Using Computer Assisted Qualitative Software (CAQDAS) to Evaluate a Novel Teaching Method for Introductory Statistics

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The purpose of this study was to use Computer Assisted Qualitative Data AnalysiS (CAQDAS) software to evaluate and integrate two sets of data collected from introductory statistics students. The students learned statistics by reading short stories that involve a set of on-going characters that use statistics to solve everyday problems. At the end of the term, students provided qualitative and quantitative data about their shared experience with fictional experts. The goal was to see if using CAQDAS technology could efficiently uncover a detailed and accurate evaluation of how students viewed the learning experience. Thematic and statistical analyses pointed to the success of the teaching method and the ease and efficiency of using CAQDAS technology for qualitative analysis in educational research.

Keywords: teaching statistics, mixed methods, computer assisted qualitative data analysis

INTRODUCTION

According to Conners, McCown, and Roskos-Ewoldsen (1998), the statistics instructor faces four major challenges: to motivate students to value a topic they think is irrelevant to their life, to deal with the anxiety that is often associated with learning statistics, to effectively teach both high and low achievers, and to make the learning memorable (pp. 40-42).

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In an effort to meet these challenges, instructors have experimented with a number of teaching methods. Approaches that have been tried include cooperative learning (Borresen, 1990), student projects (Fillebrown, 1994), humor (Berk & Nanda, 1998), journal writing (Sgoutas-Emch & Johnson, 1998), and games (Biesterfeld, 2001) just to name a few. From a teaching/learning standpoint, however, these, and other novel teaching methods, have been evaluated by collecting only quantitative data in the form of questionnaires and various attitude and anxiety inventories (D'Andrea & Waters, 2002; Sciutto, 1995). Understandably, relatively few teachers collect narrative data from students about their learning process because of the laborious task of coding and evaluating the responses. Consequently, we have relatively little information from students with which to evaluate and grow new more effective teaching methods.

Teaching in the climate of high-stakes testing and shrinking budgets makes the classroom, at all levels, hectic and complex (McMillan, 2011). The idea of hand-coding piles of student responses using different colored highlighters, then sorting copied responses onto index cards to be sorted into still more theme piles requires time and energy that today's teacher does not have. Using computer assisted data analysis software to study and summarize student comments might be one way to encourage teachers to become scientist-practitioners and use new advances in technology and software to evaluate and improve their effectiveness.

The goal of this study was to combine the instructional design elements of humor, writing, and real data in a single learning approach by creating short stories that involve some *sleuthing,* by on-going characters, to teach introductory statistics. Both quantitative and qualitative data were collected in order to measure students' opinions about their experience learning with this somewhat light-hearted and practical approach.

In order to evaluate this teaching method, and to more credibly generalize the findings, it was decided that a mixed methods approach would yield the most information (Hanson, et al, 2005). We felt that in order for us to be able modify and improve this method in the future, it was important to gather quantitative data to give us an overall combined sense of the essence of the students' experience and qualitative data to tell us specifically what contributed or subtracted from the experience.

We were also interested in evaluating the potential use of Computer Assisted Qualitative Data AnalysiS software (CAQDAS) to achieve our teaching goal. The acronym CAQDAS was presented at the first Surrey Research Methods Conference in 1989, which focused on using software designed to analyze qualitative data (Lewins & Silver, 2008, p. 6). Since that time, these types of computer programs have developed to include text retrieval and database capabilities as well as many options for visually displaying the data. Teachers are constantly encouraged to use new technology and tools to develop and evaluate teaching methods, but standard methods of qualitative analysis are too time consuming to be practical in the current educational climate. CAQDAS might be one way to encourage teachers to develop and evaluate creative learning experiences for their students.

Since CAQDAS is capable of supporting a range of research strategies, and because we decided on a mixed method approach, we selected MAXQDA (www.maxqda.com) as our data management and analysis tool to handle both our textual and numeric data.

Text search tools, such as MAXQDA, allow for automated searches of text for words, phrases, and co-occurring themes with more accuracy and time efficiency than hand sorting and counting. This technology also allows researchers to interrogate the data set, look for co-occurrences of codes or themes, relationships between codes, and to play with ideas in an exploratory fashion (Lewins & Silver, p. 11). The writing tools included in CAQDAS provide additional efficiency by allowing real-time records of thoughts and ideas for subsequent analyses, visual maps of the codes, and themes.

DESCRIPTION OF THE STORIES

The authors wrote a series of stories ranging from 800-1500 words that describe the sleuthing activities of a cast of on-going characters (a contemporary statistics professor and her friends). Each story focuses on a practical problem that can be solved using statistics. This approach was meant to provide students with a form of *cognitive apprenticeship* (Cognition and Technology Group at Vanderbilt, 1990) that would allow them to share experiences with the characters as they apply statistics to problems. The idea is to let students see how experts, in this case fictional statistics experts, use statistical methods to solve puzzles and problems in their daily life. Students "helped" the characters by using the information in the story to reason to the answer along with the professionals (Cognition and Technology Group at Vanderbilt, 1990). The story format also allowed us the flexibility to attempt to address the challenges summarized above. The stories allowed us to:

- Increase motivation and interest by asking students to solve everyday problems using the statistics they were learning in class

- Increase the likelihood of success with hand calculations and reduce math-related anxiety by providing step-by-step instructions for each problem

- Provide several levels of difficulty so that students could decide if they wanted to be challenged or led through the steps

- Make learning memorable by using culturally diverse characters, humor, student-friendly topics, and involve students with characters that use statistics in interesting ways

For each story, students were asked to solve the problem using the given facts related to the case and the step-by-step instructions. The formulas were given in two forms, symbolically and in words. For example, in a case that involves testing whether glass from a fish tank (F) is different in makeup from glass from a window (W), the formula for the estimated standard error of the mean was presented as shown in Figure 1 below. Given that a low sense of mathematical ability is correlated with high statistics anxiety (Murtonen & Lehtinen, 2003, p. 172), providing both symbols and words allowed students to use the method they felt most comfortable with (i.e., words or symbols) thus putting them more in control of their learning.

$$SE_{M\_F} = \frac{SD_F}{\sqrt{N_F - 1}}$$

$$SE_{M\_W} = \frac{SD_W}{\sqrt{N_W - 1}}$$

In Words: The estimated standard error of the mean (SE_M) —also known as the standard deviation of the distribution of means—is *equal to* the standard deviation (SD) of the distribution of sample values *divided by* the square root of the number of values in the sample (N) *minus* one.

Figure 1. Formulas provided in symbols and in words (Sprinthall, 2007).

At the end of each case students were asked to write their statistical conclusion as well as provide a short written explanation of how and why they arrived at the conclusion.

SAMPLE CASE ABSTRACTS

A total of nine stories were handed out that corresponded to the lecture topic that week. The actual data for each story was fictional but actual research was used as a basis for creating the data set so that the solution was consistent with what a researcher in the area might actually find. A short description of two of the stories is provided to give the reader an idea of the topics and flavor of the stories.

Pizza or Prunzz . . . don't mean to throw you a curve. Dr. Delfino and her friends get involved with helping the owner of an Italian restaurant determine which of two menus, kid food, such as pizza, or senior food, such as prune Danish, will serve the most customers. Given the information the restaurant owner has collected from a guest check survey (mean age of the customers and standard deviations), students are asked to calculate and compare z scores to determine which group (under 12 or over 55) make up the largest percentage under the standard normal curve. For their efforts, they get a free meal and then use z scores to determine who, relative to their gender, got the most free food.

Another Case Of Variance . . . Getting the Point Across, and Down. In a later case, Dr. Delfino gets involved in a dispute about the outcome of a crossword tournament. When the rival team wins the tournament, the Campus Puzzlers want to appeal the decision suspecting that puzzles were selected from different populations. One sample of puzzles was randomly selected from Monday through Saturday *New York Times* newspapers, and the other from Wednesday through Saturday papers. Students are asked to do Analysis of Variance to determine if the average solving times are significantly different between the days of the week and, if so, to calculate Tukey's HSD to determine where the difference lies.

In the other stories, the characters involve the students in creating charts and graphs, calculating single sample and independent samples t tests, correlations, probabilities, and developing a research project. Since the material was continuous across the entire semester, students got to know the characters and apprentice with them as they solved problems that came up in the story plot.

METHOD

DESIGN

A parallel mixed methods design was used to capture the experience the students had learning with this method (Tashakkori & Teddlie, 1998). Quantitative and qualitative data were collected simultaneously and integrated after the analyses for each set of data was complete (Hanson, et al., 2005). We chose a mixed method design for this study in order to get a more comprehensive understanding of the students' experience by categorizing specific student comments into themes that would represent combined opinions or problem areas in the instruction that would not be visible to us with only quantitative data. We then attempted to use specialized data analysis software, CAQDAS, to verify the presence and intensity of the themes and to further verify these findings with quantitative analysis methods (Onwuegbuzie & Leech, 2004).

SAMPLE

Participants were 57 college students enrolled in two graduate-level, introductory statistics courses in the College of Education. The average age for the sample was 37, the majority of which were female. Most of the students were education majors and reported taking the class because it was a required course in their program. Approximately half the class reported having taken a statistics class before and the rest had not previously taken a statistics class. A variety of career goals was reported, including professor, school psychologist, consultant, administrator, and teacher.

DATA COLLECTION

Data were collected over the course of two semesters. There were 35 students enrolled in the first semester class and 22 in the second one. Approximately 57 sets of data were collected which yielded 404 relevant comments for analysis. Because participation was voluntary and because one class did not receive one of the stories because of a holiday, there was some variation in the number of questionnaires collected for each story.

The questionnaire had two parts. The first part consisted of five statements that required students to reflect on the story they just read and indicate to what degree they agreed with the statement using a Likert-like scale, where 1 indicated they strongly disagreed with the statement, 3 indicated neutrality, and 5 meant they strongly agreed with the statement. The second part of the questionnaire asked students to respond to four reflective questions relating to what they specifically liked about the story, specifically did not like, how the story could be improved, and what other comments, suggestions, or thoughts they had about learning statistics by reading the stories. Students were assured that no link would be made between how they responded to the questions and their class performance (course grade).

DATA ANALYSIS

A parallel mixed methods sequential analysis of the data was conducted after all data was collected (Tashakkori & Teddlie, 1998). The process of analysis started with examination of the transcribed text in MAXQDA with the goal of identifying categories of statements that reflected how students felt about their learning experience (thematic analysis). The quantitative data were then analyzed and compared to findings from the qualitative analysis in order to see if both sets of data pointed to the same overall experience.

QUALITATIVE ANALYSIS

Thematic Analysis. Analysis began with two people independently reading the aggregated, transcribed student comments from beginning to end two times. One reader was one of the researchers and the other reader was not originally involved in the study and was blind to the purpose of the study. The purpose of the first readings was to get an overall feel for how the students felt about their learning experience (Cohen, Kahn, & Steeves, 2000). After the first two readings, we began to reduce the data by discussing which words and phrases seemed to appear consistently throughout the narrative

(Moustakas, 1994). We agreed on several tentative categories, and independently read the comments again.

After the third reading, we color coded what we felt were specific examples of each category and discussed why we assigned particular words and phrases to that category. From the five initial categories, we agreed to refine the categories further by subsuming two of the categories into a new, broader category, and then independently read over the comments again.

We met once again and agreed that the categories we decided on were large enough to include a variety of experiences yet small enough to differentiate between them. A third researcher was then asked to read the comments and note which comments exemplified each of the three categories. After a final reading by all three researchers, and a final meeting to discuss our impressions of the data, we unanimously concluded that the themes we identified encapsulated the students' learning experience. We identified two themes related to the content of the stories, *the story helped me learn statistics*, and *the story helped me learn how statistics can apply to the real world*. We classified the third theme as having to do with the process of learning with this method and identified this theme by words and phrases that referred to how students felt about the experience as a whole.

A final consensus check, in the form of inter-rater agreement, revealed that we agreed on the placement of words and phrases into categories between 93 and 98 percent of the time across all nine stories for an average overall inter-rater agreement of 96%. The transcribed document was then loaded into MAXQDA for analysis.

QUANTITATIVE ANALYSIS OF THE QUALITATIVE DATA

Binarization of the Data. Once the three themes were identified, an inter-respondent matrix (i.e., participant x theme) was created (Onwuegbuzie, 2003). The matrix was created by binarizing the data, that is, by assigning a "1" when a word or phrase exemplified the theme, and a "0" if the theme was not exemplified by the statement (Sechrest & Sidana, 1995). Quantitizing the data this way allowed us to introduce a degree of empirical precision to our findings by determining frequency, in percentage terms, of each theme (Onwuegbuzie, 2003). Determining the prevalence rate of each theme then allowed us to assign and speculate about the differential weights of each theme (Cohen, 1988; Sandelowski, 2001).

QUANTITATIVE ANALYSIS OF THE QUANTITATIVE DATA

Descriptive Statistics. Since MAXQDA is 100% compatible with Microsoft Excel and PASW Statistics (formerly SPSS), it was a simple process to export the numeric data from the CAQDAS program to a spreadsheet for analysis. Results allowed us to corroborate the relative weights, in terms of frequency of occurrence, of the themes identified in the qualitative portion of the questionnaire. The rationale for these calculations was that, if the quantitative responses supported the theme frequencies generated from the qualitative data, it would add collateral evidence for the hierarchical structure of the identified themes (Onwuegbuzie, 2001). Inter-item correlations, means, and standard deviations were calculated and used to identify relationships among the questionnaire items and subsequent themes.

RESULTS

QUALITATIVE ANALYSIS

Three overarching themes relating to how students reacted to learning statistics using short stories emerged from the comments. Two themes, *learning statistics* and *applying statistics*, had to do with how the method helped the students learn statistics and apply them, and the third theme, *the experience of learning statistics with this method*, related to comments students made about their affective experience. The text portrait, generated in MAXQDA, illustrates the distribution and prevalence of each theme throughout the text document of student responses (Figure 2).
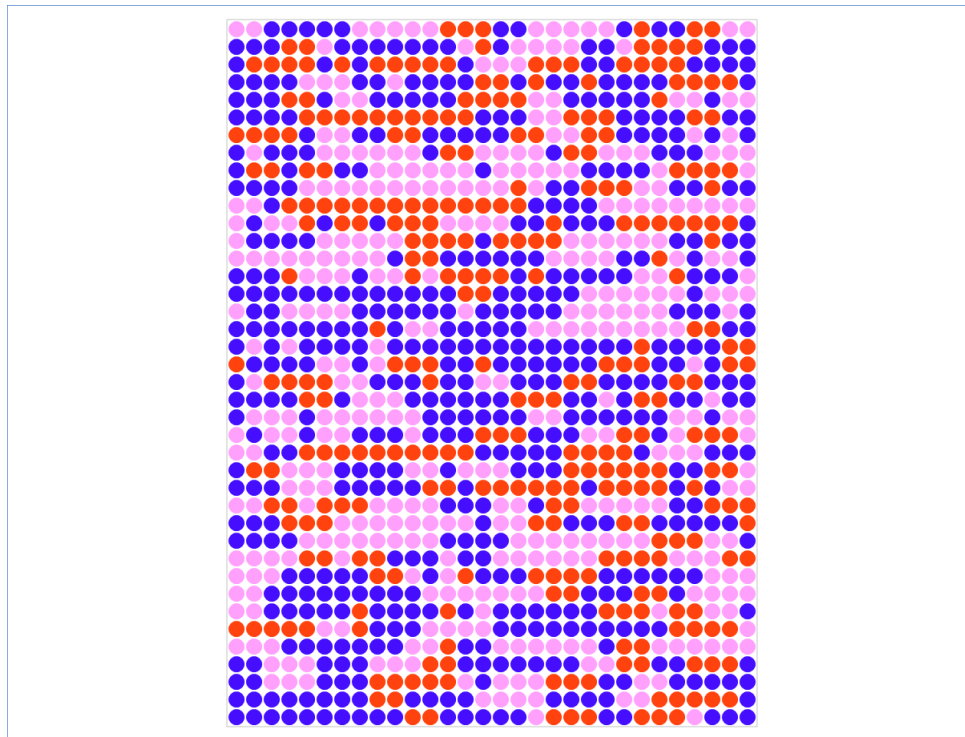

Figure 2. Text portrait generated in MAXQDA showing the three themes identified. Pink = *The story helped me to learn the statistic*, Orange = *The story helped me to apply the statistic*, Blue = *I enjoyed learning through stories*.

The text portrait option in MAXQDA allows the researcher to see the sequence and dispersion of codes for a given document. Each color depicts a different code and each dot represents a certain fraction of the coded segments. The portrait takes the size of the segments into account and weights color according to the size of the segment. The colors associated with the code are displayed in a matrix with 1,200 dots, arranged in 30 rows, each with 40 dots. The dots are divided according to proportion of coded segments. In our case, the three codes are shown in pink, orange, and blue.

*Learning Statistics (*pink*).* The pink dots represent student comments about how the stories helped them to learn and understand the topic statistic. For example comments such as, *This case study taught me so much about statistical designs. I was confused last week, but now I feel comfortable with the idea,* and, *This story really helped me understand how statistics can be used to solve problems*, were coded in pink, and are shown in the text portrait as being dispersed throughout the document suggesting that

students felt all the stories were at least to some extent helpful. It was encouraging to find that, while comments related to how much learning took place varied in intensity, no comments suggested that the stories prevented or hindered learning.

Applying Statistics (orange). The second theme to emerge from the data was identified by the orange dots in the portrait. These comments were of an application nature, for example, *I wouldn't think of applying statistics to a romantic situation!; I liked that the story showed how a real life situation can be solved using statistics; I liked the fact that this was a real-life story that could happen to me* were coded as belonging to the theme of students learning to apply what they were learning to the real world.

As can be seen in the portrait, the applicability theme was not salient to every student; however, it did appear that to those students who noticed the attempt to widen the use of statistics, this feature of the stories was motivating.

The Overall Experience (blue). The blue dots show comments made about the overall learning experience. Some students said they enjoyed the characters the most; *The stories are very creative and entertaining. I feel like I'm getting to know your characters; I love that the characters in the story tie back to the other stories.* Other students commented on enjoying the sleuthing aspect of the stories. For example, one student said, *I like solving mysteries and the case study was a fun exercise to play detective in;* another one said, *The thinking plot was fabulous—I felt like I was a CSI investigator.* All similar comments were coded as belonging to this theme of enjoying the learning process.

The visual tools in the software make it possible to see the structure of the study document in its entirety and quickly see if and when themes, or comments, are dominant. In our study document, the text portrait shows that the themes are of different intensities and are spread throughout the document.

EFFECT SIZE

In order to evaluate which of the above themes, *learning*, *applying*, and *enjoying*, was most prevalent in the data, frequency effect sizes, in the form of percent occurrence, were calculated using the lexical search tool within MAXQDA (Onwuegbuzie, 2003). This tool allows the researcher to use logical operators to search for specific codes, words, phrases, and combinations thereof in order to get quantitative information about the intensity of each theme. It is worth noting here that translator in MAXQDA allows analysis of documents in any language.

Text segments and corresponding frequencies can be exported to spreadsheets for quantitative analyses. As can be seen in Table 1, comments with the highest frequency in our document were related to students' enjoyment of learning by reading the stories. More than half the comments indicated that they either enjoyed or had fun learning with this method. The second most common theme had to do with what they learned from the stories, 43% of the comments concerned how the stories helped them learn the topic statistic or understand why it was used. Just over a third of the comments referenced the value of the stories in helping them apply various statistics to every day (non-academic) problems.

Table 1. *Intensity Effect Sizes and Frequencies for the Three Themes Associated with Learning Statistics from Short Stories*

Theme	Frequency of Occurrence	Intensity Effect Size (percentage of total comments)
I learned how to calculate and interpret statistics with this method	173	43
I learned how to apply statistics to the real world with this method	138	34
I enjoyed/had fun learning with this method	230	57

NEGATIVE RESPONSES

While the majority of the student comments were positive, there were some negative comments as well. The text portrait created for negative responses was helpful in informing us about the nature and location of the negative comments.

Figure 3. Text portrait generated in MAXQDA of the presence and distribution of negative student responses. Purple = *The story was not helpful;* Gold = *The story did not help me to apply the statistic*, Turquoise = *I did not enjoy this story.*

As can be seen in the text portrait above (Figure 3), the fewest negative comments were related to the application of the statistic, followed by *enjoyment*, and *learning* themes. Using the text retrieval tool, we were able to instantly search for purple, gold, and turquoise colored words and phrases in order to study what exactly students found unhelpful. We found that most comments, regardless of theme, centered on the story being too long, thus adding to students' already heavy reading load. Comments such as, *Make it more concise, it was interesting, but a little too long in parts; I thought it had too many details;* and, *I don't like to read, so it felt like these stories were an overload* represent the negative aspect of this method for some students. Other negative comments related to not liking the story topic or wanting more problems to work were also noted. Happily, no comments suggested that the method interfered with or prevented learning.

QUANTITATIVE ANALYSIS

  Results of the quantitative analyses, done outside MAXQDA, verified the relative weights of the themes identified in the qualitative analysis. Descriptive statistics, summarized in Table 3, show that the highest agreement values were with statements related to feeling the stories were entertaining and interesting (98% and 91%, respectively). The second and third themes were approximately equal in terms of agreement. The second highest agreements were with statements that related to students feeling the stories helped them to understand how the statistic could be used, how the statistic could be applied to the real world, and that the story was worth their time and effort (85%, 82%, and 82% respectively). Modal values provide additional evidence that the majority of students reacted positively to this experience.

Table 2. *Descriptive Statistics Summarizing Student Responses on the Quantitative Portion of the Study Questionnaire*.

Question	M	Mode	N	% Agreed or Strongly Agreed
This story was entertaining and held my interest	4.52	5.00	56	98
I found this story helpful in understanding how [statistic] can be used	4.24	5.00	56	85
This story helped me to see how [statistic] might apply to my life	4.13	4.00	56	82
I found the topic of this story interesting	4.36	5	56	91
Overall, I found this story helpful and worth my time and effort	4.18	4	56	82

  Within the mixed methods design protocol is the requirement to cross-validate findings from each phase of analysis. To this end, a non-parametric inter-item correlation analysis of responses to items on the quantitative portion of the questionnaire was also done. After using the Bonferonni correction to the significance level (Kirk, 1982), results revealed statistically significant positive relationships between the degree to which students found the topic of the story interesting and how much it held their interest (τ =.77, p < .001, r^2 = .87); and between how interesting the story was and how helpful it was in understanding the statistic (τ =.70, p < .001, r^2 = .79). In other words, the more students found the topic interesting, the more attentive they were to the story, and the more interesting the story was, the more they reported learning from it. The relatively strong effect sizes associated with these correlations suggests that in both cases approximately 80% of the variance was accounted for by the correlation (Gilpin, 1993). This cross check of data analysis methods gave us additional confidence in our conclusions that this method has pedagogical promise.

DISCUSSION

The purpose of this study was to measure student opinions about their learning experience and to use computer assisted qualitative software to evaluate the data. Using both qualitative and quantitative techniques to identify and cross-validate themes, descriptions of student experiences seemed to center around two content themes, learning from the material and applying the material, and one process theme, the overall learning experience. These themes were visible to us through the tools available in our CAQDAS program.

Analysis tools available in the computer program also facilitated quantitative descriptions of the study document. Both the text retrieval and lexical search tools allowed us to determine intensity effect sizes and to easily determine the number of incidents of certain thematic comments.

From a research standpoint, we were pleased at the efficiency and variety of tools available to evaluate the data in this CAQDAS. The time savings compared to hand coding and sorting, and data entry was significant, making it, in our estimation, a viable option for teachers and educational researchers in schools and university settings.

CAQDAS programs allow several people to code a single document. This means that several teachers at a school that are experimenting with a new book, teaching method, or program, can work together. The program keeps track of who applied each code to what and also compiles the accompanying memos related to what each researcher is thinking as they code the text. Ideas about themes can be compared and inter-rater reliabilities can be calculated in an instant. This process alone makes investing in these programs worthwhile.

Another advantage is that CAQDAS programs such as MAXQDA work with projects just like Word and Excel do, so anyone familiar with these windows programs will find them easy to use. The learning curve for basic operation of CAQDAS programs is about 1.5 hours (Corbin & Strauss 2008) making it possible for busy teachers and researchers to become familiar with the technology in a reasonable amount of time.

The quality and variety of visual tools in CAQDAS programs is another advantage, not only for the time saving aspect, but also for ease of locating and interpreting code patterns and interesting text segments. Between the visual tools, such as the document portrait, and the data analysis tools, the educational researcher has a complete tool kit for conducting mixed methods research.

LIMITATIONS

As with any subjective study, regardless of the computer programs used, this one has limitations. Although students were assured anonymity and assured that their comments would not be read until final grades were posted, it may have been the case that they responded more positively than they actually felt knowing that their instructor would be reading their comments. Future evaluation studies might include in-person interviews by someone other than the instructor after the course has ended. Checks across data sources, independent readings, and inter-rater agreement were measures taken to minimize researcher bias, however, the possibility remains that the subjective findings were influenced by the researchers. This is a limitation of all qualitative inquiry. Finally, it is impossible, at this point, to separate the effects of the teaching method from the effects of the instructor on student experiences. Future studies should include a variety of instructors with a different personalities and teaching styles using this method.

CONCLUSIONS

With the increasing demand for evidence-based practices, teachers and researchers will likely do more instructional research than ever before. Using Computer Assisted Analysis software to make the research process both more accurate and less time consuming may well be the most important development in the area of educational accountability in this decade. Future enhancements might include transcription capabilities and more sophisticated code mapping that will make educational research even more accessible to educators as a means of enhancing the quality of educational research and subsequent evidenced based practices.

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