The Effect of Using RStudio to the Performance of Students in their Data Management Class Under Flexible Learning

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# CHAPTER I - INTRODUCTION

## Rationale

The book entitled *International Handbook of Research in Statistics Education* edited by Ben-Zvi et al. (2018) offers a wide array of topics concerning statistics. The book has three main parts which are interrelated to each other: Part I: Statistics, Statistics Education, and Statistics Education Research; Part II: Major Contributions of Statistics Education Research; and Part III: Contemporary Issues and Emerging Directions.

An article in the said handbook entitled “What Is Statistics Education?” succinctly discusses the nature and necessity of statistics education at all levels – from secondary to tertiary up to graduate level. The authors defined statistics education this way:

Statistics education is an interdisciplinary field that is focused on the teaching and learning of statistics. Evolving from the field of mathematics education, which supplied valuable theories of learning, models of conceptual development and change, and methods of qualitative research (e.g., teaching experiments, clinical interviews), statistics education has emerged as an independent area of inquiry and scholarship with its own journals, conferences, organizations, websites, and curriculum standards (Zeiffler et al., 2018).

Based from the definition of statistics education, it is said to be an evolving field from the field of mathematics wherein it is “interdisciplinary” that focused on both “the teaching and learning of statistics” and thereby “emerged as an independent area of inquiry and scholarship.”

Perhaps the next inquiry is, why is statistics education necessary in everyday life and specifically in the curricula as well as how will its integration in the curricula help students be abreast with advances and developments brought about by the 4th industrial revolution (Schwab, 2016).

The discussion of the book article “What Is Statistics?” by Wild et al. (2018) directs our attention to the nitty-gritty of statistics, how this field is important in our day to day life given the advent of technological advances that produce rich data. For example, the authors argue that “In today’s data-rich world, all educated people need to understand statistical ideas and conclusions, to enrich both their professional and personal lives.” Thus, in this context of today’s world where data is accessible everywhere from mass media especially social network such as Facebook, it can be said that “the widespread availability of interesting and complex data sets and increasingly easy access to user-friendly visualization and analysis software mean that anyone can play with data to ask and answer interesting questions.” Statistics is vigorously gaining importance and recognition in today’s society.

Other authors also recognize the necessity of statistics:

“Statistics is a central tool in moving science, economics, politics, schools, and universities forward.” Quantitative information is omnipresent in media and in the everyday lives of citizens worldwide. Data are increasingly used to add credibility to advertisements, arguments, or personal and professional advice. Therefore, there is a growing public and policy consensus that being able to provide reliable and persuasive evidence-based arguments and critically evaluate data-based inferences are crucial skills that all citizens of the twenty-first century should have (Ben-Zvi & Makar, 2016).

In addition, “statistical methods are used in almost all knowledge areas and increasingly are used by businesses, governments, health practitioners, other professionals, and individuals to make better decisions” (Wild et al., 2018). This is true wherein based on my observations, most government and private agencies rely on statistical methods through surveys to make policies, laws and even programs that are geared towards communities and nation’s development.

In this case then, academic institutions also integrated statistics in the curricula thinking that “probably no academic subject is more useful to both working professionals and informed citizens on a daily basis than statistics” (Wild et al., 2018). On this note, we can say then the impending necessity of statistics in the educational system. For instance, the book article “International Perspectives on the Teaching and Learning of Statistics” posits:

Being able to provide sound evidence-based arguments and critically evaluate data-based claims are important skills that all citizens should have. It is not surprising therefore that the study of statistics worldwide at all educational levels is gaining more attention. The study of statistics provides students with tools, ideas and dispositions to react intelligently to information in the world around them. Reflecting this need to improve students’ ability to think statistically, statistical literacy and reasoning are becoming part of the mainstream school and university curricula in many countries. As a consequence, statistics education is becoming a thriving field of research and curricular development (Ben-Zvi & Makar, 2016).

However, “the rapid development of data science… provides challenges for statistics educators in determining learning goals, and opportunities for statistics education researchers to explore what instructional methods can best achieve those goals” (Wild et al., 2018). Moreover, the said article also points out present challenges of statistics education especially to students:

What are the areas where statistics may need to adapt to be relevant to data science? In addition to pedagogy and content, technology is a key realm. While the Guidelines for Assessment and Instruction in Statistics Education (GAISE) K-12 (2005) and College (2016) reports encouraged the use of technology (which, on a more positive note, is now widespread in most courses), hundreds of thousands of high school students still use calculators rather than computers for their analyses, limiting their ability to move beyond simple calculations or gain any sense of realistic workflows that they might encounter in the real world. But much worse, it also narrowly constricts their vision of what statistics is and can be and neglects the huge potential of the visual sense for gaining insights from data (Wild et al., 2018).

Given these challenges of statistics education in terms of pedagogy and content, one factor to consider is technology: most students use calculator over computer in statistical analyses. Aside from this, statistics can be seen in both perspectives wherein “despite the increasing awareness of the importance of statistical literacy, statistics has been viewed by many students as difficult and unpleasant to learn” (Ben-Zvi & Makar, 2016). On the other hand, “many university instructors find statistics and research methods courses equally frustrating and unrewarding to teach” (ibid.). Not only that, “in schools, mathematics teachers often view statistics as a marginal strand in the mathematics curriculum and therefore minimize or ignore its teaching” (ibid.). Hence, it is no wonder how one article describes the dilemma of learning and teaching statistics wherein “many countries still lack sufficient resources, updated curriculum materials, effective professional development of teachers, and current technologies, infrastructure essential to carry on the reform movement in statistics education” (MacGillivray et al., 2014).

With this background on learning and teaching statistics, as well as on issues of statistics in researches, it is hope that this preliminary study will somehow fill in the gaps as pointed out in different literature. This is where my study would like to investigate.

Tracing these developments in mathematics education, particularly in the field of statistics education, Cobb (1992) reported that statistics has been changing in technique, practice, and theory due to the computer revolution. With this as basis, the report recommended emphasize statistical thinking, include more data and concepts, and foster active learning to reform the teaching of introductory statistics. From these recommendations, Moore (1997) suggested that content should have more data analysis and less probability, fewer lectures and more active learning for pedagogy, and technology should be used for data analysis and simulation. In the following years, Franklin et al. (2007) put forth the Guidelines for Assessment and Instruction in Statistics Education (GAISE) Report for both the pre-K-12 and college level. In the pre-K-12 GAISE report, statistical literacy is the goal. A statistical problem-solving framework with four components was introduced: 1) formulating a question; 2) collecting data; 3) analyzing data; and 4) interpreting results. On the other hand, the GAISE college report recommended the following for the teaching and assessment of introductory statistics at the tertiary level: 1) emphasize statistical literacy and develop statistical thinking; 2) use real data; 3) stress conceptual understanding rather than mere knowledge of procedures; 4) foster active learning in the classroom; 5) use technology for developing conceptual understanding and analyzing data; and 6) integrate assessments that are aligned with course goals to improve as well as evaluate student learning. The GAISE College Report ASA Revision Committee (2016) re-evaluated the GAISE college report and found that it was still effective and relevant. It was also updated to “reflect modern practice and take advantage of widely available technologies” (ibid.). The framework is now the standard of statistics education in the United States and in many countries who adopted it (Zeiffler et al., 2018).

In New Zealand, David Vere-Jones was instrumental to the introduction of statistical learning outcomes in the curriculum because of his involvement with the International Association for Statistical Education (IASE) (Vere-Jones, 1995). Another major change in New Zealand for teachers and the curriculum was initiated by Pfunnkuch et al. (2013). They discussed and showed that computer-based methods make learning of inferential statistics accessible and transparent. Moreover, the International Statistical Literacy Project (ISLP) under the IASE – both members of the International Statistical Institute (ISI) – with its statistical literacy competitions and other activities, has influenced statistics education not just in New Zealand but all over the world (Forbes et al., 2013). Also, resources relevant to statistical literacy are available at the ISLP website.

One of the most successful contributions to statistics education is the Census at School project of Connor et al. (2000) in the United Kingdom. Since then, New Zealand, Australia, Canada, Ireland, Japan, South Africa, USA and Korea has joined the program. Students complete a survey and the data will become part of an international database that is used by participating schools for teaching and learning to enhance statistical literacy. Teaching resources are also available for participating schools at the project’s website.

These underpinning reports, initiatives, and projects mentioned above gave way to a lot of studies that are shaping statistics education all over the world; making it relevant at current times. Mostly all of these studies are compiled in handbooks and proceedings published through the years by associations such as the Statistical Society of Australia (SSAI), International Commission on Mathematical Instruction (ICMI), ISI, IASE, the entire community of the International Research Forum on Statistical Reasoning, Thinking and Literacy (SRTL), and the entire community of statisticians and statistical educators which the International Conference on Teaching Statistics (ICOTS) and Australian Conferences on Teaching Statistics (OZCOTS) brought together (Batanero et al., 2011; Ben-Zvi et al., 2018; Ben-Zvi & Makar, 2016; Clements et al., 2013; Gentle et al., 2012a; MacGillivray et al., 2014; MacGillivray & Phillips, 2010).

In the Philippines, how did mathematics education cope up in this big data world specifically in the field of statistics education? The study of Bersales (2010) entitled “The Teaching of Statistics in the Philippines: Moving to a Brighter Future” discusses how statistics education begun in the country. Bersales reported that in 2006, there are already 19 colleges and universities that provide statistics degree programs in the tertiary level. Bersales also reported that through the years, statistics continues to become popular in many disciplines in the country because it enhances research and analytical skills. However, to cope up with the current global reform efforts in statistics education, E. D. Reston & Bersales (2008) identified that sustainable collaboration among the government, academic institutions offering statistics programs and teacher education institutions, and professional mathematics and statistics associations is necessary to support training and preparation of future statistics teachers and also to support ongoing professional development of statistics teachers when it comes to content, pedagogy and assessment. Bersales and some authors also reported some problems of teaching statistics in the Philippines:

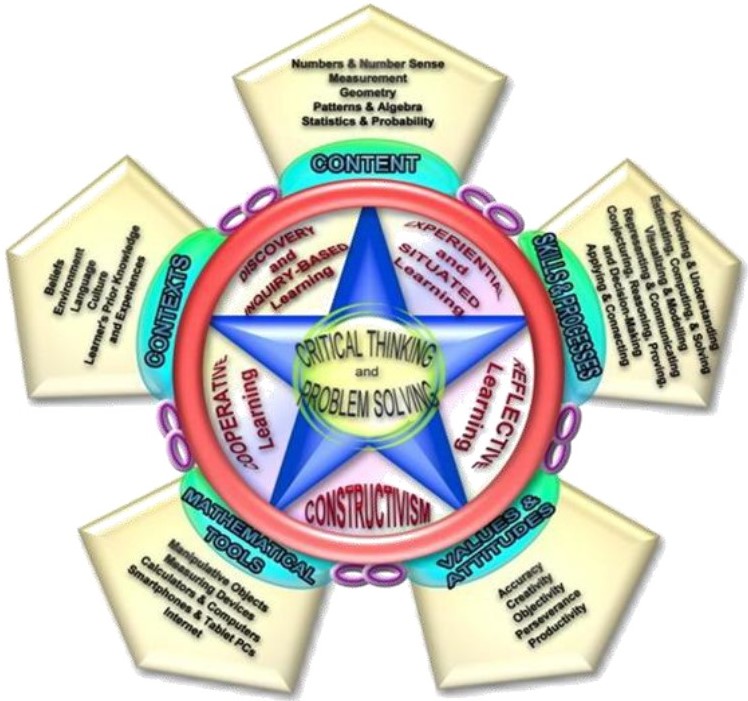
lack of good quality statistics books, lack of qualified teachers in statistics, inadequate facilities such as computer laboratories to aid in teaching statistics, teaching methods that do not enhance students’ learning of statistics. Additional problems were identified during the teacher training of the Philippine Statistical Association: lack of recognition of statistics as an important course in their respective colleges, dearth of local reference materials that have passed the review of a panel of experts, teachers’ need for more hands-on practice on handling data, unavailability of statistical software in their colleges, lack of qualified statistician as member in research/thesis advisory committee. (Bersales, 2010)

Despite these problems, according to Bersales the future is bright since reform efforts are being undertaken and are continuous. These efforts are led by the Philippine Statistical Association, the Philippine Statistical System, the Commission on Higher Education (CHED), and the academic institutions including the private sector (Bersales, 2010).

A very significant educational reform in the Philippines is the implementation of the K to 12 basic education program in 2012 by the Department of Education (DepEd). The country is already behind because it was the last one to implement the program in Asia. Moreover, together with Djibouti and Angola, they were the only countries in the world not implementing the program before it was finally implemented in the country. The government finally took the first step to make the basic education curriculum competent among Asia-Pacific countries.

The implementation of the K to 12 basic education program brought challenges not just to the basic education sector but also to the higher education sector and to other sectors as well. Before the full K to 12 implementation, CHED aligned its curriculum with outcomes-based education to have the same pedagogy as in the K to 12 program (*CHED K to 12 Transition Program*, 2017). The General Education curriculum was also revised by CHED to complement the new subjects taught in senior high school. Moreover, before K to 12 graduates entered college in 2018, CHED technical panels for each particular course/field have already reviewed the college curriculum and fine-tuned the courses for each specialization.

The K to 12 curriculum starts with kindergarten level and then 6 elementary education levels followed by 4 junior high school levels and 2 senior high school levels. The mathematics curriculum from grade 1 to 10 adopted the spiral approach and Statistics and Probability is taught during the last quarter. The conceptual framework of mathematics education for grade 1 to 10 is shown in Figure 1 (Department of Education, 2016). The goals are critical thinking and problem solving. These goals are important in research and decision making. Grade 11 and grade 12 students take core and specialized subjects. Core subjects are for all senior high school students and specialized subjects depend on students’ academic tract. Mathematics core courses in senior high school include General Mathematics and Statistics and Probability. Statistics concepts are random variables, probability distributions, normal distribution, sampling distribution, estimation, hypothesis testing, correlation, and regression analysis. There are also research subjects which require higher statistical concepts like statistical tests involving two or more population means (t-test and analysis of variance), and analysis of categorical data. These changes in the curriculum have led to collaborations among professionals in the field to come up with teaching guides and teaching materials that follow suggestions from the GAISE Project of the American Statistical Association, trainings, workshops, mentoring programs, and online support system for Statistics and Probability teachers to make them competent in teaching the subject (Albert et al., 2016; Ocampo & Ocampo, 2018; E. D. Reston & Loquias, 2018).



**Figure 1.** Conceptual Framework of Mathematics Education

On the other hand, in the higher education curriculum, statistics is already integrated as Data Management – a 10 hour part of Section 2 Mathematics as a tool – in the general education core course Mathematics in the Modern World (Commission on Higher Education, 2016). This is a result of the general education curriculum revision carried out by CHED (Commission on Higher Education, 2013). Learning outcomes for Data Management are: 1) Use a variety of statistical tools to process and manage numerical data; 2) Use the methods of linear regression and correlations to predict the value of a variable given certain conditions; and 3) Advocate the use of statistical data in making important decisions. For some undergraduate programs, this is the only statistics course. According to E. Reston & Jala (2013), this setup is not enough to develop among students statistical literacy – a skill very much needed in a data driven world. They proposed a curriculum for a general education elective course using youth statistics from official statistical agencies and from various national and international surveys as database in the teaching of statistical concepts and methods. In another study, E. Reston & Jala (2014) identified and took on the challenge of retooling statistics teachers in content, pedagogy, and in the use of technology in teaching statistics inline with global reform efforts in teaching introductory statistics courses.

The development of statistics education in the country both in the basic education and higher education sector are not that much compared to developed countries like the United States of America, Australia, New Zealand, or United Kingdom. However, major reforms in the basic and higher education curriculum have opened doors to many opportunities in improving statistics education in the country in all aspects; allowing us to follow and catch-up on global reform efforts in statistics education.

The use of technology has improved statistics education in the recent years. This was emphasized by

The GAISE report became very popular among professionals in statistics education. In the country, the “Teaching Guide for Senior High School Statistics and Probability Core Subject” published by CHED tries to follow suggestions of the report to go beyond lecture methods, and instead exercise conceptual learning, use active learning strategies and focus on real data.

statistical literacy, reasoning and thinking among students in these courses

These changes in both the basic education and higher education provided opportunities for

Focusing on the statistics education of K to 12 curriculum

The emergence of data science as a field has the same story. Friedman (2001) discussed that statistics as a field should be interested in taking part in the data revolution. Gentle et al. (2012b)

What are the areas where statistics may need to adapt to be relevant to data science? In addition to pedagogy and content, technology is a key realm. While the Guidelines for Assessment and Instruction in Statistics Education (GAISE) K-12 (2005) and College (2016) reports encouraged the use of technology (which, on a more positive note, is now widespread in most courses), hundreds of thousands of high school students still use calculators rather than computers for their analyses, limiting their ability to move beyond simple calculations or gain any sense of realistic workflows that they might encounter in the real world. But much worse, it also narrowly constricts their vision of what statistics is and can be and neglects the huge potential of the visual sense for gaining insights from data. (Wild et al., 2018)

accessible and transparent

learning of inferential statistics

computer-based methods

a major paradigm shift for teachers and the curriculum

Technological advances has brought us different avenues or aspects to develop in statistics education, to improve it and make it relevant. These avenues touches pedagogy, content, and technology used.

In the GAISE report, one noteworthy recommendation is “the use of technology to explore concepts and analyze data” (GAISE College Report ASA Revision Committee, 2016, p. 3). Studies have shown that the use of technology can really improve statistics education; equipping learners with relevant data skills and effective powerful tools in this era where data is very much abundant (Çetinkaya-Rundel & Rundel, 2017; Chance et al., 2007; Chance & Rossman, 2006; Doi et al., 2016; Harraway, 2012; Stander & Dalla Valle, 2017). However, when it comes to software used in doing statistical computing and teaching statistics, there is no single statistical computing tool that fits all statistical tasks (A. McNamara, 2018). Nonetheless, introductory statistics students should be taught a common statistical computing software such as SAS, SPSS, or R, enthusing them to continuously learn statistics technology since statistical tools are diverse and eventually evolve through time (Gould et al., 2018). Moreover, Gould (2010), Horton et al. (2015), Horton (2015) and Hardin et al. (2015) pointed out the importance of developing among students – with the use of statistical computing software – data management skills in introductory and second courses in statistics.

In our country, leading universities are addressing this issue and have already integrated the use of technology in their curriculum for statistics education. The University of the Philippines for example uses a number of software in its introductory statistics courses and statistics courses (e.g. R with RStudio, Python, SAS, SPSS, Stata, MS Excel, QGIS, ArcGIS, Gephi, yEd Graph Editor, and more). Most of the software used are open source.

In the province, some universities have acquired SPSS to teach statistics courses. On the other hand, some still use calculators to do and teach statistical computing. Unfortunately, both setup do not lessen the gap between statistics education and statistical practice. In reality, most institutions to which graduates from these universities get employed cannot afford SPSS. The use of SPSS requires a paid license. One can choose MS Excel as an alternative, however its functions are limited (Biehler et al., 2013).

Faced with the pandemic brought about by COVID19, the use of software in teaching statistics has become even more challenging than ever here in the province. This can be attributed to the fact that not all students can afford a laptop or a desktop, poor internet connection to no internet connection, and pedagogical challenges as a consequence of the previous two.

In this context, in an attempt to improve statistics education and the practice of statistics in NVSU, to provide a powerful tool to teach and practice statistics to future statistics teachers in the province, and to provide an alternative way of teaching statistics during the implementation of flexible learning in times of pandemic, the researcher will introduce the use of R with RStudio to the BSEd Mathematics and BS Mathematics students in their Data Management class. Then the researcher will see if there is a significant change in their performance in the class. Finally, the researcher will identify themes and categories that will anchor the study to the bigger context of statistics education and thereby serve as departure points as basis for policies that will lead to curriculum, instruction and assessment development with respect to statistics education in NVSU specially with flexible learning.

## Statement of the Problem/Objectives

To adapt to the changes in technology brought about by the 4th industrial revolution, to be abreast with the global community when it comes to statistics education, and to address the pedagogical challenges brought about by flexible learning in teaching statistics in times of pandemic, RStudio as a statistical computing tool in learning data management will be introduced to BSEd Mathematics and BS Mathematics students of NVSU. The researcher will then answer the following questions after gathering profile variables, employing a two group counterbalanced measures design, and letting the students share their stories and narratives in using R and SPSS through essay:

1. What are the profile variables of the respondents?
2. What are the pre-test scores of the respondents?
3. What are the first and second post-test scores of the respondents?
4. Is there significant difference in the pre-test scores among the respondents in both groups?
5. Is there significant difference in the first post-test scores among the respondents in both groups based on their pre-test scores?
6. Is there significant difference in the second post-test scores among the respondents in both groups based on their pre-test scores?
7. What are the categories and themes on the narratives of the participants in using RStudio?

## Statement of Null Hypotheses

Is there a significant difference in the pre-test scores among the respondents in both groups?

H0: There is no significant difference in the pre-test scores among the respondents in both groups.

Ha: There is significant difference in the pre-test scores among the respondents in both groups.

Is there significant difference in the first post-test scores among the respondents in both groups based on their pre-test scores?

H0: There is no significant difference in the first post-test scores among the respondents in both groups based on their pre-test scores.

Ha: There is significant difference in the first post-test scores among the respondents in both groups based on their pre-test scores.

Is there significant difference in the second post-test scores among the respondents in both groups based on their pre-test scores?

H0: There is no significant difference in the second post-test scores among the respondents in both groups based on their pre-test scores.

Ha: There is significant difference in the second post-test scores among the respondents in both groups based on their pre-test scores.

## Theoretical Framework

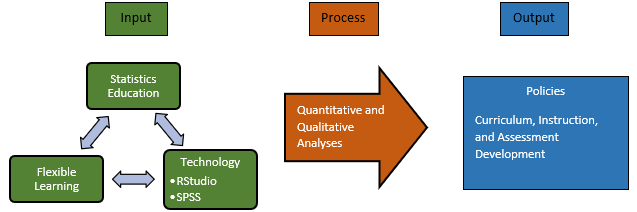
Analysis

## Conceptual and Analytical Framework

Using RStudio in teaching statistics with flexible learning, four concepts were identified.

1. Technology Pedagogy Content Knowledge (TPCK) (Mishra & Koehler, 2006). According to Mishra and Koehler, the introduction of new technology reconstructs the dynamic equilibrium among technology, pedagogy, and content knowledge. Flexible learning has changed the face of using technology in education. In this situation, it is very critical and important that teachers should rethink their technology, pedagogy and content knowledge.
2. Guidelines for Assessment and Instruction in Statistics Education (GAISE) College Report 2016 (GAISE College Report ASA Revision Committee, 2016). The report enumerated six recommendations: 1) Teach statistical thinking. 2) Focus on conceptual understanding. 3) Integrate real data with a context and purpose. 4) Foster active learning. 5) Use technology to explore concepts and analyze data. 6) Use assessments to improve and evaluate student learning. It is with these recommendations that statistics education can be improved. However, it can be really challenging to adopt these recommendations with flexible learning.
3. Reproducibility. The use of RStudio actually promotes reproducibility since it is a tool designed for reproducible research (Gandrud, 2020). The use of RStudio will help teachers create reproducible documents and analysis that can be easily reproduced by students. Reproducibility will play a huge role in overcoming the pedagogical challenges posed by flexible learning in teaching statistics.
4. Bridging the gap between tools for learning and doing statistics (A. A. McNamara, 2015). This has been the challenge in statistics education through the years. And it can be even more challenging now with flexible learning. RStudio can help with this with its capabilities for reproducible research. RStudio is designed for statistics education and also for the practice of statistics.

Statistics education is currently under flexible learning. In this study, technology will be integrated to statistics education. Figure 1 shows the analytical framework of the study. The analytical framework is input process output. The interaction among statistics education, flexible learning, and technology will be the input. Then through quantitative and qualitative methods, policies on curriculum, instruction, and assessment development will be the output.



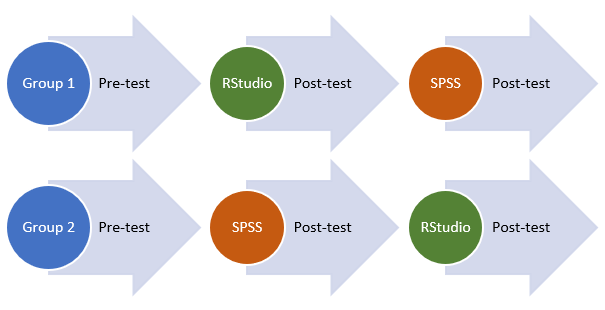
**Figure 1.** Analytical Framework

# CHAPTER II - METHODOLOGY

## Research Design

The researcher will administer true experimental design. It will be a post-test only control group design. Randomization will be performed to come up with the control and the experimental group. This will be based on students’ mathematics entrance examination scores. Score range in the said examination will be divided into upper and lower halves. This will justify comparability of the two groups without conducting a pre-test. The experimental group will be using R with RStudio.

The research design will be a combination of quantitative and qualitative methods. For the quantitative method, a two group counterbalanced measures design will be employed. The two groups are already intact and there will be no randomization. A pre-test will be conducted to both groups. Then group 1 will use RStudio and group 2 will use SPSS for the first topic. A post-test will then follow. Then group 1 will then use SPSS and group 2 will use RStudio for the second topic. Another post test will follow. Figure 2 shows the diagram of the two group counterbalanced measures design to be employed. Both post-tests will be compared to see if there is significant difference in the scores of both groups.



**Figure 2.** Two Group Counterbalanced Measures Design

The qualitative method will focus on the narratives and experiences of the participants to come up with categories and themes that will anchor the study to the bigger context of statistics education and thereby serve as departure points to craft policies that will lead to curriculum, instruction and assessment development with respect to statistics education in NVSU specially with flexible learning.

## Research Environment

The research will be conducted in Nueva Vizcaya State University at Bayombong, Nueva Vizcaya.

## Research Respondents

The respondents of the study are BSEd Mathematics students and BS Mathematics students of NVSU taking Data Management class in their Mathematics in the Modern World subject during the first semester of the the school year 2020-2021.

## Instrumentation

The research instrument will be a survey questionnaire for the profile variables.

## Data Gathering Procedure

Data for test scores will be gathered by conducting a pre-test and two post-tests. Narratives and experiences on using RStudio and SPSS will be gathered through an essay question to be answered by the respondents. The essay question will also come with the survey questionnaire for the profile variables.

## Ethical Considerations

# References

Albert, J. R. G., Albacea, Z., Ayaay, M. J. V., David, I. P., & de Mesa, I. E. (2016). *CHED teaching guide for senior high school Statistics and Probability*. EC-TEC Commercial.

Batanero, C., Burrill, G., & Reading, C. (Eds.). (2011). *Teaching statistics in school mathematics-challenges for teaching and teacher education: A joint ICMI/IASE study: The 18th ICMI Study*. Springer.

Ben-Zvi, D., & Makar, K. (Eds.). (2016). *The teaching and learning of statistics: International perspectives*. Springer.

Ben-Zvi, D., Makar, K., & Garfield, J. (Eds.). (2018). *International handbook of research in statistics education*. Springer.

Bersales, L. G. S. (2010). The teaching of statistics in the Philippines: Moving to a brighter future. In C. Reading (Ed.), *Data and context in statistics education: Towards an evidence-based society: Proceedings of the Eight International Conference on Teaching Statistics (ICOTS8, July, 2010), Ljubljana, Slovenia*. International Statistical Institute; International Association of Statistical Education.

Biehler, R., Ben-Zvi, D., Bakker, A., & Makar, K. (2013). Technology for enhancing statistical reasoning at the school level. In M. A. Clements, A. J. Bishop, C. Keitel, J. Kilpatrick, & F. K. S. Leung (Eds.), *Third international handbook of mathematics education* (pp. 643–690). Springer.

Çetinkaya-Rundel, M., & Rundel, C. (2017). Infrastructure and tools for teaching computing throughout the statistical curriculum. *The American Statistician*. <https://doi.org/10.1080/00031305.2017.1397549>

Chance, B., Ben-Zvi, D., Garfield, J., & Medina, E. (2007). The role of technology in improving student learning of statistics. *Technology Innovations in Statistics Education*, *1*(1). <https://escholarship.org/uc/item/8sd2t4rr>

Chance, B., & Rossman, A. (2006). Using simulation to teach and learn statistics. In A. Rossman & B. Chance (Eds.), *Proceedings of the Seventh International Conference on Teaching Statistics*. International Statistical Institute.

*CHED K to 12 transition program*. (2017). CHED. <https://ched.gov.ph/k-12-project-management-unit/>

Clements, M. A., Bishop, A. J., Keitel, C., Kilpatrick, J., & Leung, F. K. S. (Eds.). (2013). *Third international handbook of mathematics education*. Springer.

Cobb, G. (1992). Teaching statistics. In L. A. Steen (Ed.), *Heeding the call for change: Suggestions for curricular action*. Mathematical Association of America.

Commission on Higher Education. (2016, October). *Mathematics in the modern world syllabus*. <https://ched.gov.ph/wp-content/uploads/2017/10/KWF-Mathematics-in-the-Modern-World.pdf>

Commission on Higher Education. (2013). *General education curriculum: Holistic understandings, intellectual and civic competencies* [CMO No. 20, Series of 2013].

Connor, D., Davies, N., & Holmes, P. (2000). CensusAtSchool 2000. *Teaching Statistics*, *22*(3), 66–70. https://doi.org/<https://doi.org/10.1111/1467-9639.00025>

Department of Education. (2016). *K to 12 curriculum guide*. Author.

Doi, J., Potter, G., Wong, J., Alcaraz, I., & Chi, P. (2016). Web application teaching tools for statistics using R and Shiny. *Technology Innovations in Statistics Education*, *9*(1). <https://escholarship.org/uc/item/00d4q8cp>

Forbes, S., Campos, P., & Helenius, R. (2013). Promoting statistics to youth through the international statistical literacy project. *Proceedings of the 59th World Statistics Congress of the International Statistical Institute, 2013*. <http://www.statistics.gov.hk/wsc/IPS068-P1-S.pdf>

Franklin, C., Kader, G., Mewborn, D. S., Moreno, J., Peck, R., Perry, M., & Scheaffer, R. (2007). *Guidelines for assessment and instruction in statistics education (GAISE) report: A pre-k-12 curriculum framework*. American Statistical Association.

Friedman, J. H. (2001). The role of statistics in the data revolution? *International Statistical Review / Revue Internationale de Statistique*, *69*(1), 5–10. https://doi.org/<https://doi.org/10.2307/1403524>

GAISE College Report ASA Revision Committee. (2016). *Guidelines for assessment and instruction in statistics education college report 2016*. <http://www.amstat.org/education/gaise>

Gandrud, C. (2020). *Reproducible research with R and RStudio* (3rd ed.). Chapman and Hall/CRC. https://doi.org/<https://doi.org/10.1201/9780429031854>

Gentle, J. E., Härdle, W. K., & Mori, Y. (Eds.). (2012a). *Handbook of computational statistics*. Springer.

Gentle, J. E., Härdle, W. K., & Mori, Y. (2012b). How computational statistics became the backbone of modern data science. In J. E. Gentle, W. K. Härdle, & Y. Mori (Eds.), *Handbook of computational statistics* (pp. 3–16). Springer.

Gould, R. (2010). Statistics and the modern student. *International Statistical Review*, *72*(2), 297–315. <https://doi.org/10.1111/j.1751-5823.2010.00117.x>

Gould, R., Wild, C. J., Baglin, J., McNamara, A., Ridgway, J., & McConway, K. (2018). Revolutions in teaching and learning statistics: A collection of reflections. In D. Ben-Zvi, K. Makar, & J. Garfield (Eds.), *International handbook of research in statistics education* (pp. 457–472). Springer.

Hardin, J., Hoerl, R., Horton, N. J., Nolan, D., B. Baumer, with:, Hall-Holt, O., Murrell, P., Peng, R., Roback, P., Lang, D. T., & Ward, M. D. (2015). Data science in statistics curricula: Preparing students to “think with data.” *The American Statistician*. <https://doi.org/10.1080/00031305.2015.1077729>

Harraway, J. A. (2012). Learning statistics using motivational videos, real data and free software. *Technology Innovations in Statistics Education*, *6*(1). <https://escholarship.org/uc/item/1fn7k2x3>

Horton, N. J. (2015). Challenges and opportunities for statistics and statistical education: Looking back, looking forward. *The American Statistician*, *69*(2), 138–145. <https://doi.org/10.1080/00031305.2015.1032435>

Horton, N. J., Baumer, B. S., & Wickham, H. (2015). Taking a chance in the classroom: Setting the stage for data science: Integration of data management skills in introductory and second courses in statistics. *CHANCE*, *28*(2), 40–50. <https://doi.org/10.1080/09332480.2015.1042739>

MacGillivray, H., Martin, M. A., & Phillips, B. (Eds.). (2014). *Topics from australian conferences on teaching statistics: OZCOTS 2008-2012*. Springer.

MacGillivray, H., & Phillips, B. (Eds.). (2010). *Proceedings of the 7th Australian Conference on Teaching Statistics: OZCOTS 2010*.

McNamara, A. (2018). Key attributes of a modern statistical computing tool. *The American Statistician*. <https://doi.org/10.1080/00031305.2018.1482784>

McNamara, A. A. (2015). *Bridging the gap between tools for learning and for doing statistics* [PhD thesis]. University of California.

Mishra, P., & Koehler, M. J. (2006). Technological pedagogical content knowledge: A framework for teacher knowledge. *Teachers College Record*, *108*(6), 1017–1054. https://doi.org/<https://doi.org/10.1111/j.1467-9620.2006.00684.x>

Moore, M. G. (1997). Theory of transactional distance. In D. Keegan (Ed.), *Theoretical principles of distance education* (pp. 22–38). Routledge.

Ocampo, S., & Ocampo, B. (2018). Capacity building of statistics teachers through mentoring and innovative ways. In M. A. Sorto, A. White, & L. Guyot (Eds.), *Looking back, looking forward. Proceedings of the Tenth International Conference on Teaching Statistics (ICOTS10, July, 2018), Kyoto, Japan*. International Statistical Institute; International Association of Statistical Education.

Pfunnkuch, M., Forbes, S., Harraway, J., Budgett, S., & Wild, C. (2013). *“Bootstrapping” students understanding of statistical inference*. Teaching and Learning Research Initiative. [https://www.tlri.org.nz/sites/default/files/projects/
9295\_summary%20report\_0.pdf](https://www.tlri.org.nz/sites/default/files/projects/ 9295_summary%20report_0.pdf)

Reston, E. D., & Bersales, L. G. (2008). Reform efforts in training statistics teachers in the philippines: Challenges and prospects. In C. Batanero, G. Burrill, C. Reading, & A. Rossman (Eds.), *Joint ICMI/IASE study: Teaching statistics in school mathematics: Challenges for teaching and teacher education: Proceedings of the ICMI Study 18 and 2008 IASE Round Table Conference.*

Reston, E. D., & Loquias, C. M. (2018). Improving statistical pedagogy among k to 12 mathematics teachers in the philippines. In M. A. Sorto, A. White, & L. Guyot (Eds.), *Looking back, looking forward. Proceedings of the Tenth International Conference on Teaching Statistics (ICOTS10, July, 2018), Kyoto, Japan.* International Statistical Institute.

Reston, E., & Jala, L. L. (2013). Educational uses of youth statistics for the revised tertiary general education curriculum in the philippines. In S. Forbes & B. Phillips (Eds.), *Proceedings of the Joint IASE/IAOS Satellite Conference, Macao, China*. IASE/IAOS.

Reston, E., & Jala, L. L. (2014). Sustaining teachers’ capacity for teaching statistical inference through reflective practice. In K. Makar, B. de Sousa, & R. Gould (Eds.), *Sustainability in statistics education: Proceedings of the Ninth International Conference on Teaching Statistics (ICOTS9, July, 2014), Flagstaff, Arizona, USA*. International Statistical Institute.

Schwab, K. (2016). *The fourth industrial revolution*. World Economic Forum.

Stander, J., & Dalla Valle, L. (2017). On enthusing students about big data and social media visualization and analysis using R, RStudio, and RMarkdown. *Journal of Statistics Education*, *25*(2), 60–67. <https://doi.org/10.1080/10691898.2017.1322474>

Vere-Jones, D. (1995). The coming of age of statistical education. *International Statistical Review*, *63*(1), 3–23.

Wild, C. J., Utts, J. M., & Horton, N. J. (2018). What is statistics? In D. Ben-Zvi, K. Makar, & J. Garfield (Eds.), *International handbook of research in statistics education* (pp. 5–36). Springer.

Zeiffler, A., Garfield, J., & Fry, E. (2018). What is statistics education? In D. Ben-Zvi, K. Makar, & J. Garfield (Eds.), *International handbook of research in statistics education* (pp. 37–70). Springer.