Designing a "Cyber-Based" Article Bank to Enhance Statistics Education

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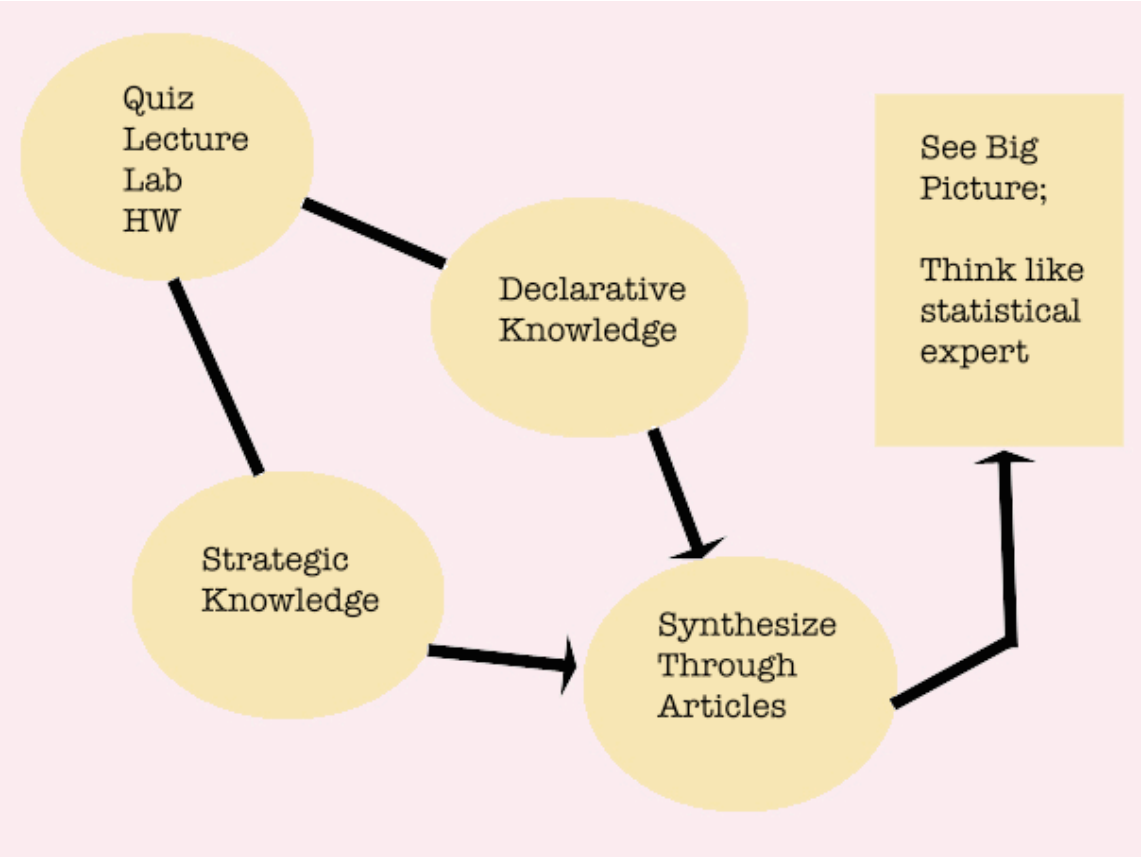
Part I: Major Goal of the Study:

Showing the "novice" how an "expert" uses statistics to solve "real world problems"

How do we plan to do this?



Typical ways in which a novice sees the world

- Tries to fit the problem at hand to the models learned
- Does not see the big picture
- Gets lost in the details
- Feels insecure if the familiar recipes, stepwise solutions, and calculations are taken away
- Is aware of the importance of practical significance but, does not have the experience of planning for it.

Typical ways in which an expert sees the world

- Tries to model the question at hand or the problem to be solved
- Is aware of and is sensitive to issues related to practical significance
- Believes in the principle of parsimony and seeks the simplest model
- Sees the big picture
- Does not construct the big picture using the details
- States the results of complex statistical analysis so that it can be followed by people who are consumers of statistics

Types of knowledge

Declarative, descriptive, or propositional knowledge …

- is factual information stored in memory
- is static in nature
- describes things, events, processes
- shows the relationship between things events and processes
- is knowledge about problem solving

Procedural knowledge or imperative knowledge …

- is Knowing how to perform
- is knowing how to operate
- can be directly applied to a task
- involves more hands-on experience
- requires a better understanding of the limitations of specific solutions
- is Knowledge used to solve problems

Examples of declarative knowledge:

- A computer algorithm in multiple languages in pseudo-code.
- Different sampling strategies and different experimental designs.

Examples of strategic knowledge:

- Implementing computer algorithms to solve a specific problem.
- Designing interventions
- Advice on sampling strategies

Part 1a. Theoretical underpinnings of the model proposed:

Teach the students the mathematical underpinnings of the statistical methods through

- Lecture
- Quizzes
- Homework
- Lab
- Articles
- Projects

Theoretical underpinnings of the model proposed Continued:

- Zone of Proximal Development (ZPD) as defined by Vigotsky (1978): The distance between the actual developmental level as determined by independent problem solving and the level of potential development as determined through problem solving under adult guidance, or in collaboration with more capable peers.
- "Zone of Reflective Capacity" as defined by Wells, G. (1999): Adults' capacity for reflection can expand when collaborating with other adults with similar goals over an extended period of time.
- Wells (1999) showed that the zone of reflective capacity is constructed through interaction between participants engaged in a common activity and expands when it is mediated by positive interactions with other participants, exactly along the same lines as the ZPD.
- Tinsley and Lebak (2009) found that as adults shared their feedback, analyses, and evaluations of each other's work in a collaborative working environment, their potential for critical reflection expanded. The zone of reflective capacity expanded as trust and mutual understanding among the peers grew.

Theoretical underpinnings of the model proposed continued:

Implementing "Generative Theory of Learning" as defined by Wittrock:

- Motivate the leaner
- Get the learner's attention
- Go from the familiar to unfamiliar
- Help learners generate their own knowledge
- Have the learners be active participants rather than passive recipients.

Implementing "Cooperative Learning" as a means of expanding the "zone of reflective capacity" by allowing the students to engage in ...

- Reflection
- Problem solving
- Giving and receiving explanation
- Pinpointing their misconceptions
- Working toward narrowing the gap between how a "novice" and an "expert" approach problem solving in statistics.

Theoretical underpinnings of the model proposed continued:

Holding actual and virtual office hours with groups of students as another mean of expanding the "zone of reflective capacity" and making it possible for the them to….

- Clarify their misconceptions
- Examine the gap between their way of thinking and an expert's way of thinking
- See the connection between theory and practice
- See how statistics is implemented in scientific research

Theoretical underpinnings of the model proposed continued:

Implementing formative assessment through immediate feedback on the weekly online quizzes as well as homework, labs, and articles to…

- Activate prior knowledge and ascertain that the students have the pre-requisite knowledge to understand the material discussed.
- Ascertain that the students have the proper scaffolding to move to the next step.
- Help the students revise the concepts and strategies with which they have difficulty.
- Help the instructors pinpoint the students' misconceptions and design review exercises for addressing these misconceptions.
- Help the instructors re-teach the statistical concepts and strategies that the majority of the students have difficulty comprehending.

Theoretical underpinnings of the model proposed continued:

Enhancement of statistical literacy through teaching the students:

How to write the results of statistical analyses…

- Within context
- For a statistical audience
- For a non-statistical audience

How to read and interpret statistical results reported in …

- Refereed journal articles
- Mass media
- Statistics books

Part II: Methods

Strategy for implementation of the cyber-based article bank

- In the first week of the quarter the students are placed in groups of six (with each group member selected from the top 16.7% to the bottom 16.7%). This is done based on UCLA GPA or performance in review quizzes.
- After introduction and/or revision of sufficient background material, two to four articles are assigned, and the students are required to…
  - read the assigned articles individually and answer a number of open-ended questions.
  - meet with their group and discuss the answers to the questions.
  - meet with the instructor/TA in actual or virtual office hours to discuss the article further and clarify potential ambiguities
  - write a group report answering the open-ended questions
- Articles plus participation in virtual/actual office hours counts for 25% of the final grade.
- Online quizzes, homework, final project, and in-class assessments count for 75% of the grade.

Cyber-based article bank was implemented in teaching…

- An upper division course in “Statistics for Social Sciences” in regular quarter and summer session.
- An upper division course in “Introduction to Experimental Design “ in regular quarter.
- A lower division course in “Statistics for Biological Sciences” during summer Session.

Questions to be answered?

Are the actual and virtual office hours equally effective in enhancing students' strategic and declarative knowledge of statistics?

Are the actual and virtual office hours equally effective in enhancing students' perceptions of their ability to

- construct their own knowledge,
- think like a statistics expert,
- communicate statistical results, and
- engage in statistical thinking?

Are actual and virtual office hours equally effective in enhancing students' knowledge and perceptions in the regular quarter and a six-week summer session?

Variables of the study and how they were measured?

- Strategic and declarative knowledge of statistics were measured by the scores on the…
  - online quizzes
  - score on the final exam
  - overall score in the course consisting of exams, labs, homework, articles, and projects.

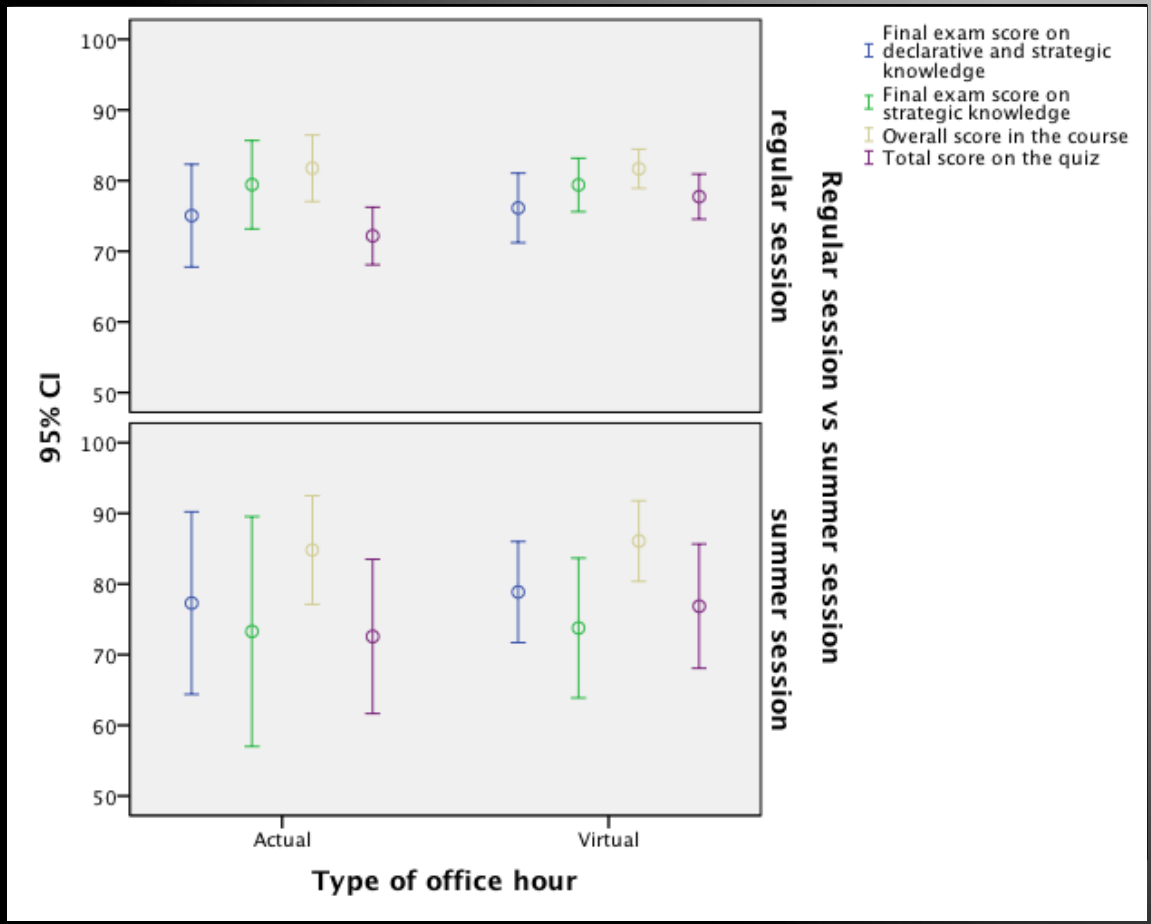
Students' perceptions of their ability to construct their own knowledge was measured by…

- five Likert Scale items based on Wittrock's theory of "generative learning"
- confirmatory factor analysis showed that all the items loaded on a single factor explaining 64.8% of the variance
- reliability, as measured by Cronbach's alpha was equal to 0.859

Students' attitudes toward the role of statistics in scientific research was measured by a 25-item Likert scale based on a review of statistics literature (Chance, Moore, Cobb)

- Exploratory factor analysis yielded three distinct factors explaining 67% of the variance.
- The three factors were…
  - thinking like a statistics expert explaining 27% of the variance,
  - ability to communicate statistical results explaining 22% of the variance, and
  - engaging in statistical thinking explaining 18% of the variance.
- The reliability of the three resulting factor as measured by Cronbach's alpha were 0.937, 0.869 , and 0.853 for thinking like a statistics expert, communication of statistical results, and engaging in statistical thinking respectively.

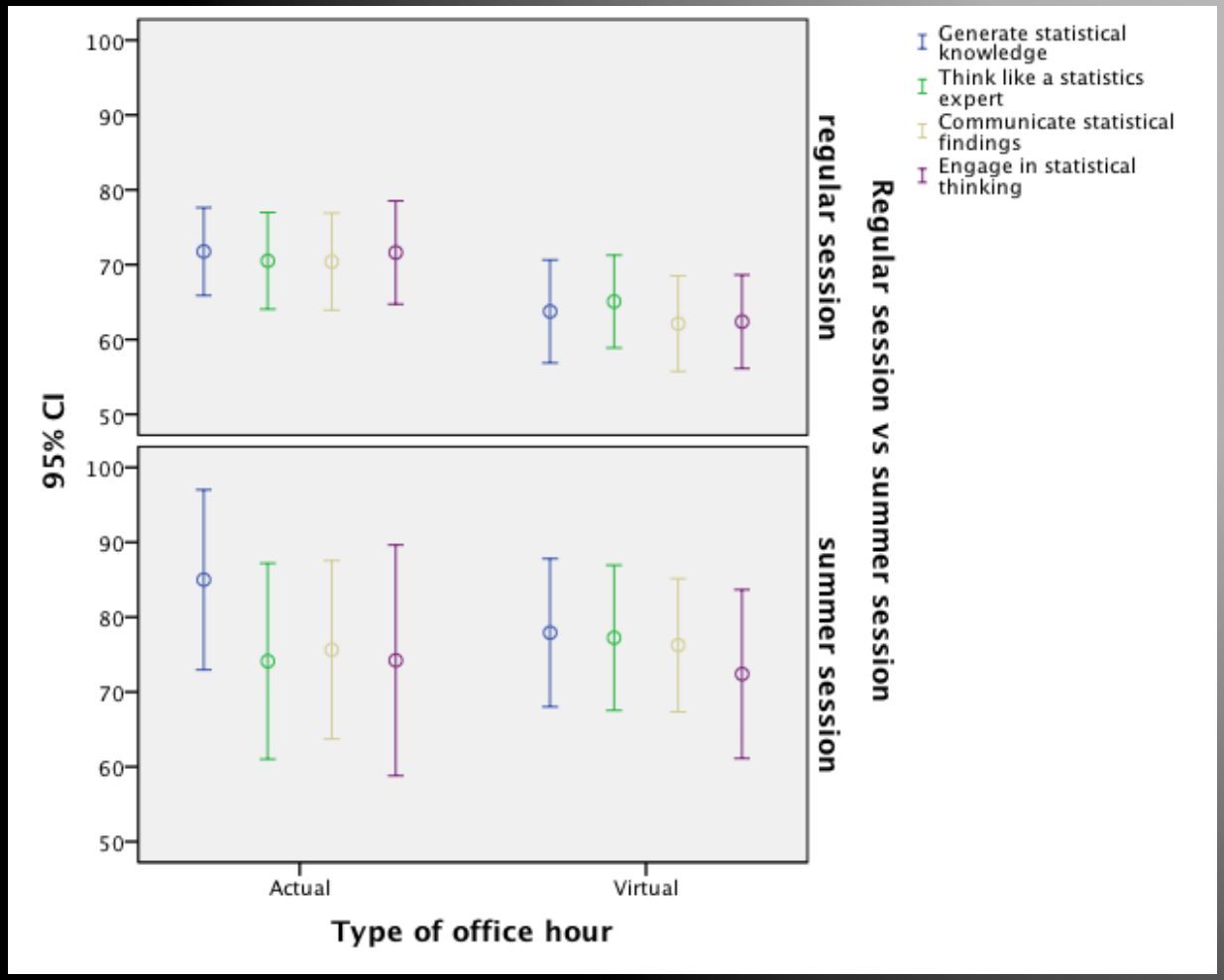
Part III: Results



Plot 1: Confidence intervals for strategic and declarative knowledge by type of office hours and session

Students' scores on ….	Regular Quarter			Summer Session		
	Actual office Hours (N = 43) Mean (SD)	Virtual Office Hours (N = 55) Mean (SD)	P	Actual Office Hours (N = 10) Mean(SD)	Virtual Office Hours (N = 15) Mean(SD)	P value
Final exam score on declarative and strategic knowledge	75.0 (23.9)	76.1 (18.3)	0.799	77.3(18)	78.9(12.9)	0.802
Final exam score on strategic knowledge	79.4 (20.6)	79.4 (14.1)	0.933	73.3(22.7)	73.8(17.9)	0.953
Overall score in the course	81.1 (15.5)	81.7 (10.4)	0.976	84.8(10.7)	86.1(10.3)	0.789
Total score on the quiz	72.7 (13.4)	77.7 (11.9)	0.031	72.6(15.3)	76.8(15.9)	0.509

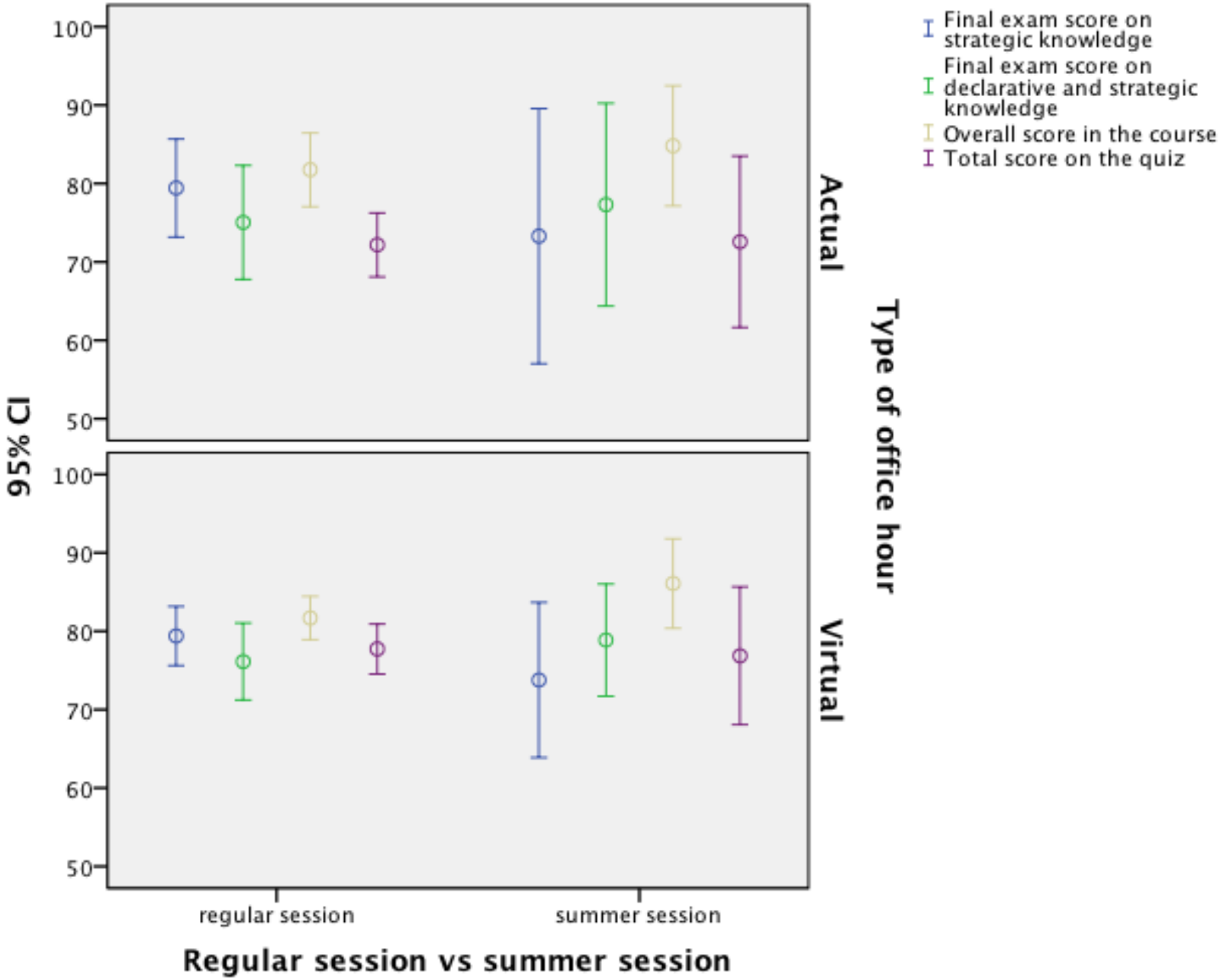
Table 1: Means, standard deviations, and P values for strategic and declarative knowledge by type of office hours and session



Plot 2: Confidence intervals for attitude toward the use of statistics in scientific research by session and type of office hours

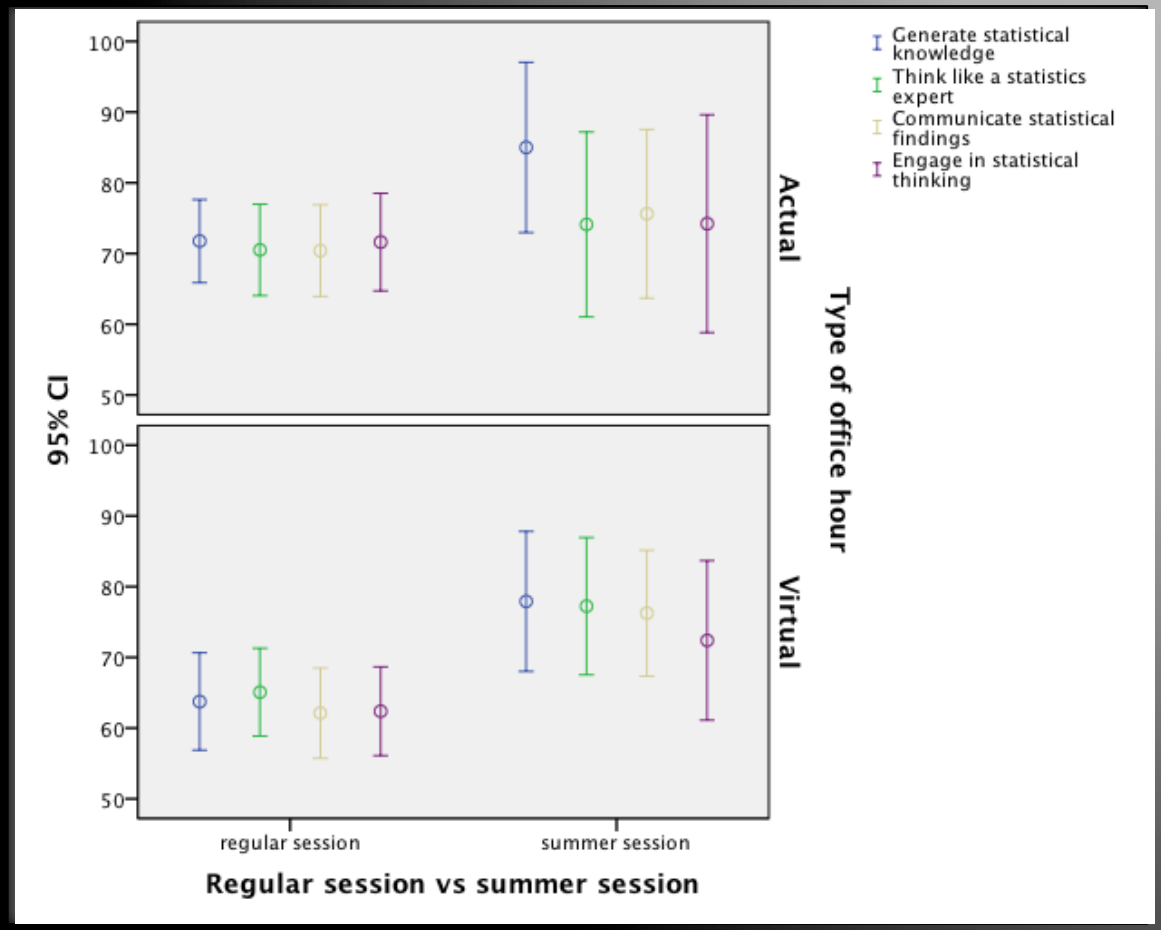
Students' perception of the extent to which they can…	Regular Quarter			Summer Session		
	Actual office Hours (N = 43) Mean(SD)	Virtual Office Hours (N = 55) Mean(SD)	P value	Actual office Hours (N = 10) Mean(SD)	Virtual Office Hours (N = 15)	P value
generate statistical knowledge	69.4 (17.5)	63.7 (24.4)	0.200	80.0 (16.5)	75.0 (15.7)	0.452
think like a statistics expert	70.0 (19.4)	65.0 (22.3)	0.274	70.0 (16.5)	76.0 (14.2)	0.320
communicate statistical results	68.8 (18.5)	63.2 (21.6)	0.155	71.3 (16.8)	74.8 (16.7)	0.767
engage in statistical thinking	69.0 (21.7)	62.1 (21.5)	0.063	70.0 (16.5)	71.7 (16.0)	0.899

Table 2: Means, standard deviations, and P values for attitude toward the use of statistic in scientific research by type of office hours and session


Final exam score on strategic knowledge
Final exam score on declarative and strategic knowledge
Overall score in the course
Total score on the quiz
95% CI
100
90
80
70
60
50
Actual
Virtual
Type of office hour
regular session
summer session
Regular session vs summer session

Students' scores on	Actual			Virtual		
	Regular N= 44 Mean (SD)	Summer N = 10 Mean (SD)	P	Regular N = 55 Mean (SD)	Summer N = 15 Mean (SD)	P value
Total exam score on declarative and strategic knowledge	70.41 (20.6)	73.3 (22.7)	0.407	79.0 (14.1)	73.8 (17.9)	0.200
Total exam score on strategic knowledge	75.0 (23.9)	77 (18)	0.781	76.1 (18.4)	78.9 (12.9)	0.589
Overall score in the course	81.7 (15.5)	84.8 (10.3)	0.557	81.7 (10.4)	86.1 (10.3)	0.148
Total score on the quiz	72.2 (13.4)	72.6 (15.3)	0.935	77.7 (11.8)	76.9 (15.9)	0.816

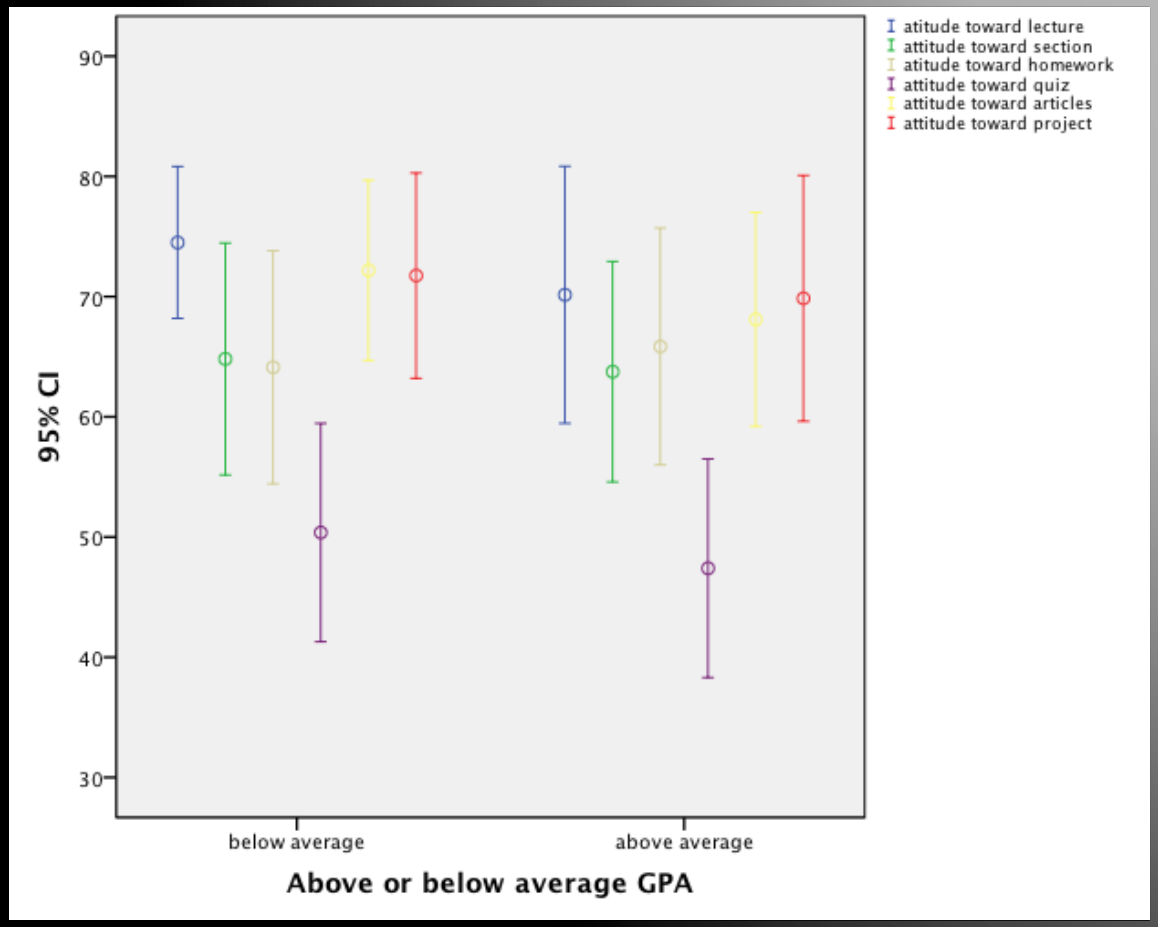
Table 3: Means, standard deviations, and P values for strategic and declarative knowledge by type of office hours and session



Plot 4: Confidence intervals for attitude toward the use of statistics in scientific research by session and type of office hours

Students' scores on ….	Actual office Hours			Virtual Office Hours		
	Regular session N= Mean (SD)	Summer Session N = Mean (SD)	P	Regular Session N = Mean(SD)	Summer Session N = Mean(SD)	P value
Generate Statistical Knowledge	69.4 (17.5)	80.0 (16.5)	0.088	63.7(24.4)	75.0(15.7)	0.095
Think like a statistics expert	68.3 (19.2)	71.7 (17.8)	0.626	62.1(22.4)	73.8(16.0)	0.080
Communicate statistical knowledge	70.1 (20.4)	71.5 (19.0)	0.851	61.8(22.2)	70.5(17.4)	0.177
Engage in statistical thinking	75.0 (23.9)	77.3 (18.1)	0.781	76.1(18.3)	78.9(12.9)	0.589

Table 4: Means, standard deviations, and P values for attitude toward the use of statistic in scientific research by type of office hours and session



Plot 5: Stat 101A Students' perceptions of the effectiveness of lecture, section, homework, quiz, articles, and final project with regards to helping them enhance their declarative and strategic knowledge of the concepts discussed in the course

Students' scores on ….	Overall UCLA GPA as reported by students		
	Below Average N= 18 Mean(SD)	Above Average N = 22 Mean(SD)	P
Lecture	77.4(12)	73.6(23)	0.531
Homework	66.9(18)	68.6 (21.8)	0.803
Section	68.0 (18.4)	65.5 (20.4)	0.700
Articles	74.9 (14.7)	70.5 (19.6)	0.437
Project	75.7 (16.9)	73.7 (22.9)	0.755
Quiz	54.0 (16.9)	49.8 (19.9)	0.437

Table 5: Mean, SD, and P value for Stat 101A Students' perceptions of the effectiveness of lecture, section, homework, quiz, articles, and final project with regards to helping them enhance their declarative and strategic knowledge of the concepts discussed in the course by GPA

Part IV: What will the article bank include?

- Refereed journal articles classified by content including…
  - descriptive statistics, graphics
  - simple inferential techniques such as one and two sample tests, correlation, simple linear regression
  - more advanced statistical techniques including ANOVA, ANCOVA, MANOVA, MANCOVA, multiple linear regression, hierarchical models, etc. and
  - non-parametric techniques

- **Each article in the bank will be accompanied by**
- A 10-30 item multiple-choice test covering the major dimensions of the article discussed…
- 10-20 open-ended questions that require the reader to write their responses to
- answers to the open-ended questions
- answers to multiple-choice questions
- **example of how we are using the articles to enhance declarative and procedural knowledge?**

- http://cyberarticles.stat.ucla.edu

Part V: Overall conclusions resulting from quantitative analysis of the data:

- Actual and virtual office hours were equally effective in ten-week quarters and six-week summer sessions with regards to enhancing students' declarative and strategic knowledge of statistics as measured by…
- Weekly quizzes
- Score on the final exam
- Overall score in the course

- Actual and virtual office hours were equally effective in regular ten-week quarters and six-week summer sessions with regards to students' perceptions of their ability to…
- Generate statistical knowledge
- Think like a statistics expert
- Communicate statistical results
- Engage in statistical thinking

- Students with above average and below average overall UCLA GPA found articles, lecture, and projects to be most effective in enhancing their declarative and strategic knowledge of experimental design.

Results of qualitative evaluation:

The students were asked to indicate the most effective features of articles, actual, and virtual office hours. Analyses of the responses indicated that they found the articles to be the best part of the course (this is aligned with the quantitative finding). The following major clusters resulted from the qualitative comments…

- Developing a better understanding of the role that statistics plays in conducting causal and non-causal research
- Seeing how statistics is used in solving real world problems
- Developing a better understanding of the material discussed in lecture
- Having a chance to interact with the peers and the instructor
- Developing the ability to communicate statistical findings within context
- Clarification of misconceptions

How can the "cyber-base article bank" be used?

- The "cyber-based article bank" can be used for **teaching** through….
  - Regular methods
  - Online teaching
  - Blended instruction
- **Formative assessment** of student learning and enhancement of teaching through having students respond to multiple-choice questions designed around each article and get immediate feedback…
  - Prior to lecture
  - During lecture using clickers
- **Summative assessment** of student learning through assigning articles as take-home exams and having them respond to the open-ended questions designed around each article.
- **Enhancing oral and written communication** of findings to a statistical and non-statistical audience through having the students…
  - Respond to open-ended questions
  - Discuss them with their peers, and the instructor
  - Examine the correct answers provided
- **Promote student-student and student-instructor interaction.**
- **Help professionals and researchers** become more skilled at following the statistical findings that result from the research in their field.

Plan for expanding and disseminating the "cyber-based" article bank

We have a pedagogical model for teaching statistics online and we have demonstrated that it works. This infrastructure that has been designed based on sound theories of cognition, teaching, learning, and evaluation can be expanded and disseminated through…

- Having different organizations such as high schools, community colleges, extension, use the resources developed by us.
- Having different organizations develop their own resources following the proposed module .
- Designing workshops to show how the "cyber-based article bank" can be used for teaching, learning, and student assessment.
- Dissemination of the "cyber-based article bank" through our colleagues at CAUSE (Consortium for the Advancement of Undergraduate *Statistics* Education)
- Implementing the "Cyber-based article bank" as part of TA training.
- Having the Office of Instructional Development at UCLA use the idea for training teaching assistants across campus

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