Teaching Statistical Collaboration Classes in Sequence

Dandan Liu[1], Mario A. Davidson[1*]

[1] Department of Biostatistics, Vanderbilt University, 2525 West End Avenue Suite 11115 Nashville, TN 37203

[*] Equal contributor and corresponding author: mario.davidson@Vanderbilt.Edu

Abstract

The same as its literal meaning, the phrase "statistical collaboration" implies two key components of a successful relationship: statistics and collaboration. Many statistics/biostatistics graduate programs offer statistical collaboration courses to prepare students with work ready statistical skills. However, an important component is often missing in the curriculum of statistical collaboration courses, i.e. effective interaction and communication skills. The biostatistics graduate program at Vanderbilt University offers a year-long signature course “Statistical Collaboration in Health Sciences” to the 2nd year graduate students focusing both components in sequence. The first course places a heavy emphasis on communication, teamwork, and interdisciplinary collaboration. Students role-play with real investigators and confront real-life problems such as opaque scientific direction, poor scientific formulation, lack of time, and ill-formulated data. The importance of understanding the underlying science behind collaborations is emphasized. In the second course of the sequence, students are exposed to a variety of statistical and methodological problems that can arise in collaborative arrangements. The course’s goal is to sharpen students’ skills in applying their statistical knowledge in real world settings, while exposing them to the application of advanced statistical techniques in routine health science applications. Teaching statistical collaboration classes in such a sequence prepares students with both “hard” and “soft” skills for a successful career.

Key Words: statistical consulting, experiential learning, cooperative learning, statistical training with clients, peer and group assessment, consulting course sequence

1. Introduction

The same as its literal meaning, the phrase "statistical collaboration" implies two key components of a successful relationship: statistics and collaboration. Many statistics/biostatistics graduate programs offer statistical collaboration courses to prepare students with work ready statistical skills. However, an important component is often missing in the curriculum of statistical collaboration courses, i.e. effective interaction and communication skills.

The ideal statistical education requires that students receive real-world experiences regarding problem solving, oral and written communication, problem formulation (Watts 1970; Russell 2001), and teaching methods that are not always provided in traditional classrooms (Belli 2001). Students should be able to identify important aspects of the research such as the goals, actions needed, personal and team expectations, and roles assumed (Zahnand Isenberg 1983). It is important to teach time management reinforcing the importance of deadlines, punctuality and professionalism. Students should be encouraged to contribute statistical and discipline knowledge focusing on real problems from a variety of contexts. They should be actively engaged while taking ownership of their own knowledge. Structured learning activities, open-ended problems, reflection, and consistent constructive feedback on their performance should be utilized. The course should provide students multiple opportunities to discuss their knowledge and performance with reports and presentations (Garfield 1993).

Cooperative learning entails students working in small group toward a common goal that is beneficial to all (Johnson and Johnson, 2017). Cooperative learning lends itself well to this course as it creates an active learning environment whereby students construct knowledge. It often leads to better productivity, understanding, attitudes, and achievement while helping students learn to function as a team. By rotating roles, positive interdependence is encouraged. In cooperative learning, tasks may not be completed without each person contributing. There must be both group and independent rewards to stimulate achievement. This pedagogy helps students develop problem solving skills and encourages multiple solutions (Garfield, 1993; Sisto, 2009; Brush, 1997).

Juxtaposed with cooperative learning, project-based learning engages students in a lengthy student centered process whereby they have an end product. It encompasses student initiative and critical thinking that develops expertise. Students are able to develop their own strategy at their pace while gaining experiential knowledge(Helle et al., 2006; Heitman, 1996; Schon, 1983; Duffy et al, 1996; Blemenfeld, 1991). Students produce higher achievement and greater productivity. The collaborative project may lead to intrinsic motivation and ability to transfer knowledge to other problems. Students may also learn to work better as a team (Kapp, 2009). Project-based learning involves formative feedback, and detailed rubrics (Markham 2011).

Project-based learning often involves real experiences but is not experiential learning in itself. The experiential learning model poses a cycle of four modes: concrete experience, reflective observations, abstract hypotheses and active testing (Kolb and Kolb, 2005). We believe cooperative, project-based, and experiential learning are the ideal student centered pedagogy needed to train statistical collaborators (See Figure 1).

To build the aforementioned ideal learning environment in teaching statistical collaboration class, the biostatistics graduate program at Vanderbilt University developed and implemented a year-long signature course "Statistical Collaboration in Health Sciences" (SCHS) offered to second-year graduate students. This course meets for three hours each week in both semesters. The fall semester focuses on preparing the students to engage with investigators and helping students formulate statistical solutions through corporative and experiential learning. The course also works on personal skills and behaviors such as communicating, interacting professionally, presenting, supervising, and interviewing. The spring semester allows students gain hands-on practical experience interacting and responding to investigators through project-based learning. The purpose of the course is to build students' knowledge, skills, attitudes, and behaviors necessary to interact with researchers and collaborators of all types. The key elements of the SCHS courses are rooted in sound educational principles utilizing appropriate learning goals, pedagogy, objectives, and assessments of student's level of competency with critical performance improving feedback.

In general, the term collaborator is used for all members of the collaboration team: the statistician, researcher, clinician, etc. For clarity, we will use the terms statistician and investigator, and student (at all levels of learners) throughout this paper.

2. Sequence I: Fall Semester

The fall semester emphasizes engagement. During this time students are actively engaged in various teaching or instructional strategies that allow them to reflect on the profession and prepare them to engage with investigators. Students are responsible for collaborating with investigators, and observing ten statistical clinics. Clinics are the department's free consultation service to investigators. In the clinics, investigators discuss their ideas among multiple professional and graduate level statisticians. The statisticians pose questions and offer advice on subjects like study design, power, sample size, and analysis. From the students' experiences they are required to reflect on the various communication aspects of the investigator(s) and professional statisticians. Additionally, each student must write a mock statistical analysis plan and critique the process of at least one of the observed clinic projects. Students also participate in role playing, presentations, and discussions of real/simulated and video scenarios. They teach, brainstorm on a variety of topics, and assess each other.

2.1 Cooperative Learning

2.1.1 Role Playing

Frequent role playing allows students to assume the role of a professional statistician while the instructor acts as an investigator. The instructor playing the role of the investigator will employ various behaviors. These roles may demonstrate different personalities such as being argumentative, disagreeable, passive, shy, knowledgeable, and/or ignorant. The "investigator" may or may not provide adequate information or well formulated research questions; posing real-life scenarios commonly faced by statisticians.

2.1.2 Brainstorming

Students engage in large and small group brainstorming activities to identify challenges and solutions on difficult topics such as behaving professionally and managing investigator questions. After brainstorming in small groups, students evaluate and discuss the others groups' suggestions. Similarly, when generalizing the appropriate questions to be asked of investigators, students are split into groups and asked to suggest questions about the following topics: data collection, research design, confounders, power, correlated data, sampling schemes, measurements, and sample size. By the time students meet with investigators, they have created a repository of typical questions that may be posed to investigators.

2.1.3 Presentations

Students engage in mock presentations devoted to developing presentation skills. At least twice in the semester, students pair, discuss, and practice teaching basic statistical concepts. Afterward, they teach the topic to the entire class. They also practice presenting a research problem they observed during a statistics clinic. This presentation addresses the research problem, design, limitations, statisticians' recommendations, and personal critique of the recommendations. Finally, they present a mock statistical analysis plan based on an observed clinic. Students engage in peer support and feedback during all mock presentations.

2.2 Case-Based Learning

Case-based learning is a unique staple of the course. The students are presented four cases in the semester. Each case has a written goal. Some cases include a research topic and data. The students determine the leader and scribe for the case. The leader is responsible for moderating the discussion of the case. The scribe is responsible for writing four main topics: student derived learning objectives, important case information, interesting questions, and potential analyses that should be conducted.

On the first day of the case, students read one excerpt at a time – typically a paragraph – together. After each excerpt, they discuss one or more of the four main topics. Students determine how they divvy up the necessary research; however, the facilitator (i.e. the instructor), emphasizes that each student is responsible for knowing each objective. On the second day of the case – four days later - the students teach each other. The facilitator helps to guide the conversation when the students go astray or fail to discuss an important learning objective adequately. After the students finish discussing the case, the facilitator releases the official learning objectives. The official learning objectives are the objectives created by the instructor when writing the case. If the students failed to discuss any of the official learning objectives, they are expected to conduct more research. At the end of the session, students discuss their strengths and areas of improvement in proceeding through the case. After each case, students are required to complete a task: a quiz, a discussion board, a report, an interview, or an essay.

The cases delve into typical issues that arise in a statistical working environment. The first case is about a recently graduated, new biostatistician being mentored in ways to become successful and to satisfy scientific collaborators. The goal of the case is to explore the qualities and expectations of a (bio) statistician that lead to a satisfied collaboration. The second case describes a junior staff biostatistician developing a statistical analysis plan for the first time. The goal of the case is to understand the purpose and communication of a statistical analysis plan (SAP). The third case discusses a two junior faculty who have professionalism issues. The goal of the case is to debate some aspects of a professional image and behavior. Finally, the fourth case deals with a poor biostatistician supervisor. The goal of the case is to understand the role of a supervisor.

2.3 Project-Based Learning

Students engage in collaborative projects and live investigator consultations. Teamwork is the focus of the collaboration projects. Students work together to develop the best solutions to the investigators' research questions. Students are required to complete three, investigator-focused, group projects within three week timeframes. Students are assigned to and rotate through different team roles for each project. Team roles include leader, scribe/data manager, statistical writer, analyst, and report writer. (See role descriptions below.) Teams remain consistent throughout the semester without team switching. Projects consist of investigator consultations, duties associated with each student's assigned role, and project deliverables. Team dynamics and project deliverables are assessed using standard rubrics. Relatively often, students are given career building opportunities whereby their analyses are used for national meetings and local projects.

2.3.1 Investigator Characteristics

The majority of investigators have a medical doctorate with wide variability in their research, clinical, and statistical knowledge and experience. Finding volunteer investigators within the school of medicine has proven to be relatively easy. The ease of recruiting is offset by the value of the free consultation with the students and instructor. The time commitment for investigators is limited (less than 90 minutes) which makes participation easier. School of medicine faculty investigators are also accustomed to teaching and interacting with students, which has proven beneficial in their giving student feedback after each session.

2.3.2 Format of Investigator Consultations

Investigators are asked to bring a former or current research question to consult with the students. They must bring real data. The students and instructor are blinded to the investigator's research question. Investigators present their question and challenges during class for forty-five minutes. Research questions and projects vary in their statistical considerations (describing, hypothesis driving, designing, modeling, predicting, surveying, validating, etc.). Fifteen minutes are allotted for feedback and reflection at the end of each consultation. Student teams actively listen to and ask questions of the investigator. Consultations are videotaped and posted on a secure website for students to continue their collaborative team activities after the class. Students are responsible for arranging the room, greeting the investigator, leading the consultation, and managing the session time.

2.3.3 Student Roles and Expectation

Students receive project instructions that detail the roles each student will assume and the format of the class. Students decide collectively how to complete the assignment. For each project, they rotate through one of five assigned roles: leader, scribe/data manager, statistical analysis plan writer, analyst, and final report writer:

- Leader: manages the project, and understands the scientific knowledge and research based on a literature review. He or she is responsible for understanding the group members' roles, and presenting the results in a project meeting,
- Scribe/Data Manager: creates the meeting minutes, the mock data set based on distributions provided in the literature (if necessary), and the data dictionary,
- Statistical Analysis Writer: writes the analysis plan,
- Analyst: cleans and analyzes the data, and
- Final Report Writer: writes the final report.

Students are expected to understand the investigator's purpose and derive a manageable three week project. The time frame prevents them from completing advanced methods requiring extensive work. Requirements of a project include submitting meeting minutes, a data dictionary, a statistical analysis plan, an analysis file, and a final report. Peer assessments and evaluations are also submitted. Students meet outside the classroom to determine the logistics and establish milestones/deadlines. They communicate via emails and are responsible for reviewing team members' work. Students serving in the role of leader are expected to participate in an instructor led one-on-one project meeting. In this meeting, the instructor assesses the student leader's ability to communicate the research, manage the team, and present themselves professionally.

2.3.4. Student Assessments

Students are assessed for knowledge, attitude, skills, and behaviors/performance. They are assessed by their peers and the instructor or teaching assistant. Grades are comprised of both peer and instructor assessments. After the in-class consultation, students receive immediate verbal feedback from the instructor and investigator in a fifteen minute period. Rubrics and questionnaires are used to assess the students' roles for each project period. Both tools serve as an instructional guide for students who have yet to perform other roles. Students assess their classmates using a specific role questionnaire and provide an anonymous evaluation. The rubric allows instructors to provide specific formative feedback. Feedback is given based on the students' professionalism, communication skills, attitudes, knowledge, time management, effectiveness, efficiency, questions (not) posed and overall performance. Students are asked to reflect on and respond to the feedback they received as part of an improvement plan or intent to change behaviors. Peer role assessments account for forty percent of the team leader's grade and thirty percent for other students. The remaining percent of the students' grade is based on the group's collective work. The instructor encourages students to discuss any rubric items that may not be applicable for their role or project.

To deter biased peer ratings, the instructor requires students to write comments if they rate their peers as substandard or above standard in four or more rubric items. As outlined in the project instructions, the instructor reserves the right to evaluate and overturn unwarranted assessments. Students who inappropriately provide poor ratings or unsubstantiated comments are subject to a professionalism grade penalty**.** The professionalism grade is a weighted percent of students' overall grade that measures participation, attentiveness in class, appropriate peer assessments, and proper attire during presentations and guest visits. It also captures punctuality, ability to follow instructions, responsiveness to communication, proactivity to completing tasks, respect for others, etc. Finally, students are reminded of the institute's honor code and code of conduct.

3. Sequence II: Spring Semester

Statistical Collaboration in Health Sciences sequence II is offered in the spring. Comparing to sequence I offered in the fall, this course puts more emphasis on the 'hard skills' while continuing to practice the 'soft skills'. Students engage in hands-on practical experience collaborating with investigators on real world problems which might result in conference abstracts or papers. Students receive instructions on asking appropriate questions to understand clinical problems, writing statistical reports, reviewing literature and presenting. Guest speakers are invited for question-and-answer forums on topics about ethics, industry versus academic employment, supervision communication tools in collaboration. The spring semester consists of approximately 28 classes.

3.1 Collaboration Projects

3.1.1 Class Allocation

The purpose of collaboration projects is to gain a practical understanding of the complexities of working in a collaborative environment. Students are required to complete three investigator-initiated projects (one group project and two individual projects) each within a six week timeframe. Each project consists of four classes with three held in the classroom and one held outside of classroom. The three in-classroom classes consist of an investigator consultation, interim analysis presentations, and final presentation. For the out-of-class meeting, students meet with investigators at their preferred location. Students deliver their final results and discuss any follow-up questions or potential opportunities for co-authorship. The instructor intentionally makes the second project the most comprehensive in order to avoid conflict with final exams of other classes. In addition, overlaps between projects are arranged to simulate a multi-tasks collaborative environment. See Table 1 for a detailed schedule.

3.1.2 Investigator Engagement

The majority of investigators have a medical doctorate with wide variability in their research, clinical, and statistical knowledge. Due to strong collaborative relationship between the Department of Biostatistics and School of Medicine, finding volunteers and appropriate investigators has proven to be relatively easy. The instructor typically chooses investigators who have collaborated with Biostatisticians and are accustomed to teaching or interacting with students. Investigators are invited to present a current research question in their preferred manner for which data has been collected. Projects vary in their statistical considerations: describing, hypothesis driving, designing, modeling, predicting, survey validating, etc. The students are usually unaware of the investigator's research question before class.

Investigators are expected to invest approximately four hours within six weeks of the project life span. This includes one hour in-classroom consultation, two hours after-class preparation and one hour out-of-classroom final result delivery. The in-classroom consultation includes thirty minutes of problem description and thirty minutes of discussion. The after-class consultation is conducted mainly through email where investigators will answer more detailed questions for clarification purpose. For some instances and upon investigator's availability, investigators might be invited to the classroom again to further clarify more post data exploration and scientific understanding. At the end of the project cycle, investigators meet with the students and instructor outside of the classroom to discuss the final results and follow-up questions for dissemination. Overall, investigators are involved in 6 (22%) classes and spend 6 after-class hours.

3.1.3 Student Engagement

In the first class of each project where investigators present the scientific problem, students are provided a project summary template to be completed after the consultation. The summary includes: overall goal, specific aims/hypotheses, and design of the study with inclusion/exclusion criteria, outcomes, predictors, variables for description or adjustment purpose and proposed statistical analysis plan. The summary is used as a bridge to facilitate communication with investigators and is included in the statistical reports. Students are required to complete appropriate CITI-training and have their names added to the approved IRB of the corresponding study before they are granted access to the research data.

Two weeks after the first class, students/groups present interim analyses with descriptive statistics, visualizations, and questions for investigators including data cleaning problems. Critiques from peer students and the instructor are provided instantly. Students choose their preferred format of presentation such as slides or drafts of statistical reports. The instructor sends relevant questions collectively to investigators after the interim analyses.

Two weeks from the interim analyses, students/groups present final statistical reports in the classroom and receive feedback from peers and the instructor for final revision. In the last class of each project, students meet at the investigator's office to deliver the final results. In this meeting, students formally present their findings to investigators and discuss additional work needed. More in-depth discussion happens if students express interests in continuing the collaborative work in their spare time. Overall, 6 (22%) classes are led by students for collaboration projects presentations.

3.2. Medical Journal Article Review

In addition to working on collaboration projects, students are required to review and present one or two medical journal articles and provide critiques. The instructor chooses the journal papers based on the investigators' suggestions. The purpose of the reviews is twofold. First, reviewing medical journal articles relevant to ongoing projects helps students better understand the scientific background of projects. Second, students learn the role of Biostatistician in various collaborative research studies partially reflected from published peer-reviewed medical papers. They get a better understanding of basic information that assists investigator, preferred formats and illustration of the results. In addition, by providing critiques on the design of the study, analysis plan and the interpretation of the results, students gain more insight from a statistical reviewer's point of view. This may help them avoid common mistakes when they work on projects. Two classes are designated to journal review per project. This results in a total of 6 (22%) student led classes for journal review.

3.3 Instructor Engagement

In addition to coordinating classes led by students, investigators, and guest speakers, the instructor gives 6 (22%) lectures focusing on writing statistical reports, important but often neglected statistical techniques in collaborative projects such as assessment of nonlinear effect, model assumption checking, handling missing data etc. The instructor also provides critiques in writing for interim analysis report and final report.

Most importantly, but not reflected in the class schedule in Table 1, the instructor serves as a bridge between investigators and students to ensure smooth communications. The instructor also serves as a role model for students to learn effective oral and verbal communication. For example, the instructor will review scientific questions with investigators before class in order to ensure that the data is available and the project is feasible within the expected spectrum. The instructor summarizes questions from students in emails to investigators and CC's the students. The instructor also provides questions and answer sessions intermittently, e.g. at the end of journal reviews or students collaboration project presentations.

4. Remarks

The ideal statistical education should allow students to experience real world situations. It should help students learn to communicate, problem solve, and formulate problems. The ideal statistical education should also use interactive, collaborative pedagogy that encourages students to build on their own knowledge.

We introduce a unique curriculum teaching statistical collaboration classes in sequence while aligning with current evidence of statistical collaboration education. This curriculum is designed to prepare students for a successful career with hands-on collaborative experiences. Sequence I focuses on the 'soft' skills, i.e. communications for collaboration, and sequence II emphasizes more of the 'hard' skill, i.e. reading, writing and statistical analysis for collaboration projects.

Belli (2001) suggested three models commonly used for statistical collaboration education: 1) consultations whereby the students attend consultations with a mentor, 2) a course where students work on a project, and 3) a consulting center whereby students learn with a mentor. Our curriculum is a hybrid of all three models with the addition of meaningful topics useful in molding a successful biostatistician. Designed and implemented using a student-centered approach, our curriculum has 45% of the classes led by students. See Table 2 for detailed statistics of class leading roles.

Investigators are an important component of a statistical collaboration education. Sabo (2016) suggests the need for non-statistical investigators and highlights the difficulty in attracting these investigators and appropriate projects. Our curriculum integrates non-statistical investigators into simulated and mock experiences in sequence I and real world collaboration in sequence II. It has proven successful using non-statistical investigators from the medical school that are relatively easy to attract and desire our students' assistance. Our students work with multiple non-statistical investigators in both sequences. In sequence I, students observe at least ten statistic clinics. In sequence II, students practice communication skills they learned from sequence I and technical skills learned from other statistical courses in a real collaborative environment, which might provide potential opportunities of co-authorship in collaborative studies.

Sabo (2016) also identified a lack of feedback in many collaboration courses. We uniquely designed our curriculum with multiple opportunities to provide feedback for improvement. In sequence I, students receive formative feedback during presentations from their peers, teaching assistants, investigators and the instructor focusing more on their communication skills. This feedback entails both their strengths and areas for improvement. In sequence II, students also receive feedback orally and verbally from their peers, the instructor and investigators.

In summary, we developed a feasible, project-based statistics curriculum in sequence using a multi-modal, experiential and practical learning approach emphasizing communication and professionalism as supported by the literature. This curriculum focuses on oral and written communication skills, professionalism, investigator challenges, and techniques for teaching investigators about statistics that often are not experienced in other courses published in the literature. The strengths of the SCHS course are that it: 1) provides students the opportunity to interact with real investigators, 2) allows students to manage the complexities of a research projects while assuming multiple roles, 3) encourages students to study science by performing limited literature reviews, 4) challenges them to take ownership of their learning and collaborate as a team, 5) requires a relatively small amount of full time equivalent, and 6) incorporates the interaction of real-world topics and statistics often not encountered in other courses. The SCHS curriculum provides students the opportunity to give and receive peer, investigator, and faculty feedback. Students in our SCHS curriculum are gaining valuable experiences responding to the investigator's open-ended questions in multiple forms, and experiencing mock on-the-job training that will ultimately support their performances and onboarding in future career roles.

Acknowledgements

We would like to thank all of the students who provided valuable curriculum design feedback. We also want to thank our investigators, Regina Russell, Leora Horn, Amy Fleming, Charlene Dewey, Tyler Reimschisel, Katherine Gifford, Maame Yaa Yiadom, Michael Ward, an advisor, Eric Vance, and last but not least Matthew Shotwell who helped coordinate the course in the past.

Figure 1: Conceptual Model of the Learning Theories used to Inform the Preparation of a Statistical Collaborator. The training of a collaborative statistician should entail interactive, experiential, and group learning. This pedagogy is captured using project-based, cooperative, and experiential learning. The training should lend itself to the trainees' professionalism, communication, and problem solving skill competencies. These competencies encapsulate the trainees' knowledge, attitude, behavior, and skills.

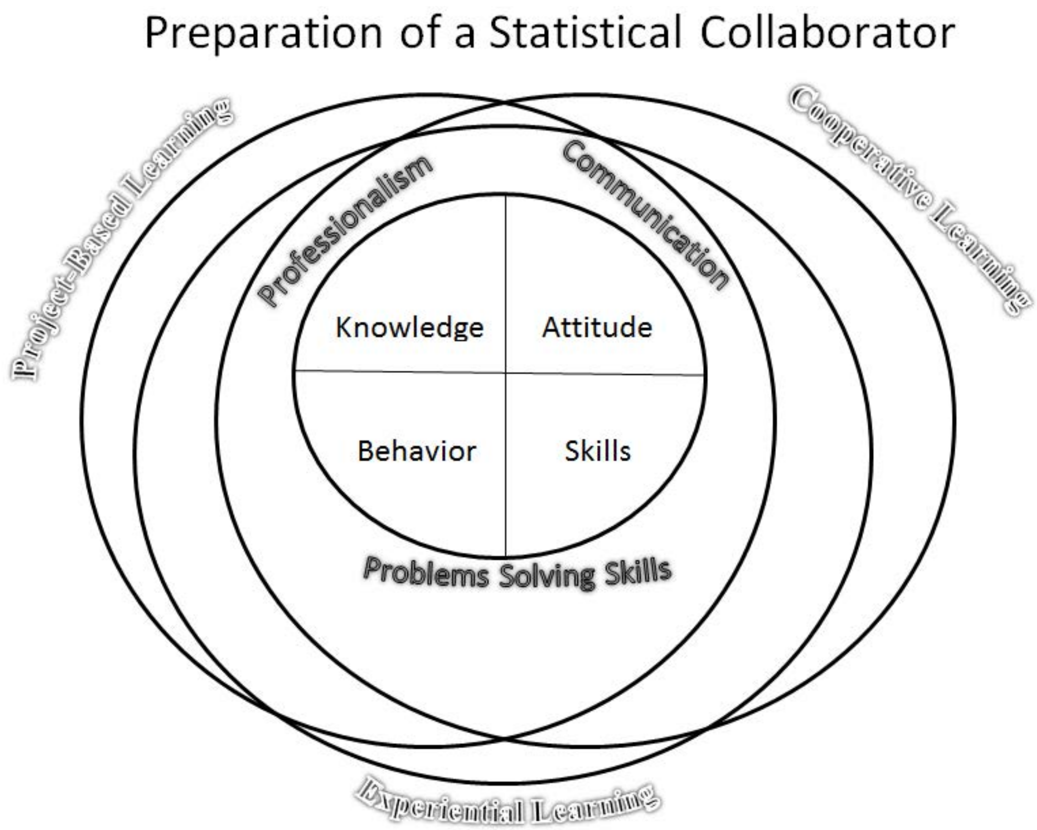

Table 1: Sample Schedule of Sequence II

Class	Week	Project*			Discussion Topics	Leaders
1	1					Instructor
2	1	P1				Investigator 1
3	2					Instructor
4	2				Journal Review	Students
5	3				Guest Lecture	Guest
6	3					Instructor
7	4	I1				Students
8	4				Journal Review	Students
9	5					Instructor
10	5		P2			Investigator 2
11	6		↓		Journal Review	Students
12	6	F1	↓			Students
13	7	M1	↓			
14	7		↓		Guest Lecture	Guest
15	8		I2			Students
16	8		↓		Journal Review	Students
17	9		↓	P3		Investigator 3
18	9		↓	↓	Guest Lecture	Guest
19	10		↓	↓		Instructor
20	10		F2	↓		Students
21	11		M2	↓		
22	11			I3		Students
23	12			↓	Journal Review	Students
24	12			↓		Instructor
25	13			↓	Journal Review	Students
26	13			↓	Guest Lecture	Guest
27	14			F3		Students
28	14			M3		

*P1-P3 denote the first class of each project; I1-I3 denote interim analyses presentation of each project; F1-F3 denote in-class final presentation of each project; M1-M3 denote final meeting with investigators for each project.

Table 2: Summary of Classes Engagement

Leaders	Sequence I	Sequence II	Overall
Students	13 (48%)	12 (44%)	25 (45%)
Instructor	7 (26%)	6 (22%)	13 (24%)
Collaboration	4 (15%)	6 (22%)	10 (18%)
Guest Speakers	3 (11%)	4 (12%)	7 (13%)
Total # of Classes	27	28	55

References

Belli, G. (2001), "The Teaching/Learning Process in University Statistical Consulting Labs in the United," *Training Researchers in the Use of Statistics*, 325-338.

Brush, T. (1997), "The Effects on Student Achievement and Attitudes when Using Integrated Learning Systems with Cooperative Pairs" 45 (*1*), 51-64.

Duffy, T. M. & Cunningham, D. J. (1996). "Constructivism: Implications for the Design and Delivery of Instruction," in *Handbook of Research for Educational Communication and Technology*. New York, Macmillan Library Reference.

Garfield, J. (1993), "Teaching Statistics Using Small-group Cooperative Learning," *Journal of Statistics Education*, *1*(1), 1-9.

Garfield, J (1994), "Beyond Testing and Grading: Using Assessment to Improve Student Learning," *Journal of Statistics Education* (electronic journal), *2*(1).

Helle, L., Tynjala, P., & Olkinuora, E. (2006). "Project-Based Learning in Post-Secondary Education: Theory, Practice and Rubber Sling Shots," *Higher Education,* 51(*2*), 287-314.

Heitman, G. (1996), "Project-Oriented Study and Project-Organized Curricula: A Brief Review of Intentions and Solutions," *European Journal of Engineering Education*, 21, 121-132.

Johnson, D.W. & Johnson, R (2017), "An Overview of Cooperative Learning" Available at http://www.co-operation.org/what-is-cooperative-learning/

Kapp, E. (2009), "Improving Student Teamwork in a Collaborative Project-Based Course," *College Teaching"*, 57(*3*), 139-143.

Kolb, A.Y. & Kolb, D.A 2005, "Learning Styles and Learning Spaces: Enhancing Experiential Learning in Higher Education," *Academy of Management Learning & Education*, 4 (2), 193-212.

Markham, T. (2011). "Project Based Learning," *Teacher Librarian* 39(2), 38-42.

Russell, K. G. (2001), "The Teaching of Statistical Consulting," *Journal of Applied Probability*, *38*, 20-26.

Sabo, R. T.(2016), "Providing Consulting Experiences through Role Playing in a Graduate Statistics Course," *Australian & New Zealand Journal of Statistics*, 58, 319-333.

Schon, D. M. (1983), "The Reflective Practiioner. How Professionals Think in Action. New York: Basic Books.

Sisto, M. (2009), "Can You Explain that in Plain English? Making Statistics Group Projects Work in a Multicultural Setting," *Journal of Statistics Education*, 17(*2*).

Watts, D. G. (1970), "A Program for Training Statistical Consultants," *Technometrics*, *12*(4), 737-740.

Zahn, D. A., & Isenberg, D. J. (1983), "Nonstatistical Aspects of Statistical Consulting," *The American Statistician*, *37*(4a), 297-302.