Experiential Statistics Learning with RStudio: Study on Students’ Engagement

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Abstract. The aim of this paper was to determine students’ statistics engagement level in an experiential statistics learning process with RStudio (an open-source statistical package) in a Malaysian public university. A descriptive quasi-experimental with control group design was employed. This study was conducted on 50 first year students enrolled in various non-mathematics/statistics oriented fields of study. The students were equally assigned to the experimental (used RStudio) and control (did not use RStudio) groups respectively. Descriptive analysis showed that experimental group students had higher students’ engagement than control group students. It also indicated that students’ engagement of experimental group students was high, while that of control group students was moderate. Independent samples \textit{t}-tests revealed there were significant differences in all components of students’ engagement (behaviour engagement, emotion engagement, cognitive engagement and social engagement) and overall students’ engagement between students in both groups. Moreover, the mean differences between both groups were also statistically significant and favourable to experimental group. These findings implied that integration of RStudio exerted positive effects on students’ engagement in statistics classroom. Essentially, integration of RStudio in introductory statistics course has proven to be beneficial and significant to substantially improve students’ engagement to learn and to perform better in statistics course.

1. Introduction

1.1. Background

During the past few decades, statistics educators have been involved with rectifying undergraduate education, particularly the introductory statistics course in statistics education. Courses in statistics are crucial to multiple disciplines like business studies, health sciences, sport sciences, human resources and development, agriculture, educations and etc. Analytical skills and fundamental statistics literacy are two important components that might be useful for student career path. The analytical skills gained from this course may improve students’ ability to read, interpret, synthesize and use reported results. Nowadays, statistics is fundamental to the well-being of all nations where its statistical literacy underpin every sector of modern enterprise. Statistics enables science as the base of any research, development and innovation in every aspects of civilization. For example Nicholson et al. \cite{1} stated that the statistics curriculum in the United Kingdom’s education system have gone through tremendous changes in the recent years, regardless of the level of education. Carvalho and Solomon \cite{2} also reported that in Portugal, their curriculum has recently changed by...
including the development of statistical literacy in cross-disciplinary competencies. Meanwhile, in Vietnam, non-mathematics major students were required to learn probability and statistics using simulation by integrating statistical software packages as a part of their syllabus [3]. Other researchers also declared that courses in statistics trigger anxiety arousal specifically for students in non-mathematics/statistics-oriented disciplines [4].

Frequently found in previous literatures, various approaches have been used to enhance learning experiences in introductory courses [5, 6]. Hall and Rowell [7] defined introductory statistics as basic terminology and the lay groundwork of statistics taught in introductory applied statistics courses especially for other multidisciplinary background. Guidelines for Assessment and Instruction in Statistics Education (GAISE) College Report (2005) has rigorously discussed and finalised the six principle guides for teaching introductory statistics course which are accentuate statistical literacy and cultivate statistical thinking, real data usage, conceptual understandings as weightage rather than mastering the statistical procedures, avoid ‘spoon-feed’ environment in the classroom, integrate technology for better conceptual understanding and analysing data, and evaluating students learning using suitable assessments [8]. National Science Foundation (NSF) aided GAISE’s idea by providing financial support to their projects, based on the above mentioned recommendations for solving many issues in introductory statistics education.

1.2. Role of Technology in Statistics Learning

In this study, technology implementation in introductory statistics learning was chosen as one of GAISE recommendations stated earlier. The use of technology generally has been an alarming issues in transforming statistical research for many years corresponded to the emerging and advancement of technology. Yet, it has also been a major component in the revised statistics education curriculum [9, 10]. Technology resources have become extensively accessible and 76% of students were supported by statistics software package in the statistics classroom [11]. McNamara [12] discussed the use of different statistical tools that should be used as a companion tools in statistical instruction, while the evolution of statistical software for inclusion into statistical learning need to be controlled and evaluated. In Doehler and Taylor [13] and Van Gundy et al. [14], the implementation of web-based instruction into statistics courses benefitted and affected students’ outcome. A study by Baglin and Da Costa [15] found that students with strong fundamental statistics knowledge were able to develop better skills in using statistical software package. Students can adapt and know how to use the tools at their own pace and do not need to familiarise with the programming language [16]. At the same time, Kiet and Lagrange [3], Hall and Rowell [7], and Friel [17] agreed the opportunity given to utilise the technology (access to hardware or software) enhances the quality of statistics learning by exploring the statistical concepts and ideas.

In parallel to these evolution of technologies, many statistical software packages were developed for supporting statistical practitioners across multidiscipline. Modern software packages contain statistical features that may enhance the students’ outcomes in introductory statistics courses in which students need to fully understand the statistical concepts and techniques before they can successfully use them. By combining the new statistical experience in statistical conventional approaches this study employed RStudio to support the statistics lessons for selected topics in an introductory statistics courses syllabus. RStudio is one of the integrated development environment (IDE) for R. R is a well-known environment for statistical computation and graphics that are widely used in statistical and data analysis tasks [18]. This expert-friendly system is available freely for practitioners from various field as an optimal choice to support experimentation in mathematical statistics for undergraduate students. The needs for statistical software usage while teaching introductory statistics courses has been discussed by Horton et al. [19] in detail. Verzani [16] also indicated that the popularity of using R as a tool in introductory statistics courses is increasing year by year. They used R as a toolbox to
scrutinize their analytical skills specifically in statistics. The necessity in R obligate students to input commands rather than to click on drop down menus like other statistical software. However, RStudio provides students with an easy to use editor for their commands [20]. The advantage of using RStudio was stated clearly in Stander and Dalla Valle [21]. Therefore, the preconception about statistics is assumed to have a big impact on numerous students from any background hence will help them in their jobs later.

Recurrently seen arguments or debates when it comes to using any statistical tools in statistical learning as a barrier for conceptual understanding in statistics class. Incongruently, few advantages stated in previous scholars are students able to solve complex problems and calculations in a blink of eyes accurately and efficiently [22]; students able to produce many graphs smoothly and precisely [23]; students can visualise and demonstrate the statistical concepts and processes easily [24]; students can enhance their ability to study and observe random processes and statistical concepts in simulation techniques [3, 25]; and encourage students to relate the real-world problems into statistics classroom in intriguing manner [26]. Olive and Makar [27] indicated that when investigating the use of technology in the view of improving the learning in statistics, technology implementations in statistics need to be very powerful and interactive, concentrating on theory rather than computations, and giving chance to observe and utilise raw data to activate students’ engagement. To get engaged in statistics, students need to understand the nature of this subject theoretically and practically. Statistics is considered as a practical subject. The content of the syllabus or module should be designed accordingly to ensure that the concept and methods introduced will achieve the objectives of the course, develop a better understanding and engage the students. Carvalho and Solomon [2] explored students’ statistics engagement by giving a statistical problem to elementary school students. Lehrer et al. [28] came up with an idea of measuring and modelling variability by using TinkerPlots 2.0 to investigate students’ engagement and as reinforcement in statistics classroom.

1.3. Student’s Engagement in Statistics Learning
Research on engagement has grown tremendously through past two decades debating through several theoretical traditions. The growth of engagement concept increased dramatically as a way to evaluate students’ understanding and enhance students’ outcomes, whose performance is at the borderline or poor [29]. Greene [30] and Sinatra et al. [31] found that consequence to the diversity of theoretical traditions lead the scholars to select measures from prior research without arguing the theoretical framework and constructed definition of engagement. Incongruity also exist in the definitions and measurements of engagement constructs [32, 33, 34]. Regardless of this discrepancy, mutual understandings persist in many academic literature in students’ engagement construct [33, 35, 36, 37]. Hu et al. [38] defined engagement generally as student’s psychological investment in moving forward through the process of learning, understanding, or mastering knowledge, skills, or crafts that academic work is expected to improve. Additional to that, few researchers indicated engagement is something more than motivation, where students not only need to commit while completing certain tasks but to perform well for better grades and social approval [38].

Students’ engagement is a multidimensional construct. The existence of variation in the number of engagement components in recent years (three or more components) were discussed in many academic literatures [34, 39, 40, 41]. However, the most common and ordinary conceptualisation of students’ engagement consist of three components, namely behavioural, emotional and cognitive engagement [42, 43, 44]. Even though many different terminology occurs, four components appear regularly as social engagement component has been included in the new framework [29, 45, 46, 47]. Behavioral engagement is a continuity of developing participation [35]. Similarly, Fredricks et al. [34] has defined in term of involvement in classroom...
activities, occupancy of positive conduct, and absence of disturbing behaviour. Emotional engagement focuses on the presence of positive or negative emotional reactions to instructors, peers, and class-based activities or learning environment; individuals’ sense of belonging and interest towards specific task or subject domains [38, 44]. Fredricks and McColskey [48] measured emotional engagement as students’ interest, happiness and perceived value of learning. Cognitive engagement is defined as an expenditure of thoughtful energy to think outside of the box and the desire for challenge [35]. Finn and Zimmer [29] indicated that the behaviour of cognitive engagement consists of concepts inquiry (two-ways interaction between instructor and students), persisting with complex tasks, exploring and reading more than the assigned materials, doing revision regularly and using self-regulation or other cognitive strategies to enhance learning. Social engagement focuses on the quality of social interactions with peers and adults, as well as giving a commitment in forming and sustaining the relationship while learning [29]. Additionally, Linnenbrink-Garcia et al. [45] defined social engagement as interrelation among students during participation in the classroom activities while Rimm-Kaufman et al. [37] added social engagement scale with item that set forth mathematical ideas and other academic context. Academicians’ added social engagement component due to the important impact of social relations and synergy in learning process.

Recently, students’ engagements issues have been discussed specifically in mathematics and science education among secondary school students using a multidimensional indicator that has been a good reference for mathematics and science scholars [35]. In conjunction with that, student engagement issues had been discussed for better understanding in mathematics engagement among primary school students in Australia [36]; engaging science, technology, engineering and mathematics (STEM) courses among students and instructors [46]; and difference among urban and rural schools’ students’ engagement in mathematics [49]. Studies mentioned above gave a variety of research findings showing that which engagement component that will give highest impact in student engagement, particularly in mathematics or statistics context. Nevertheless, there was insufficient resource and literature specifically in the conceptualisation and instrumentation of engagement in mathematics and science (see Kong et al. [35], for one exception). Scholars lack reliable and valid instruments to accurately and precisely assess students’ engagement in mathematics or statistics. It is crucial to build domain-specific measures because the approach in instruction vary between specific tasks or subjects. When developing and conceptualising the instrument in any particular subject, the type of tasks and emphasizing on cognitively challenging tasks in the subject can be build and relates with how students engage in every components tested.

In this study, four components of engagement were included namely behavioral, emotional, cognitive and social engagement adapting the instrument developed by Fredricks et al. [46]. Considering that the interest in understanding the effects on student engagement after implementing RStudio as a supporting tool in introductory statistics courses. The objective of this study is to determine students’ statistics engagement level in an experiential statistics learning process with RStudio in a Malaysian public university. Henceforth, students who were exposed to and integrated RStudio during statistics tutorial classroom will be referred to as experimental group students; while students who were not exposed to RStudio during statistics tutorial class will be referred to as control group students. This paper is divided into four sections. Methodology of this study is elaborated in the following section followed by the findings & discussions and finally conclusions.

2. Methodology

This study employed quasi-experimental with control group design using pre-test, post-test and post-delay-test framework. The respondents were 50 undergraduate students from Faculty of Forestry who enrolled in an introductory statistics course offered by the Department of
Mathematics in a public university in Malaysia. They were randomly selected from the whole course during Semester 1 in 2016/2017. In addition, other students from various faculty are also required to take this course which is mandatory as graduation requirement and taken during the first semester. Respondents were assigned into two groups equivalently. Integration of RStudio during tutorial class is intended to be a supporting tool for the experimental group. However, both groups need to follow the conventional practice (attending the introductory statistics course lecture) to get the fundamental and concepts of statistics.

The RStudio module was build focusing on five topics from the original syllabus namely Describe Data with Graph, Numerical Measure, Probability, Random Variable and Discrete Distribution. Three performance tests that are pre-test, post-test and delayed-post test were conducted to measure students’ statistics performance during the experiment. Pre-test was distributed to both groups before the first lecture of this course started. However, before the first tutorial class started using this module, the experimental group was exposed to the basic usage of RStudio itself. The support class offered notably to familiarise the respondents with the precise nature of coding using this statistical software package. Moreover, majority of the respondents in experimental group do not have computing backgrounds especially with command-line software and computational thinking. After two sessions of intensive support, experimental group had employed the support offered and was taught using RStudio module for the next six weeks. Following that, both groups were required to sit for the post-test and post-delay test two weeks later.

In accordance to that, a set of questionnaire was designed and adapted from multidimensional construct on engagement outlined in Fredricks et al. [46] that measured students’ engagement based on four prevalent components namely behavioral, emotional, cognitive and social engagement. This design aided to determine the level of students’ engagement in a domain specific that is statistics. To guarantee that the list of items adapted corresponded to the construct of statistics student engagement within Malaysian context, certain adjustment to the items have been made including: (1) revising the wording of some items specifically to statistics; (2) adding the statistics term to create the specific learning environment; and (3) deleting or dropping terms about mathematics and science (too general). This new adapted items were validated by the experts to judge the clarity in statistics domain. Level of students’ engagement in statistics was examined through 37 items comprising four components specifically in the behavioural (11 items), emotional (11 items), cognitive (8 items) and social engagement (7 items). There were 21 positive items and 16 negative items (reverse coded) during data analysis in this questionnaire.

Respondents were required to categorise their degree of agreeableness towards statistics engagement questionnaire items using a five-point Likert scale classified by (1): Strongly Disagree, (2): Disagree, (3): Unsure, (4): Agree and (5): Strongly Agree. Cronbach alpha was computed (given in Table 1) during pilot test to determine the reliability of the questionnaire items. From Table 1, internal consistency of the items was reliable and valid according to Hair et al. [50]. Students’ statistics engagement were categorised by three levels; low, moderate and high. Mean scores (M) value were used to analyse and calibrate students’ feedback whereby the maximum mean values will be divided into three levels (5 by 3). Students’ engagement is high in statistics if $3.68 \leq M \leq 5.00$, moderate if $2.34 \leq M \leq 3.67$ and low if $1.00 \leq M \leq 2.33$. The hypotheses tested in this study were as following:

\[ H_{01}: \text{There exists no significant difference in behavioral engagement between experimental group students and control group students;} \]
\[ H_{02}: \text{There exists no significant difference in emotional engagement between experimental group students and control group students;} \]
\[ H_{03}: \text{There exists no significant difference in cognitive engagement between experimental} \]
group students and control group students;

$H_{04}$: There exists no significant difference in social engagement between experimental group students and control group students;

$H_{05}$: There exists no significant difference in overall students’ statistic engagement between experimental group students and control group students.

### Table 1. Reliability Indices.

|                              | Cronbach’s alpha |
|------------------------------|------------------|
| Behavioural engagement       | 0.860            |
| Emotional engagement         | 0.889            |
| Cognitive engagement         | 0.851            |
| Social engagement            | 0.822            |
| Overall students’ statistics engagement | 0.955            |

#### 3. Findings and Discussions

The overall mean score for students’ statistics engagement of experimental group students was 4.39 (SD = 0.16) showing that students’ engagement level in statistics was high; while the overall mean score of control group was 3.57 (SD = 0.38) showing that students’ engagement in statistics was moderate. Among all four components of students’ statistics engagement, students in experimental group scored highest for emotional engagement ($M = 4.49$, $SD = 0.18$) followed by social engagement ($M = 4.47$, $SD = 0.34$), cognitive engagement ($M = 4.41$, $SD = 0.25$), and behavioral engagement ($M = 4.25$, $SD = 0.19$). Contrarily, students in control group scored highest for social engagement ($M = 3.83$, $SD = 0.43$) followed by behavioral engagement ($M = 3.66$, $SD = 0.43$), emotion engagement ($M = 3.51$, $SD = 0.57$), and cognitive engagement ($M = 3.32$, $SD = 0.46$). The mean scores and corresponding standard deviation (SD) values are displayed in Table 2.

### Table 2. Descriptive Statistics.

|                                | Control Group M(SD) | Experimental Group M(SD) |
|--------------------------------|----------------------|--------------------------|
| Behavioral engagement          | 3.66 (0.43)          | 4.25 (0.19)              |
| Emotional engagement           | 3.51 (0.57)          | 4.49 (0.18)              |
| Cognitive engagement           | 3.32 (0.46)          | 4.41 (0.25)              |
| Social engagement              | 3.83 (0.43)          | 4.47 (0.34)              |
| Overall students’ statistics engagement | 3.57 (0.38)          | 4.39 (0.16)              |

The independent samples $t$-test is an inferential statistics test that compares whether there is a statistically significant difference between experimental group and control group as displayed in Table 3. $H_{01}$ was rejected because independent $t$-test for behavioral engagement ($t = -6.32, p < 0.05$) showed that there was a statistically significant difference in the first student engagement component between both groups. As for emotional engagement, independent $t$-test ($t = -8.21, p < 0.05$) revealed that $H_{02}$ was rejected as there was a statistically significant difference in the second student engagement component between both groups. Followed by cognitive engagement with $t$-test value of $t = -10.34 (p < 0.05)$ revealed that $H_{03}$ was rejected as there was a statistically significant difference in the third student
engagement component between both groups. While for social component, independent t-test ($t = -5.94, p < 0.05$) indicated that $H_{04}$ was rejected as there was a statistically significant difference in the fourth student engagement component between both groups. Finally, $H_{05}$ was also rejected as independent t-test ($t = -9.89, p < 0.05$) indicated that there was a statistically significant difference in overall students’ statistics engagement between both groups.

**Table 3.** Independent t-tests Comparing Students’ in Control and Experimental Groups.

|                          | $t(\text{df} = 48)$ | Sig. (2-tailed) |
|--------------------------|---------------------|-----------------|
| Behavioral engagement    | -6.32               | 0.00            |
| Emotional engagement     | -8.21               | 0.00            |
| Cognitive engagement     | -10.34              | 0.00            |
| Social engagement        | -5.94               | 0.00            |
| Overall students’ statistics engagement | -9.89 | 0.00 |

The mean differences between experimental group students and control group students by using Tukey’s post hoc test (pairwise comparison) are displayed in Table 4. The mean differences for all four student engagement components and overall students’ statistics engagement were statistically significant at 5% level ($p < 0.05$). From the table, it is shown that mean differences ($\text{experimental group scores} - \text{control group scores}$) were positive. This indicated that students’ statistics engagement in experimental group students was higher than control group students. The highest difference was obtained for cognitive engagement while the smallest difference was for behavioral engagement.

**Table 4.** Pairwise Comparison.

|                          | Mean Difference | Std. Error | Sig.  |
|--------------------------|-----------------|------------|-------|
| Behavioral engagement    | 0.59            | 0.09       | 0.00  |
| Emotional engagement     | 0.98            | 0.12       | 0.00  |
| Cognitive engagement     | 1.09            | 0.11       | 0.00  |
| Social engagement        | 0.65            | 0.11       | 0.00  |
| Overall students’ statistics engagement | 0.82 | 0.08 | 0.00 |

4. Conclusion
This study aimed to investigate the effects of implementing RStudio in introductory statistics courses as an approach to boost students’ statistics engagement level among undergraduate students in a Malaysian public university. The level of students’ engagement was determined in a domain-specific (statistics) because variety of development and innovation in instructions, the type of tasks, and cognitively challenging activities in statistics learning can evaluate and interact with how students engage behaviourally, emotionally, cognitively and socially in a specific manner [31], [51]. The inclusion of social engagement component was considered important as to see the social dimensions as a pivotal facet of the contemporary instructional prominence in statistics. The conceptualisations of this component ought to go beyond accentuating individual aspects but also to acknowledge social dimensions [46].
Findings revealed that students' statistics engagement in experimental group students who were exposed to RStudio as a supporting tool during statistics learning was high. As for the control group students' statistics engagement was only at moderate level. The analysis was taken specifically in detail for all four student engagement components, i.e.; behavioural, emotional, cognitive and social engagement. It indicated that the mean scores obtained in experimental group students were higher compared to the control group students. Emotional engagement among students who took this course was found to be the most engaging components among the other components (for experimental group students). Students were identified to be emotionally engaged after being exposed to this module where they felt more encouraged during the tutorial class. Students were found to be enjoying the tutorial class and they started to care about the importance of learning statistics. Secondly, results also revealed that social engagement did play a major role in engaging students when the new implementation was added. Some of the students may engage themselves in group discussion with peers during tutorial class. Most of them agreed that when involving themselves in the activities conducted, it may enhance their skills in learning statistics using RStudio. Apparently, cognitive engagement, emotional engagement and social engagement may be reflected in students’ behavior. In this study, it was found that engaged students were conscientious, vigilant and willing to give commitment in statistics classroom. They work enthusiastically on applying statistical concept while using RStudio in order to get good results. They also persistently and continuously tried to understand basic statistics concepts although they considered statistics as a complex subject. Nevertheless, using technology helped to enhance student engagement together laterally increased their performance.

Furthermore, from the independent samples t-test results, there were statistically significant differences in all four student engagement components in statistics and overall students’ statistics engagement between both groups. Corresponding to that, the mean differences between both groups were statistically significant and favoured experimental group students. Thus, it is shown that experimental group students had higher students’ statistics engagement, notably greater emotional engagement, improved social engagement, better cognitive engagement and prominent cognitive engagement in relative to control group. Between all of the components, cognitive engagement highly influenced the experimental group students in learning introductory statistics course using RStudio. As statistical software packages resources are used to support statistics learning, it will give students a different set of statistical experiences [52]. It is also considered as an important facet on modern way of constructional approach by combining the statistical computing tool in learning statisticis [53]. Nicholson et al. [1] purported that while inspecting students’ statistical experience, combining conventional approach together with supporting tools like RStudio will fulfill educational academic preciseness, industrial demands and the criteria of professional partnerships. In conclusion, it is believed that a deeply engaged student will excel in any instructional approaches used and able to cope with current innovation in statistics learning.

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