# TAKING PROJECT-BASED STATISTICS ABROAD: LEARNING EXPERIENCES AND OUTCOMES OF A PROJECT-BASED STATISTICS COURSE IN WEST AFRICA

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## ABSTRACT

*To evaluate the impact of a multidisciplinary, project-based course in introductory statistics, this exploratory study examined learning experiences, feelings of confidence, and interest in future experiences with data for undergraduate students in Ghana, West Africa. Students completed a one-semester, introductory statistics course utilizing the Passion-Driven Statistics curriculum. Results showed more than half of the students put more effort into the course and found the material more challenging compared to other courses, while nearly three-quarters reported interest in one or more follow-up courses. Importantly, students also reported increased confidence in a variety of applied statistical skills. These findings demonstrate the positive impact of a multidisciplinary, project-based curriculum on undergraduate students in Ghana, West Africa and demonstrate the potential for its global portability.*

***Keywords:*** *Statistics education research; International education; Applied statistics*

## 1. INTRODUCTION

As our data-filled, technology-saturated world continues to expand and change, there is an international push for statistics education to become more inquiry- and technology-based (Pfannkuch, 2018). This push has led many colleges and universities, particularly in the United States, to revise their statistics curriculum to include project-based learning components and exposure to a range of technological tools and software (Ridgway, 2016). Although there is little empirical research on statistics education at the post-secondary level in Africa, research on mathematics education more broadly points to a predominantly theoretical and procedural approach to the teaching and learning of mathematics on the continent (Oduro et al., 2007; Vavrus et al., 2011; Akyeampong et al., 2013). Such an approach to statistics education does not adequately prepare college students in Africa to take up the challenges and opportunities presented by the vast amounts of data now becoming available. For example, in 2015, African governments adopted the Africa Data Consensus—a roadmap of initiatives, commitments, and values for a data revolution in Africa. More than 21 Sub-Saharan African countries now have open data initiatives at various stages of implementation (van Schalkwyk et al., 2017).

In order to bring practical benefit to these efforts, African universities need to update their introductory statistics courses so students gain the skills needed to access open data, manage large datasets, use technology to visualize and analyze the data, and evaluate, interpret, and communicate the results. In response to this need, we describe how a university in Ghana, West Africa transitioned from a traditional-style textbook-based introductory statistics course to a project-based, flipped classroom approach that utilized the Passion-Driven Statistics curriculum (Dierker et al., 2012) and a range of new technologies. The transition was made possible through the support of a mentoring relationship between

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the first author, an introductory statistics instructor at Ashesi University in Ghana, and the third author, an experienced faculty member at a selective liberal arts college located in the United States.

### 1.1. THE CHANGING FACE OF STATISTICS EDUCATION

Whether based in the United States or Africa, a central challenge of *any* introductory statistics course is the development of a curriculum that not only serves diverse students but also sparks interest and develops quantitative reasoning that crosses disciplinary boundaries. Many students express negative feelings about introductory statistics courses and emerge from these classes with few useful skills (Gal & Ginsburg, 1994; North & Zewotir, 2006). Petocz and Reid (2005) interviewed undergraduate students who recently completed an introductory statistics class, finding that students who described the class as focusing on statistical techniques did not believe that statistical analyses were a useful way to evaluate information and planned to avoid the use of statistics in their professional lives. In contrast, students who described the class as focusing on analyzing and interpreting data were more likely to believe that statistical techniques could be used to understand real issues in a wide range of areas. Bailey, Spence, and Sinn (2013) suggest that developing this type of statistical thinking can best be achieved through inquiry-based projects.

Project-based learning is an instructional approach based on authentic, real-world activities aimed at engaging student interest and enthusiasm (Buck Institute for Education [BIE], 2012; Krajcik & Blumenfeld, 2006). Designed to answer a question or solve a problem, project-based learning allows students to face challenges that lead to answers, reflection on ideas, and decision making that affects project outcomes (Aditomo et al., 2013). There is an emerging literature base that demonstrates that project-based learning is more effective in promoting deep thinking—the ability to apply knowledge, communication, and reasoning skills—when compared to traditional didactic approaches (e.g., Harada & Yoshina, 2004; Hickey et al., 2000; Hmelo-Silver et al., 2007; Langer, 2001; Lynch et al., 2005; Walker & Leary, 2009).

In creating a project-based curriculum for introductory statistics, one issue is deciding whether students should collect primary data or use secondary data. Having students use secondary data is an opportunity to address an increasingly important aspect of statistical literacy; accessing open data and becoming familiar with officially generated statistics. According to Gal and Ograjenšek (2017), an understanding of official statistics is a civic competency needed by adults in order to interpret, evaluate critically, and express opinions about data-related arguments concerning societal matters. Open datasets and official statistics cover many topics, such as health, education, economics and the environment, and often contain hundreds, if not thousands, of variables, so projects designed around secondary data can take advantage of students' natural curiosity and provide a common language for approaching quantitative research questions across numerous disciplines (Cobb, 2007).

Further, North and Zewotir argue that introductory statistics should "focus on how to make use of descriptive statistics instead of how it is programmed into a pocket calculator or computer" (2006, p. 509). They advocate eliminating time spent on tedious repetitive calculations, which can be done faster and more accurately with a computer, and instead spending more time helping students understand underlying principles. Using secondary data together with statistical software in an introductory statistics course allows for students' inquiry-based projects to go beyond descriptive statistics to include statistical inference and tackle bivariate, and multivariate, research questions.

### 1.2. STATISTICS EDUCATION IN THE SUB-SAHARAN AFRICA CONTEXT

Students typically enter an introductory, undergraduate statistics course with a range of backgrounds, experiences, and interests in mathematics formed from earlier schooling. These differences are amplified in the Sub-Saharan Africa context due to highly inequitable systems of schooling, with wide variations in quality between urban and rural schools, schools in different regions of the same country, and between public and private schools (Tanaka, 2012; Taylor & Muller, 2014). Unfortunately, research has shown that students' mathematics background is strongly associated with their ability to meet learning outcomes in traditional statistics courses (Nielsen et al., 2018).

Dierker and colleagues (2015) demonstrated that project-based introductory statistics courses in the United States enroll higher numbers of under-represented minority students compared to a traditional introductory statistics course. In terms of course experiences and outcomes, Dierker, Flaming et al., (2018) demonstrated that students enrolled in a project-based course had more positive course experiences, showed a greater likelihood of increases in confidence with regard to managing data, choosing the correct statistical test, and writing code to run statistical analyses compared to students enrolled in a traditional statistics course. Students in their study also showed greater interest in pursuing additional coursework in statistics and related topics.

Two additional issues are important for the transition to a project-based introductory statistics course in the Sub-Saharan African context. First, textbooks and learning resources for introductory statistics are typically produced outside of Africa, with examples and datasets relevant to a Western context. As the open data movement accelerates across the continent, a transition to a project-based approach can take advantage of secondary data generated by governments and research institutions collected in, and relevant to, Africa. Second, information and communication technology infrastructure at African universities is improving, making a technology intensive course increasingly feasible.

## 1.3. THE PROJECT-BASED COURSE

The development of the curriculum for this project-based introductory statistics course (Dierker et al., 2012) was funded by the United States' National Science Foundation (NSF) and was first introduced into the curriculum at a selective liberal arts college in the United States. The course was designed to be multidisciplinary, in other words, to engage students in applied statistical projects across a wide range of academic disciplines. Following the *Guidelines for Assessment and Instruction in Statistics Education (GAISE) College Report* (Carver et al., 2016), the curriculum focuses on statistical thinking (GAISE Recommendation #1) by asking students to choose their own research project and giving them time to think critically about statistical issues related specifically to their project. Supporting students to make their own decisions about the most appropriate ways to visualize, explore, and analyze data, the project-based course emphasizes conceptual understanding over hand calculations (GAISE Recommendation #2). Students learn to recognize the usefulness of data for answering questions of interest to them (and to society) and tackle complicated real-world questions (GAISE Recommendation #3).

The curriculum covers themes common to introductory statistics courses such as measurement and descriptive and graphical representation, as well as more specific inferential methods needed to test hypotheses and/or explore the empirical structure of data. All topics are introduced as students' own research questions dictate. We accomplish this in two ways. First, the curriculum follows an ordering of topics appropriate for any quantitative project (e.g., manage data before conducting descriptive statistics and conduct descriptive statistics before applying inferential tools). Second, while working through the content, students choose tools and procedures that best address their research question. For example, when learning inferential tools, a student who initially selected categorical variables can choose to learn about and gain fluency with a Chi-Square Test of Independence before introducing quantitative variables into their question. With the addition of quantitative variables, students would then learn about Analysis of Variance. In this way, students are not exposed to statistical concepts serially, but are given opportunities to select the tools and ideas that are most appropriate to both address and modify their research questions. Using statistical software (GAISE Recommendation #5), students are exposed to a variety of codes and scripts and learn to choose and use them flexibly as they are needed. The project-based course also encourages a flipped classroom approach, where students access statistics content online outside of class, freeing class time for active problem solving (GAISE Recommendation #4). All statistical analyses are conducted within the context of our students' research questions, culminating with a poster presentation that allows for a meaningful summative assessment of student learning (GAISE Recommendation #6).

This project-based model was used in the introductory statistics course that is part of Ashesi University's liberal arts core curriculum and is required of all business administration, management information systems, and computer science majors. Each course section was taught by one faculty member supported by one recent graduate in the role of faculty intern. Students go through the liberal arts core as a cohort and the introductory statistics course is completed in the first semester of the second year. All students enrolled in the introductory statistics course have had one year of mathematics (either pre-calculus or calculus) and one semester of introduction to computing, which includes some programming. Following the statistics course, students will apply the coding skills gained in the statistics course to a required quantitative methods course and will build on the research skills gained in a required research methods course taken in the third year. All students complete a final year capstone course that involves independent quantitative or qualitative research: a full-year undergraduate thesis, a one semester applied project, or a two-semester entrepreneurship course.

Ashesi University's introductory statistics course adopted the Passion-Driven Statistics curriculum (Dierker et al., 2012) and flipped classroom model in 2015. In this course, rather than using a textbook, students work through online content in probability and statistics accessed through Carnegie Mellon's Open Learning Initiative (OLI) website (https://oli.cmu.edu). Through text, short videos, interactive activities, including calculations and coding, and short assessments, students work on-line outside the classroom, preparing them with appropriate background for the workshop-oriented class sessions. Class sessions can then be used for a combination of hands-on activities and simulations using R, as well as work on students' semester-long individual research projects. The individual research project takes students through the following steps in quantitative research: developing a feasible research question, conducting a literature review, cleaning and managing data, creating data visualizations, using statistical inference (e.g., Analysis of Variance, Pearson Correlation, Chi-Square Test of Independence), and presenting the results of the research in the form of an academic poster. In the first weeks of the course, students develop their own research question based on existing, publicly available, large datasets. Students also read published research based on the datasets they will be using in the course and begin to develop their own research questions. Datasets used for the course include Ghana Living Standards Survey (GLSS6) (Ghana Statistical Service [GSS], 2014), *Afrobarometer* Round 6 (University of Capetown et al., 2017), and Ghana's 2014 Demographic Health Survey (GSS et al., 2015). Examples of questions our students have sought to answer are: Are perceptions of domestic violence associated with the level of education attained by women in the Ghanaian context? Is social media usage associated with attending a campaign rally among Malawians age 18 to 40? Is poverty level associated with paying a bribe for different government services in Ghana? What factors predict contraceptive choices among women in Ghana?

Students' research questions evolve as they continue through the course and apply newly learned statistical techniques. Traditional introductory statistics themes are organized to focus on the decisions and skills involved in statistical inquiry. The process of inquiry culminates in an interactive poster session. During the poster session, faculty, students, representatives from research organizations such as Ghana Statistical Service, Afrobarometer, and representatives from local non-governmental organizations and private companies interact with student presenters allowing the students to present their work multiple times to a range of audience members. When presenting their work, students describe their process of inquiry, including decisions made along the way, as well as their premises, conclusions, and barriers faced when completing their research projects. The present study aims to demonstrate the portability of the project-based course (Dierker et al., 2012) to a cohort of business administration, computer science, and management information systems students attending Ashesi University in Ghana, West Africa. As the first known course of its kind to be implemented in Africa, this study will also evaluate the course experiences of these students, their confidence in applied statistical skills, and interest in future exposure to statistics.

## 2. METHODS

### 2.1. PARTICIPANTS

The participants in this study were a sample of 131 college students enrolled in the semester-long, project-based introductory statistics course at Ashesi University in Ghana, West Africa, in 2015. 78% of the participants were Ghanaian, with the remaining 22% of students coming from 9 different African countries. This mirrors the composition of the university population. Nearly a third (30.7%) of students in the class were on full scholarship and 24.6% were receiving partial scholarships. The gender balance was 47% male and 53% female, with 28.3% reporting being first-generation college students.

A total of 71.8% of the student participants reported that they were "good" or "very good" at math and 63.3% reported that they had done "well" or "very well" in previous math courses they had taken. One-quarter of the sample reported having previously taken a statistics course and a majority of students

(58.1%) had taken a course employing video lectures. Only 6.0% of students reported on the pre-survey that they were "very likely" to have taken the course if it was not required and only 14.5% were very interested in conducting research. Because they had taken a required introduction to computing course in the first year at Ashesi University, most students reported previous experience with programming. Academic background characteristics are summarized in Table 1.

*Table 1. Student academic profile*

| Academic Profile | N = 131 |
|---|---|
| Taken a course on statistics or data analysis | 30 (24.2%) |
| Any programming experience | 96 (79.3%) |
| How good at mathematics are you? | |
| 1 = very poor | 0 (0%) |
| 2 = poor | 3 (2.6%) |
| 3 = fair | 30 (25.6%) |
| 4 = good | 64 (54.7%) |
| 5 = very good | 20 (17.1%) |
| How well did you do in mathematics courses in the past? | |
| 1 = very poorly | 1 (0.9%) |
| 2 = poorly | 1 (0.9%) |
| 3 = fair | 30 (25.6%) |
| 4 = well | 49 (41.9%) |
| 5 = very well | 25 (21.4%) |
| Previously taken a course that used video lectures | 68 (58.1%) |
| How likely is it that you would take this course if not required? | |
| 1 = very unlikely | 11 (9.4%) |
| 2 = unlikely | 30 (25.6%) |
| 3 = undecided | 37 (31.6%) |
| 4 = likely | 32 (27.4%) |
| 5 = very likely | 7 (6.0%) |
| Interest in conducting research | |
| 1 = not at all interested | 4 (3.4%) |
| 2 = somewhat interested | 49 (41.9%) |
| 3 = interested | 47 (40.2%) |
| 4 = very interested | 17 (14.5%) |

*Note:* Percentages are based on the number of respondents completing each item.

## 2.2. INSTRUMENTS

Data were drawn from student surveys completed before and after the course. The pre-course survey was completed prior to the end of the second week of classes and the post-course survey was completed during the last weeks of the semester. Each survey took approximately 10-15 minutes to complete. The surveys included sections related to experiences with the course, increases in confidence, attitudes and interests in future experiences, and asking relevant and feasible questions with data, which are each described next in more detail.

***Experiences with the course*** On the post-course survey, students rated on a Likert scale the *usefulness* of course resources (i.e., in class presentations, video lectures/presentations) from 1 (not at all useful) to 5 (extremely useful). Students' perceptions of their engagement in the course were measured by three questions about their *effort* – "How hard did you work in this course?" on a scale from 1 (not at all hard) to 5 (extremely hard), "Compared to other courses you have taken, did you put in more effort, less effort, or a similar amount of effort?", and "How frequently did you prepare by completing assigned readings and/or videos before the appropriate class period?", 1 (never) to 5 (always).

Students' perceptions of *rigor* were measured on a Likert scale with the questions "How challenging did you find this course?" 1 (not at all) to 5 (the most challenging) and "Was this course more challenging, less challenging, or similarly challenging compared to other courses you have taken?". Overall impressions of the success of the course were measured on a scale of 1 (not at all) to 5 (extremely rewarding) with the question, "How *rewarding* did you find this course?", and the questions "Did you accomplish more than you expected?", "Did you find the course *more interesting*, less interesting, or the same compared to other courses you have taken?", "Did you find this course *more useful*, less useful, or similarly useful compared to other courses you have taken?", and "Did you *learn* more, less, or a similar amount compared to other courses?". Students were also asked about the amount of individualized support they received and how useful they perceived that individualized support to be relative to their experiences in other courses.

***Increases in confidence*** Increases in perceived confidence on specific data analysis and statistical skills were evaluated based on changes in student ratings from the pre- to post-course survey, using a scale of 1 (not at all confident) to 4 (very confident). These skills were developing a research question, choosing the correct test, managing data (e.g., identifying missing data, creating scales, and/or dichotomizing variables), checking assumptions, calculating a test statistic by hand, writing syntax to run a statistical analysis, interpreting results, graphing, effectively presenting results, and the more general category of conducting a statistical analysis of data. For students not rating themselves at the maximum confidence level in the pre-survey, individual dichotomous variables were created for each skill indicating whether each student's confidence increased between the pre- and post-course surveys. In addition, the total number of these skills on which students increased from pre- to post-survey was calculated. Post-test ratings of confidence, from 1 (not at all confident) to 5 (extremely confident), in abilities to learn more statistics, analyze data, answer questions with data, and master introductory material were also examined.

***Attitudes and interest in future experiences*** Increases in *interest* in statistics and data analysis were measured by a series of questions about their interest in analyzing data, answering questions with data, learning about statistics, and pursuing advanced statistics coursework. Each of these questions was rated on a 5-point Likert scale in the pre- and post-surveys with higher values indicating greater interest. For students not rating themselves at the maximum interest level in the pre-survey, dichotomous variables were created for each question indicating whether the students' interest increased between the pre- and post-surveys.

An additional outcome measure considered if students would like to take *one or more courses as a follow-up* to their project-based, introductory statistics course. Options included a course in advanced statistical tools, dataset construction, data visualization, programming, science writing, or other. Individual courses were examined separately, and an aggregate variable based on post-survey data was constructed indicating whether a student endorsed an interest in taking at least one follow-up course.

***Asking relevant and feasible questions with data*** To address improvements in the Ghanaian students' ability to ask relevant and feasible questions with data, a sample of students in one section of the course were asked, in both the pre- and post-assessment, to consider a hypothetical dataset then describe a possible research question that could be answered by analyzing this data. Responses were coded according to 1) whether answering the question would be feasible based on the description of the dataset, and 2) the level of complexity of the question, which broke questions down into univariate, bivariate, and multivariate questions. Students were further asked the steps they would use to manage and analyze the data. This second question was coded according to the relevance and level of understanding of data management and analysis demonstrated by the written steps. In an open-ended format, students were also asked, "What, if anything, do you feel you learned in this class? Note in particular, what you believe was most valuable."

### 2.3. ANALYSES

As this study is exploratory, we use descriptive statistics in the form of frequencies and percentages for ordered and binary variables. The mean and standard deviation are presented for count variables.

# 3. RESULTS

## 3.1. STUDENT EXPERIENCES WITH THE PROJECT-BASED CURRICULUM

Based on post-survey responses, self-reported experiences in the project-based course are presented in Table 2. In-class lectures were rated as being somewhat more useful than video lectures and presentations. Nearly two-thirds of student participants reported putting in more effort in the project-based statistics course than in other college courses and working “very” or “extremely hard”. Just over half of the sample, however, reported “usually” or “always” preparing for class by completing assigned readings/videos. The project-based introductory statistics course was rated as more challenging than other college courses by 57.1% of the participants while only 2.4% found the course not challenging at all. Nearly half of the sample found the course “very or “extremely” rewarding and one-third felt they accomplished more than they had expected. Though only 25% of student participants felt the course was more interesting and/or more useful than other college courses, half felt they learned more than in other courses. Nearly one third of the participants reported receiving more individualized support compared to other courses they had taken and 20.5% of the participants felt that the individualized support was more useful than what they had received in other courses.

*Table 2. Student experiences with the project-based curriculum*

| *Usefulness of Resources* | N=131 |
|---|---|
| In class presentations | 2 (1.5%) |
| 1 = not at all useful | 2 (1.5%) |
| 2 = a little useful | 6 (4.6%) |
| 3 = fairly useful | 19 (14.6%) |
| 4 = very useful | 66 (50.8%) |
| 5 = extremely useful | 35 (26.9%) |
| Video lectures and presentations | |
| 1 = not at all useful | 11 (8.5%) |
| 2 = a little useful | 18 (13.9%) |
| 3 = fairly useful | 41 (31.5%) |
| 4 = very useful | 47 (36.2% |
| 5 = extremely useful | 13 (10.0%) |
| *Engagement* | |
| Compared to other courses | |
| 1= put in *less* effort | 6 (4.9%) |
| 2= put in *similar* amount of effort | 43 (35.3%) |
| 3 =put in *more* effort | 73 (59.8%) |
| How hard did you work in this class? | |
| 1 = did not work hard at all | 0 |
| 2 = a little hard | 13 (10.3%) |
| 3 = worked hard | 37 (29.4%) |
| 4 = worked very hard | 52 (41.3%) |
| 5 = worked extremely hard | 24 (19.1%) |
| *Rigor* | |
| How challenging did you find this course? | |
| 1 = not at all | 3 (2.4%) |
| 2 = a little | 23 (18.3%) |
| 3 = somewhat | 53 (42.1%) |
| 4 = very | 39 (31.0%) |
| 5 = extremely | 8 (6.4%) |
| Course was: | |
| 1= *less* challenging than other courses | 2 (1.7%) |
| *2 =similarly* challenging to other courses | 49 (41.2%) |
| 3 =*more* challenging than other courses | 68 (57.1%) |
| *Overall Impressions* | |

| | |
|---|---|
| How rewarding did you find this course? | |
| 1 = not at all | 5 (4.0%) |
| 2 = somewhat | 15 (11.9%) |
| 3 = rewarding | 46 (36.5%) |
| 4 = very rewarding | 52 (41.3%) |
| 5 = extremely rewarding | 8 (6.4%) |
| Accomplished more than expected | 45 (35.7%) |
| *Compared to Other Courses* | |
| Course was *more* interesting | |
| 1 =*less* interesting than other courses | 21 (17.2%) |
| 2 =*similarly* interesting to other courses | 70 (57.4%0 |
| 3 =*more* challenging than other courses | 31 (25.4%) |
| Course was *more* useful | |
| 1 =*less* useful than other courses | 10 (8.3%) |
| 2 =*similarly* useful to other courses | 79 (65.8%) |
| 3 =*more* useful than other courses | 31 (25.8%) |
| Learned in this course | |
| 1 =learned *less* than in other courses | 9 (7.4%) |
| 2 =learned *similar* amount to other courses | 52 (43.4%) |
| 3 =learned *more* than in other courses | 60 (49.2%) |
| Individualized support | |
| 0=received no individualized support | 7 (5.7%) |
| 1= received *less* than in other courses | 25 (20.5%) |
| 2= received a *similar* amount to other courses | 52 (42.6%0 |
| 3= received *more* than in other courses | 38 (31.2%) |
| Usefulness of individualized support | |
| 0=received no individualized support | 6 (4.9%) |
| 1=*less* useful than other courses | 14 (11.5%) |
| 2=*similarly* useful | 77 (63.1%) |
| 3=*more* useful than other courses | 25 (20.5%) |

*Note:* Percentages are based on the number of respondents completing each item.

## 3.2. CHANGE IN CONFIDENCE OF STATISTICAL SKILLS

Based on responses to both the pre- and post-course surveys, ratings of increased confidence in applied statistical skills are presented in Table 3. Students reported increased confidence in approximately 3 ($M$ = 3.2, $SD$ = 2.17) of the listed applied skills that included developing a research question, managing data, choosing correct statistical tests, writing code, graphing, effectively presenting results, and conducting analyses. The skill that showed an increase for the largest portion of students was developing a research question (68.5%) and fully a third of the sample increased their confidence in 5 or more skills. The percentages are based on the number of respondents completing each item.

*Table 3. Increased confidence in applied skills*

| *Increased Confidence (pre to post)* | N = 131 |
|---|---|
| Developing a research question | 76 (68.5%) |
| Choosing the correct statistical test | 64 (56.6%) |
| Managing data | 52 (47.3%) |
| Writing syntax or code to run statistical analysis | 53 (47.3%) |
| Conducting a statistical analysis of data | 52 (46.4%) |
| Graphing | 43 (40.6%) |
| Effectively presenting research results | 38 (38.0%) |
| Number of Skills with Increases | $M$ = 3.2, $SD$ = 2.17 |
| Increased Confidence in 5 or More skills | 39 (33.6%) |

### 3.3. CHANGE IN ATTITUDES AND INTEREST IN FUTURE EXPOSURE TO STATISTCS

Participants' changes in attitudes as well as interest in future courses are presented in Table 4. Roughly one-fifth of the student participants reported an increase in their interest in analyzing and answering questions with data. Approximately 17 and 14 percent of participants reported an increased interest in learning about statistics and pursuing advanced statistics coursework, respectively. Further, nearly three-quarters of the student participants reported interest in one or more follow-up courses, including advanced statistical tools, constructing datasets, graphing and data visualization, scientific writing, and computer programming, with interest in computer programming being endorsed by the largest percentage of students (38.0%), followed by graphing and data visualization (31.0%).

*Table 4. Attitudes and interest in future exposure to statistics*

| *Increased interest in learning and using statistics (pre to post)* | N=131 |
|---|---|
| Answering questions with data | 20 (22.0%) |
| Analyzing data | 19 (20.9%) |
| Learning about statistics | 17 (17.2%) |
| Pursuing advanced statistics coursework | 15 (14.3%) |
| *Interest in future courses (post)* | |
| Computer programming | 49 (38.0%) |
| Graphing and data visualization | 40 (31.0%) |
| Advanced statistical tools | 32 (24.8%) |
| Constructing data sets | 22 (17.1%) |
| Scientific writing | 17 (13.2%) |
| *Interest in any of the course* | 92 (71.3%) |

*Note:* Percentages are based on the number of respondents completing each item.

### 3.4. CHANGES IN CRAFTING RESEARCH QUESTIONS

Students were asked to consider a hypothetical dataset and describe a possible research question that could be answered by analyzing the data. A total of 18 students responded to these questions on both the pre- and post-surveys. On the pre-survey, 11 (61.1%) student participants wrote a feasible research question. Of those, 7 (63.6%) participants wrote univariate questions with the lowest level of complexity, such as "what is the average income?" No student participants wrote bivariate questions, and 4 (36.4%) wrote feasible multivariate questions. On the post-survey, 17 (94.4%) of these participants wrote feasible research questions. Of those questions, no participants wrote univariate questions, 9 (52.9%) participants wrote bivariate questions, for example, "How does income of an adult affect daily internet usage?", and 8 (47.1%) participants wrote multivariate questions, such as "Is there an association between access to the internet and the income earned by an individual, and could it be moderated by gender?"

Of the 18 student participants who responded to the item requesting the steps they would use to manage and analyze the data in both the pre- and post-survey, 11 (61.6%) participants wrote no steps on the pre-survey or irrelevant steps that showed little understanding of data management and analysis, such as "find a specific location to carry out the research." Seven (39.9%) participants wrote relevant steps that showed some understanding of data management or analysis, such as "analyze the data using the appropriate tool" or "sort data based on gender and age". However, on the post-survey, all student participants wrote relevant steps, 15 (83.3%) participants wrote relevant steps that showed some understanding of data management or analysis and 3 (16.7%) participants wrote relevant steps that showed a thorough understanding of data management and analysis, such as "Remove error codes and run frequency distribution tables for each variable" and "Conduct bivariate tests of variables in relation to the main research question."

Student participants were also asked to reflect on what they learned and found to be valuable in the course. Eighty-two students responded to this question. The most common responses dealt with the value of using and understanding the concepts involved in hypothesis testing. Building skills in analyzing data was the second most common type of response, followed by learning the R language, developing research questions/conducting research, and interpreting statistical findings or drawing conclusions. A final theme noted by a smaller number of students was making and interpreting graphical displays of data. One student remarked that, "The experience in researching on my final project in the course using the Add Health [dataset] was awesome." Another student said, "Learning that data could be collected, then summarized, to tell a story was a big turning point for me."

## 4. DISCUSSION

The goal of the present study was to evaluate the portability of a project-based, flipped classroom approach for teaching statistics that utilized the Passion-Driven Statistics curriculum (Dierker et al., 2012) in an introductory statistics course in Ghana, West Africa. The aim was to look for evidence surrounding increased confidence in applied skills and indications of students' positive attitudes toward future learning. An important limitation of the present study results is a lack of a comparison group. Because the university moved the course to the project-based model prior to data collection, survey data based on a more traditional approach is not available. Further, a study design that sought to examine students' application of skills and attitudes in subsequent quantitative and research methods courses was not feasible due to the fact that a concerted effort to increase the level of technology and real-world orientation of those courses was implemented simultaneously.

Notably, half of the students reported they learned more in the project-based course than in other courses they had taken and fewer than 7.4% said they had learned less. At the same time, 57.1% of the students reported that they found the course more challenging than other courses they had taken and 59.8% said they put more effort into the project-based course than they had put into previous courses. This is consistent with research conducted in the United States where students reported they likely learned more in the project-based course than in other college courses they had taken, and at the same time found the course more challenging and requiring more effort than students taking the course in liberal arts or large state universities (Dierker, Flaming et al., 2018). These findings also suggest, at least in part, the project-based model produces feelings of successful learning in the context of productive struggle. Garfield and Ben-Zvi (2007) stress the benefit to students of struggling to solve conceptually difficult problems and associating these problems with other areas of relevant knowledge. The productive resolution of temporary intellectual roadblocks is a common occurrence in our project-based course. We hypothesize that the successful resolution of these moments of intellectual struggle may have helped students to experience a stronger sense of accomplishment about their work in the class despite the difficulty. This premise is also partially supported by the fact that more than a third of the students from West Africa felt that they had accomplished more than they had expected.

An important ingredient for the kind of productive struggle that promotes a sense of accomplishment is individualized support (Pasquale, 2015). Based on the present analyses, nearly a third of the students reported receiving more individualized support than in other courses they had taken and even fewer (20.5%) felt that the individualized support was more useful than what they had received previously. Still, instructor presentations were rated as being more useful than the video presentations, suggesting the continued importance of synchronous communication. Williams (2010) found that the physical and psychological availability of an instructor significantly improves students' feelings about learning. As more students complete the project-based statistics course, there may be interest in the role of peer mentors, and a higher level of individualized support can be offered. This will be an important focus of future research.

Based on responses to both the pre- and post-course surveys, students reported increases in their confidence for an average of 3.2 of the 7 applied skills that were assessed and nearly a third of the sample reported increased confidence in 5 or more skills. The skill that showed an increase for the largest number of students was developing a research question (68.5%). This finding is supported by the sample of students who responded to the item requesting a possible research question based on a hypothetical dataset. Among this group, 94.4% wrote feasible bivariate or multivariate questions on the post-survey. Just over a third of all respondents reported increases in their confidence in effectively presenting research results. Approximately half of the students reported increased confidence in managing data, choosing the correct statistics test, writing code to run statistical analyses, and conducting statistical analyses on data. This is particularly promising in the light of previous work from the United States where students enrolled in the project-based course showed a greater likelihood of increases in confidence in each of these skills compared to students taking a traditional statistics course (Dierker, Flaming et al., 2018). Given that many students report emerging from introductory statistics courses with few useful skills (Gal & Ginsburg, 1994), the increases in confidence in applied skills shown in the present sample is quite promising.

When asked about interest in future courses, a course in programming was endorsed by the largest number of students in the present study. By using formal syntax to write complex programs aimed at managing and analyzing data, the project-based course teaches and reinforces many of the same concepts and skills covered in programming courses (Joint Task Force on Computing Curricula, Association for Computing Machinery & IEEE Computer Society, 2013; Nolan & Temple Lang, 2010). Our approach of using individual research projects to motivate students is one that has also been undertaken in computer science courses (Goldweber et al., 2012; Jenkins, 2001) and has been shown to be particularly motivating to female students (Rader et al., 2011). Furthermore, previous research on the project-based model in the United States comparing choice of enrollment in the project-based course to a traditional introductory programming course revealed that higher rates of females and underrepresented students chose to enroll in the project-based statistics course. (Cooper & Dierker, 2017).

While nearly three-quarters of student participants endorsed interest in at least one follow-up course, only 20.9% of students increased their interest in analyzing data and 24.8% reported wanting to take an advanced statistics course in the future. This can be contrasted with the low 6% of students who reported on the pre-survey that they were very likely to have taken the course if it were not required, suggesting the possibility of improved likelihood of opting into this type of course in the future. More research will be needed to consider the future coursework and career choices of these students and how their experiences in the project-based introductory statistics course might lead to new pathways into technical occupations, both in the United States and in West Africa.

Taken together, these findings demonstrate the portability of the project-based approach for one group of university students outside of the United States and encourage future exploration of the global portability of this approach to teaching statistics. The importance of examining outcomes beyond typical content knowledge exams may be especially relevant for project-based learning given that this curricular approach has shown its most beneficial effects are on measures that consider the application, as opposed to the memorization, of knowledge (Dochy et al., 2003). Previous research also suggests that it is these additional application outcomes and attitudes about future learning that are most important to continued persistence in statistics (Wigfield & Eccles, 2000). No single course will adequately prepare students for either the amount or complexity of data they will encounter as professionals and as citizens (Collins & Halverson, 2010). Modern courses need to focus on imparting a deep interest among students, developing a belief in the importance of the discipline, and a desire to continue learning skills in data analysis and computation. The Ghanaian students in our study appear to have reaped at least some of these benefits from the project-based curriculum.

One additional benefit of the project-based statistics course has been internship opportunities that have arisen from the end-of semester poster presentations, where visitors have had the opportunity to interact with students about their quantitative research and have subsequently made internship opportunities available. Examples include internships at a local NGO focusing on community-based reproductive health, a private research company, and the local implementing agency for *Afrobarometer*. At the end of each one-hour session of the poster presentations, visitors were given a chance to offer general feedback to the students, highlighting the strengths and weaknesses of the posters and students' presentation skills and ability to answer questions about their work. The culminating poster session and interactions with outside visitors is another important opportunity for academic skill-building and confidence building that the course provides.

Instructors might also reap benefits from the project-based curriculum, as previous research has long recognized the general challenge in teaching courses in statistics. This project-based course provokes students to encounter (and struggle with) the central concepts and principles in a supportive and structured environment. Although the presented model focuses on applied statistics and programming, the emphasis on authentic real-world activities with the goal of sparking interest and enthusiasm (BIE, 2012) can be achieved in curricular content as diverse as science (Kubiatko &

Vaculová, 2011) and foreign language (Danan, 2010) instruction. This study illustrates that the course curriculum developed can benefit other universities in the international community by improving outcomes for students in the form of positive course experiences, increased confidence in applied skills, and interest in future experiences that will provide effective preparation for our data-driven economy. To this end, we are happy to make our resources widely available (https://passiondrivenstatistics.com/), and to encourage faculty to consider integrating projects into their courses.

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