more accountability to learn the course materials and to participate.
- It makes sense to provide both an online component as well as face-to-face meetings when teaching at a distance.

Business majors were also evaluated in terms of their academic performance and their persistence in a required undergraduate statistics course in a study conducted by McLaren (2004). Using five semesters of online and traditional classes, this second course in statistics covered topics such as regression analyses, time series, forecasting, introductory calculus concepts, and decision analysis. The results revealed a significance difference in students who persist (i.e., officially drop the course, remain active and complete the course, or do not complete the course and receive an "F") in their online statistics course versus those enrolled in the traditional class. Specifically, they found that more students in the online course dropped or did not complete the course than did students enrolled in the traditional course. In addition, no statistically significant differences were found between the two sections in terms of their academic performance. The author offered the following conclusions:

- Students who performed best were students who were intrinsically motivated, independent, and more mature.
- Students who were less successful were not involved or did not participate in the discussions with the instructor or other students.

The last study in 2004 that met the criteria for this review was conducted by Brown and Kulikowich (2004). In their study, students were not aware that one section of the course would be taught via distance education. Both courses used a problem-based approach in which students were provided with a dataset from which homework and assignments were used throughout the course. However, the authors reported that they found no significant differences between the two sections on several variables (see Table 3 above). The authors learned that:

- Students enrolled in the distance sections were three times more likely to take another distance education course in the future.
- Qualifications of the instructor, course content, and pedagogy are the most important components when teaching from a distance.

3.4 Summary Comments: 2003 to 2004

In years 2003 and 2004, many empirical studies emerged with an interest in comparing the academic achievement of those enrolled in online courses versus those who were enrolled in a "traditional" course. Most of the results revealed no significant differences in achievement between students in the two courses; however, a few studies reported less satisfying experiences for students enrolled in the online courses (Utts et al., 2003; Grandzol, 2004). Of the empirical studies reported during these years, each of the studies' results may have been impacted by limitations. For example, none of the studies reported any kind of random assignment into online and traditional sections. Grandzol (2004) and McLaren (2004) both indicated that their results were reported over multiple terms (i.e., over 5 semesters) while Utts et al. (2003) reported that although they used Cyberstats for their online course, they did not address how effective the program was for learning statistics.

Many researchers during this time period pointed out a need to create an improved environment online whereby students can interact more with one another as well as with the instructor (Jones, 2003; Wisenbaker, 2003; Davis and Chao, 2004). Furthermore, the role of the instructor emerged more during this time period. Specifically, the recommendations included that careful thought should be given to course design and organization, instructor preparation time, and pedagogy (Utts et al., 2003; Brown and Kulikowich, 2004). Another notable characteristic that became apparent during this time period was that teachers began to identify "types" of student who were more likely to be successful in online courses (i.e., students who were likely to be more intrinsically motivated) (Pan, 2003; McLaren, 2004). Finally, less technology "issues" related to delivering an online course due to the advances in technology was also noticeable during this review time.

3.5 Years: 2005 to 2006

Table 4: Review Period 2005

Study by Year	O/H	A/S	Technology Used	Audience	Empirical Study?	Interaction
Dutton & Dutton (2005)	H	A	Course website which included bulletin board announcements, lessons, Powerpoint slides, and lab exercises with Excel, WebAssign.	Introductory undergraduate business students.	Better performance for online students, controlling for GPA.	Online students could attend lectures and vice/versa.
Summers et al. (2005)	H	A	WebCT using daily email.	Advanced undergraduate nursing students enrolled in an introductory course.	No significant differences in statistics knowledge. Students in online course were dissatisfied with instructor explanations, instructor enthusiasm, instructor's openness and concern toward students, instructor's interest in student learning, class discussions, quality of questions/problems, and evaluation and grading.	Instructor posted questions in a threaded discussion forum.

O/H – Online (0)/Hybrid (H)
A/S – Asynchronous (A)/Synchronous (S)

Dutton and Dutton (2005) reported better performance for their online students (versus a lecture section) in their business statistics course while Summers et al. (2005) found significant differences in satisfaction level between undergraduate nursing students enrolled in their online introductory statistics course and students in their traditional course. In both studies, the students were taught by the same instructor and had the same content, assignments, activities, and examinations. Dutton and Dutton (2005) found that:

- Students in each course utilized the course resources differently: the online students utilized the website and emailed the instructor more while the lecture students utilized the resources on campus more (i.e., labs, teaching assistants).
- Students in the online course had higher academic performances when controlling for their GPA at the beginning of the semester and student effort (as measured by homework average).
- The variable "computer experience" was significantly and positively related to academic performance if the student was female.
- "Older" students enrolled in traditional full-time degree programs were more likely to be successful.

In contrast to the research conducted by Russell (1999) of *The No Significant Difference Phenomenon*, which refers to a body of literature that found no significant difference in student outcomes between students enrolled in a traditional versus a distance delivery course, Summers et al. (2005) did find significant differences with regards to their nursing students' satisfaction levels. Students in their web course were generally less satisfied in the following areas: instructor explanations, instructor enthusiasm, instructor's openness and concern toward students, instructor's interest in student learning, class discussions, quality of questions/problems, and evaluation and grading. They concluded that important factors related to "learning tasks, learner characteristics, student motivation, and the instructor" (Phipps and Merisotis 1999, p. 8) were missing in their study. The authors offered the following recommendations at the conclusion of their study:

- Choose a pedagogical framework before course development.
- Be explicit when stating grading procedures, homework, projects, and tests.
- Increase accessibility to students by offering office hours on the phone as well as online.
- Be enthusiastic about the content to improve student interest and meaningfulness about the subject.
- Use real-time synchronous discussions for better student-to-student and student-to-instructor interaction.
- Consider a constructivist pedagogical framework for developing and delivering online courses in addition to formative and summative evaluations in order to best determine pedagogical effectiveness.
- Assess the initial implementation.

Table 5: Review Period 2005-2006

Study by Year	O/H	A/S	Technology Used	Audience	Empirical Study?	Interaction
Sloboda (2005)	H	A	Course website with standard or online textbooks, Powerpoint presentations, Screenshots, Word, java applets.	Any online course in statistics.	No	Online group work, instructor acts as facilitator by posting discussion questions each week.
Mills & Xu (2005-2006)	H	A	WebCT using streaming audio/video clips of the lecture materials, SPSS Quicktime "movies', "Talking Head", Netmeeting.	Graduate-level introductory course for students in education.	No	Netmeeting with a "pen-mouse".
Rynearson & Kerr (2005)	O	Both	WebCT using digital video lectures, Powerpoint presentations, SPSS interactive whiteboard, two-way interactive television.	Graduate-level introductory course for psychology students.	No	Threaded discussions, chat, interactive television and whiteboard.

O/H – Online (0)/Hybrid (H)
A/S – Asynchronous (A)/Synchronous (S)

Sloboda (2005) and Mills and Xu (2005-2006) both reported suggestions as well as a proposed teaching model to facilitate the teaching of statistics in the online environment. They also reported using small learning groups in their threaded discussion forums. Sloboda (2005) recommended the following:

- Meet students face-to-face before the course begins to discuss the syllabus, which should include a week-by-week outline of the learning objectives, topics, and assignments for each week in addition to course or administrative policies.
- Offer standard and/or online textbooks and references.
- Have a specific outline for the lectures (i.e., PowerPoint slides): a list of objectives for the week, followed by a presentation of statistical concepts and examples that illustrate the concepts.
- Include problems for students to review and solve in order to assess their understanding.
- Post discussion questions that focus on the discussion and application of statistics concepts based on each lecture at the beginning of the week.

- Provide computing activities that can be demonstrated by capturing step-by-step screen shots of a statistics software program. Java applets allow more advanced learners to actively explore and experiment with more difficult and abstract concepts.
- Organize learning teams of 3-5 students as this will provide additional learning opportunities for students to interact and discuss the course materials.
- Incorporate ways to monitor and evaluate teaching along the way (i.e., formative feedback).

A "talking head" of the instructor or a "virtual teacher" was used to make announcements and to assist students in navigating through Mills and Xu's (2005-2006) online course. Although students reported disadvantages such as "technical difficulties, "skipping and timing out of the streaming video clips", and "not having instant feedback", approximately 85% of the students reported that they would take another hybrid or online course if offered in the future. Advantages reported by students were that they liked: 1) the flexibility of working at their own pace, 2) not having to drive to campus for class, 3) the course organization, and 4) being able to re-play the videos as often as needed.

Based on the data collected, teaching experiences, feedback from students, previous research and findings and suggestions from the literature, Mills and Xu (2005-2006) reported a descriptive model (TTRACE) inspired by Velleman (2000):

- The teacher should choose appropriate **T**echnological tools.
- The role of the teacher in online/distance courses is still to **T**each.
- There is an increased **R**esponsibility placed on the student to learn the material.
- Students need to understand that they must be **A**ctively involved with others (i.e., teacher, students) as well as the course materials on a regular basis.
- The teacher should design the course so that it maintains **C**onsistency and redundancy.
- The teacher should be prepared to plan formative and summative **E**valuations for future courses.

Lastly in 2005, Rynearson and Kerr revised their graduate-level introductory statistics course for online delivery using a model proposed by Smith and Ambrose (2004), which focuses on cognition and learning, technology and instruction, and design. With the focus being specifically related to technology, the authors recommended that technology in an online course should:

- Meet an educational gap or need.
- Assess students' prior knowledge.
- Improve students' representations of the information.
- Encourage active engagement.
- Provide feedback or guidance to learners.
- Encourage the development of students' metacognitive skills.
- Adapt to students' individual learning needs.

Rynearson and Kerr (2005) also implemented threaded discussions in their course, along with chats and an interactive whiteboard. In future courses, the authors reported that they will consider using:

- Online collaboration software, which could possibly enhance participation and collaboration.
- A content delivery system with a recordable synchronous format that would allow students' understanding to be evaluated in a real time format. As a result, feedback could be immediate.

Table 6: Review Period 2006

Study by Year	O/H	A/S	Technology Used	Audience	Empirical Study?	Interaction
Tudor (2006)	O	A?	WebCT, Blackboard, Realplayer for audio files, Powerpoint slides, Excel,Word.	Graduate-level introductory course for students in public health.	No	Large and small group discussions.
Kreiner (2006)	O	N/A	Blackboard with interactive online tutorials using Flash.	Graduate- and undergraduate-level course for students in school counseling, curriculum and instruction, physical education, and speech pathology and audiology.	Significant differences between pre and post test final exam scores.	Weekly online help sessions using a virtual classroom.
Kartha (2006)	H	A	Course Website?	Undergraduate-level business students.	No significant differences in grades between online and traditional course. Students in online course reported less satisfaction with the course.	Minimal online. Online class initiated help through email or office hours.

? – Unclear or Not Reported
O/H – Online (0)/Hybrid (H)
A/S – Asynchronous (A)/Synchronous (S)

Students in Tudor's (2006) online course reported that they were satisfied with her course and with the amount of interaction the course provided. Her master's level online statistics course consisted of mostly graduate students pursuing a public health degree. She reported following a model of instruction advocated by Gagne, Briggs, and Wager (1992) and as a result, the students indicated that they were very pleased with the organization and design of the course. She reported a number of recommendations, suggestions and comments at the conclusion of her study:

- Prepare no more than 30 PowerPoint slides in one presentation. Tutorials should last no more than 30 minutes.
- Include written notes for audio files in case the audio files are not clear or if students are having other technical problems with the technology.
- Create self-help quizzes which can be used as formative assessments along the way and can provide immediate feedback for students.
- Offer other activities such as java applets that are tied to specific learning objectives, but make sure to include very detailed written instructions.
- Include other supplementary materials such as a list of helpful websites, online textbooks, and in-house videos that can be checked out at the local university library.

A few disadvantages reported by Tudor (2006) included: 1) the amount of time related to course design and grading exams, 2) the quality of audio files related to voice clarity, and 3) a lack of interaction between the students and the instructor.

Kreiner (2006) reported that the amount of time needed to devote to an online course was also a disadvantage in his study. Specifically, he cautioned that he spent the most time:

- Implementing the course in general.
- Developing the course materials.
- Providing timely feedback to students.
- Troubleshooting technical issues.

His study investigated whether a mastery-based approach to teaching statistics online using a self-paced format would be effective in terms of student learning, as well as whether this approach would help relieve student anxiety. His course allowed students to revise their work and resubmit until they had learned the material, thereby reducing their anxiety. Despite this approach, Kreiner (2006) concluded that a self-paced course requires that students are self-motivated and have good time management skills, because several students failed to complete the course requirements.

A similar finding related to the characteristics of a successful online student was reported by Kartha (2006). The author found that students who take online courses must be independent, focused, and organized in their study habits. Based on the author's experiences in evaluating the performance and attitudes for students enrolled in an online and a traditional undergraduate business statistics course, the following findings were reported:

- Students in the online course were less satisfied with their course experiences: they indicated less satisfaction with 'gaining a good understanding of the concepts', 'whether or not the course deepened their interest in the subject', 'the amount of interaction with peers', 'getting help from the instructor', and 'the user-friendliness of Blackboard'.
- The efforts (by the instructor) to match the traditional classroom in terms of learning effectiveness will require "innovative design, implementation, instruction, and evaluation" (Kartha 2006, p.29).

3.6 Summary Comments: 2005 to 2006

Advancements in technology appeared to improve the delivery and implementation of online courses beginning in 2005. For example, students could experiment with java applets and other interactive tutorials directly in their online courses. A "talking head", interactive whiteboards, and videoconferencing were also used to improve learning and increase the interaction level among the students and the instructor (Mills and Xu, 2005-2006; Sloboda, 2005; Rynearson and Kerr, 2005; Kreiner, 2006). However, many more studies still reported students' dissatisfaction with many factors related to the interaction aspect of learning from a distance (Mills and Xu, 2005-2006; Rynearson and Kerr, 2005; Summers et al., 2005, Kartha, 2006). In addition, similar to the findings from previous years, none of the authors reported using or even considering random assignment of students for experimental purposes.

On the other hand, in addition to improving the overall level of interaction, there appeared to be more of a concerted effort toward improving pedagogy and overall course design (Mills and Xu, 2005-2006; Sloboda, 2005; Summers et al., 2005; Tudor, 2006). More instructors reported using formalized discussions as a significant part of their course (Mills and Xu, 2005-2006; Everson, 2006; Rynearson and Kerr, 2005; Sloboda, 2005; Summers et al., 2005; Kreiner, 2006; Tudor, 2006). Many studies reported considering a specific design, theoretical model, or conceptual framework for their online course (Mills and Xu, 2005-2006; Sloboda, 2005; Summers et al., 2005; Tudor, 2006). Finally, careful consideration was also devoted to how to evaluate online courses in order to better monitor student learning (i.e., formative and summative evaluations) (Mills and Xu, 2005-2006; Sloboda, 2005; Summers et al., 2005; Tudor, 2006).

3.7 Years: 2007 to 2009

Table 7: Review Period 2007-2009

Study by Year	O/H	A/S	Technology Used	Audience	Empirical Study?	Interaction
Everson & Garfield (2008)	O	A	Course website, Fathom software for undergraduates and SPSS for graduate students, statistical applets, Sampling SIM program.	Introductory undergraduate and graduate level statistics course.	No	Several small-group discussions during a semester.
Johnson et al. (2009)	H?	?	Course website?, MINITAB and java applets.	Undergraduate-level mathematics students.	Males more likely than females to prefer an internet course. The more hours spent on internet, the less likely one is to prefer an internet course.	None?

? – Unclear or Not Reported
O/H – Online (0)/Hybrid (H)
A/S – Asynchronous (A)/Synchronous (S)

In 2008, Everson and Garfield reported how they used the Guidelines for Assessment and Instruction in Statistics Education (GAISE) (Franklin and Garfield, 2006) to implement small-group discussions in their online courses. Their goal was to illustrate how to incorporate discussion assignments into an online course so that students are better able to develop a conceptual understanding of statistics concepts. When using discussion board assignments, they also recommended that the instructor should:

- Monitor the discussion forums and participate by providing encouragement, pointing out misconceptions or misunderstandings, asking questions, etc. Require students to begin participating at least by mid-week to allow time for others to respond.
- Anticipate problems students might have with all assignments in advance by providing additional explanations in handouts and notes.

The authors reported that based on their observations and experiences, student learning has been consistent with their face-to-face classes. In addition, students reported that they were satisfied with their overall course experiences.

In contrast, a study conducted by Johnson et al., (2009) revealed that students in their courses preferred more of a traditional approach to learning introductory statistics concepts. The authors found that

- The majority of the students preferred the lecture/lab approach to learning statistics as opposed to the internet approach. In addition, the students reported that an internet class may not be appropriate for all subjects (i.e., statistics).
- Males preferred the internet course more than females.
- Because students in the internet course spent more time on the internet than did students in the lecture course, they were less likely to prefer the internet course in general.

Other (negative) comments were reported by students in terms of why they preferred a lecture-based approach over the internet course. They reported that an internet class might be a challenging learning environment for those students who tend to "procrastinate". In addition, an inability to intervene and interact with the teacher when students encounter learning difficulties or technical problems was another significant disadvantage reported.

3.8 Summary Comments: 2007 to 2009

Although Johnson et al., (2009) found that their students preferred a face-to-face class over their internet course, a finding that has been somewhat consistent in the literature, it was not clear if interaction among students and the instructor was emphasized in their course. On the other hand, the Everson and Garfield (2008) study might be indicative of what many teachers are focusing on in their online classes today. Their goal was to provide "an online community where students can learn from a variety of sources, and where support and encouragement from the instructor are evident to students" (Everson and Garfield 2008, p. 8).

A look at the studies from this last decade reveals a blueprint of how teaching statistics online has evolved. In the earlier years, an emphasis on how to use technology to teach statistics online or at a distance first emerged. Issues related to course design and organization, pedagogy, and instructor preparation time were discussed. In the middle to latter part of this decade, more importance was and has been placed on:

- Selecting "appropriate" uses of technology for the online statistics environment.
- Improving interaction among students and the instructor.
- Enhancing the overall learning experience for online students.
- Conducting formative and summative evaluations to carefully monitor the teaching and learning process.

4. Conclusion

It is obvious from the literature that teaching statistics online or at a distance will be a realistic option for years to come. Despite differences among pedagogical approach, theoretical or conceptual framework, or course design for the studies reviewed in this paper, the findings and

suggestions for future teachers and learners were similar across disciplines. In fact, most if not all of the suggestions and recommendations provided by the authors might apply to *any* subject taught online.

In terms of future work in this field, there is a need for well-designed studies that control for confounding variables and other challenges related to empirical research. Studies that consider random assignment and selection of students, as well as studies that consider preliminary analyses beforehand, such as determining sample sizes needed to achieve an acceptable level of power and reporting effect sizes, would contribute to our understanding. As pointed out by Grandzol (2004), the use of qualitative methods can also help to provide additional insight into learning.

One major purpose of this paper was to provide teachers with suggestions and recommendations from the literature on best practices when teaching statistics online. An extensive review of the literature across disciplines from the last decade revealed similar findings, suggestions, and recommendations. Hopefully, future research will continue to provide guidance and advance best practices as we strive to achieve improved teaching and learning opportunities for all.

Appendix

The literature search was conducted using the following search terms: ["Online" and "Teaching" and "statistics"] and ["distance" and "teaching" and "statistics"] using the following subject databases:

General Purpose	Business	Criminal Justice
Education	Engineering	K-12 Resources
Mathematics	Social Work	Sociology
Science	Nursing and Medicine	Psychology

Within the subjects above, the following databases were searched:

ABI/INFORM Complete
Academic
EconLit
Journal Citation Reports,
PsycINFO Search Tips
Statistical
Academic OneFile (AVL)
Historical Statistics of the United States
Social Services Abstracts
Periodicals Index Online
Professional Collection (AVL)
PubMed
Wiley InterScience
Dissertations and Theses
ScienceDirect
Student Research Center (AVL)
Primary Search (AVL)
Applied Science and Technology Index
Abstracts in Social Gerontology
CogNet
Social Sciences Citation Index
General Science Index
Sociological Abstracts Search Tips
Academic Search Premier (AVL) Search Tips
Health Source: Nursing/Academic (AVL) Search Tips
International Bibliography of the Social Sciences Search Tips
Criminal Justice Abstracts Search Tips
Expanded Academic ASAP (AVL) Search Tips
Professional Development Collection (AVL) Search Tips
ERIC (EBSCO: Online) (AVL) Search Tips
ProQuest Nursing and Allied Health Source
Business Source Premier (AVL)
Current Index to Statistics
Encyclopedia of Statistical Sciences
PsycARTICLES
SpringerLink
Web of Science Search Tips
Project Muse Search Tips
JSTOR Search Tips
Education Full Text Search Tips
Intute: Social Sciences
General OneFile (AVL)
SPORTDiscus with Full Text
Compendex
IEEE Xplore
Google Scholar
Middle Search Plus (AVL)
MathSciNet
Project Euclid
CINAHL Plus with Full Text MIT
PsycCritiques
BIOSIS Previews
Social Services Abstracts

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