International Journal of Engineering & Technology, 7 (4.33) (2018) 45-48

SPC

International Journal of Engineering & Technology

Website: www.sciencepubco.com/index.php/IJET

Research paper



Hypothesis Testing on Regression: Investigating Students' Skill

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Abstract

This study aims to investigate students' ability to write a correct hypothesis based on the statement referring to regression coefficients. Different statements of regression coefficients, specifically the slope were given in the standard format of test questions and the students were asked to conduct an appropriate hypothesis test. From the decision made, the students also had to provide suitable conclusions on each of the tests conducted. 197 answer scripts were inspected and the focus was given to the hypothesis statement and the conclusion provided by the students. The results indicated that students were able to write proper hypothesis statement for a regression coefficient that directly refers to the slope of the variable. However, they failed to provide correct hypothesis when they had to translate the definition of slope to an appropriate hypothesis statement. Despite their ability to write simple hypothesis for regression slope, they still had difficulties in providing conclusions for the tests conducted. The study also clearly revealed that even though some of the students managed to write proper conclusions, they did not correspond to the hypothesis statements given earlier, as the conclusions made were merely based on the question statement.

Keywords: *Coefficient; conclusion; hypothesis; parameter; regression; slope.*

1. Introduction

Regression analysis is a statistical technique for investigating and modeling the relationship between variables [1]. A regression model identifies the type of mathematical relationship that exists between a dependent variable and independent variable(s), thus the changes in the dependent variable can be predicted based on the changes in the independent variable. In the context of Universiti Teknologi MARA (UiTM), Fundamentals of Regression Analysis (STA250) is one of the compulsory courses enrolled by students of Diploma in Statistics and Diploma in Actuarial Sciences programs. This course has three components of teaching methods that consist of lectures, computer labs and tutorials, conducted in five hours weekly throughout a 14-week semester. This course covers several topics including correlation, simple linear regression, model adequacy checking, multiple linear regression, polynomial regression, indicator variables, variable selection and model building. The application of statistical software is directly integrated into this course where students are exposed to the use of Statistical Package for Social Sciences (SPSS) and Minitab to explore data, run the regression analysis and interpret the output obtained.

Solving regression problems requires the ability to understand the terms and definitions, and being able to represent the definitions or statements with the correct symbols or notations. In most of the discussions, students need to test several hypotheses related to regression analysis that use a variety of word problems. Here, they must know whether the statement given refers to the slope, coefficient of correlation, model or *y*-intercept. They also need to be able to hypothesize the parameter correctly: whether they should run a two-tailed test, a left-tailed test or a right-tailed test, so that they perform the correct analysis in the context of the problem. Identifying the correct hypothesis is important since the conclusion made about the population should be based on this hypothesis. Therefore, students require a deep understanding about the regression concept so that they are able to conduct a relevant hypothesis test. This study investigated students' ability to conduct relevant hypothesis testing involving regression problems; and the focus was on the slope of the regression. To be specific, the objectives were set as follows:

- To investigate students' ability to write a correct hypothesis statement in the context of the given problem.
- To investigate the ability of students to make correct and meaningful conclusions.
- To compare the difference in assessment scores between students who are able to write the correct hypothesis statement to those who are unable to do so.

2. Literature Review

Researchers and educators have found that students and professionals often misunderstand some statistical ideas. As mentioned by [2], statistics is a difficult subject for non-specialists because statistics involve concepts (e.g. randomness, distributions of sample statistics, the probabilistic nature of statistical conclusions, etc.) that are abstract and complex in nature. Statistics also requires analytical skills involving problem formulation, variable identification, and model building that are essentially difficult to teach. Many researchers have reported that students face difficulties in understanding statistical concepts [3-5]. In another finding by [6], students have particular difficulty with the skills in choosing appropriate statistical displays and drawing conclusions from statis-

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tical analyses. According to [4] also support this as they indicated that developing a deep understanding of statistical concepts is a challenging task, which is time consuming and requires a well thought out learning trajectory, appropriate technological tools, activities, and discussion of questions.

Students' most common misconceptions about statistical inference have been documented extensively as recorded in [7-8]. As stated by [9], even statisticians are not immune to misconceptions about hypothesis tests. The three most difficult aspects of testing a statistical hypothesis that were recorded by [8] are understanding the concept of a hypothesis test, interpreting a *p*-value and interpreting the significance level, α. Several researchers have conducted studies to confirm misconceptions related to hypothesis testing. In [7] found only 62% of 144 participants selected the correct answer for the definition of hypothesis tests without misconception. The two major misconceptions for the concept of hypothesis test were: a hypothesis test is a mathematical (logical) proof of the null hypothesis (20%), and a hypothesis test is a probabilistic proof by contradiction (19%). Meanwhile, in [10] have developed a test called CAOS Test to assess students' conceptual understanding of important statistical ideas after a first course in statistics. Results from this test show a small percentage of students made gains in identifying a correct interpretation of a significance test when the null hypothesis is rejected, although almost half did not demonstrate this understanding on the post-test. However, although a little over half of the students recognized a correct interpretation of a *p*-value, the majority of these students also responded that an incorrect interpretation was valid, indicating that many students hold both types of interpretation without recognizing the contradiction.

Statistics educators are always searching for new or alternative teaching methods to improve understanding in statistical concepts. As suggested by [11], the application of learning statistics using Computer Simulation Method benefits students by empowering them to develop their own understanding of statistical concepts such as central limit theorem, confidence intervals, binomial distribution, regression analysis, hypothesis testing, sampling distributions and survey sampling. Students will have the opportunity to learn by constructing their own ideas and knowledge from the computer simulation experiences, with supportive direction from the instructor. On the other hand, in [12] studied the impact of a web-based interactive tutorial on student learning and found that web-based tutorials can be an effective supplement for enhancing students' learning in an introductory statistics class. Aligned with this, in [13] stated that good software reduces the students' cognitive load; replacing complex algorithmic procedure by simpler commands allowing learners to focus on a higher-level understanding. Students can use software as a tool for learning statistics where they can explore, visualize and interact with data and simulations and not simply use the software to automate calculations. Besides that, in [14] developed a cognitive tutor for data analysis called SmartLab to help students to choose appropriate analyses and draw conclusions within the context of the problem. Results from experiments showed that this tool led to significant improvements in students' approach to exploratory data analysis.

3. Methodology

This study involved a total of 197 fourth semester students from the Diploma in Statistics and Diploma in Actuarial Sciences programs of UiTM Perak Branch, Tapah Campus who enrolled in STA250 course during the December 2016 – April 2017 session. During a 14-week period of the teaching and learning process, the students were exposed to eight chapters, commencing with introduction to correlation and regression, followed by correlation analysis, simple linear regression, model adequacy checking, multiple linear regression, polynomial regression, indicator variables and model building. All chapters were discussed during three-hour lectures, one-hour tutorial and one-hour computer lab sessions, weekly. In each topic, except for the introduction, students were expected to perform hypothesis tests on a variety of parameters. Students' initial understanding was assessed in the fifth week through a set of quiz questions. This quiz assessed students on the computation of statistics values and hypothesis testing based on the second and third chapter. The result of the quiz was returned and students' answers were discussed the following week. At this level, the instructor highlighted the common mistakes made by students in identifying the correct hypothesis and making the proper conclusions. Students were also given the summary of a variety of alternative hypotheses together with the suitable conclusions, especially on the topic of slopes.

Then, the first test comprising of three questions was conducted in the seventh week. This test was again designed from topics taught to students in chapter 2 and 3. The result from the first test showed that students had difficulties in understanding and interpreting the slope [15]. The performance of students in the first test was used as a guideline to provide deeper understanding on the concept of slopes, hypothesis testing and regression analysis, in the following chapters. Throughout the remaining weeks, students were also encouraged to write the statement together with the symbol used for the hypotheses statement, in order to help them write the correct conclusion at the end of their answer.

After a series of exercises and discussions on a variety of hypothesis questions, students were assessed again in the thirteenth week on the second test. This test consisted of three questions covering chapters 4, 5 and 6. Figure 1 represents one of the questions asked on the test (focus is only given to the part on hypothesis testing). Students' answers for both of the items were examined and analysed to see how they transferred the statement in the question to a correct hypothesis. Their ability to write the conclusion at the end of each hypothesis testing procedure was also observed. These results were then analysed using SPSS to produce the descriptive statistics, the independent sample *t*-test and a chi-square test.

A psychologist is interested in investigating the effect of demographic factors and the amount of time spent sleeping per day on the depression level (measured using the Beck Depression Inventory – BDI) of a person. The independent variables used were age (in years), gender (1 = female, 0 = male) and time spent sleeping (hours/day). Data was collected from a sample of 25 respondents and the following regression output was obtained.

ANOVA

Model		Sum of Squares	df	Mean Square	F
1	Regression	4936.593	3	1645.531	9.965[b]
	Residual	3467.765	21	165.132	
	Total	8404.358	24		

a. Dependent Variable: Beck Depression Inventory
b. Predictors: (Constant), age, gender, hour sleep

Coefficients

Model		Unstandardized Coefficients		Standardized Coefficients	t
		B	Std. Error	Beta	
1	(Constant)	67.310	9.150		7.357
	Gender	4.664	1.146	.127	4.070
	Hour sleep	-8.462	1.744	-.744	-4.852
	Age	-.044	.260	-.026	-.168

a. Dependent Variable: Beck Depression Inventory

(a) The researcher claims that the depression level decrease for every one hour increases in time spent sleeping of a person, keeping other variables constant. Test this claim at $\alpha = 0.05$ and give an appropriate conclusion.
(b) At 5% significance level, test the significance of the variable age to the model. What conclusion can be made?

Fig. 1: Item used to assess students' ability to conduct hypothesis testing

4. Results and Discussion

Table 1: Demographic information of respondent (N = 197)

Variable	Frequency (%)
Gender	
Male	52 (26.4%)
Female	145 (73.6%)
Program	
Diploma in Statistics	98 (49.8%)
Diploma in Actuarial Science	99 (50.2%)

Table 1 summarizes the demographic information of the respondents. Male respondents comprised 26.4% of the total and the re-

maining 73.6% were female. 49.8% of the respondents were Diploma in Statistics students and the rest were students of Diploma in Actuarial Sciences program.

Figure 1 represents a multiple linear regression model with three independent variables: gender, hours of sleep and age. In the first part of the item (refer to Figure 1 – part (a)), the statement "the depression level decreases for every one hour increase in time spent sleeping of a person, keeping other variables constant" refers to the regression coefficients of the variable "hour sleep". From this statement, the alternative hypothesis should be written as $\beta_i < 0$ (i refers to the variable "hour sleep"). Out of 197 students, only 35 (17.8%) of them were able to write the alternative hypothesis correctly (see Table 2). It is clear that students failed to translate this statement to a correct hypothesis statement as most of them gave $\beta_i \neq 0$. This result is contradicted by the second item (refer to Figure 1 – part (b)), where 89.3% managed to write the hypothesis correctly. Could this large difference in performance be because students were unable to represent the terms "…decreases for every one hour increase…" with the symbol "<"? As can be seen, the second item used clear and direct words of "test the significance of the variable age to the model", which helped students to easily relate this statement to the regression coefficient of the variable "age" and successfully wrote the alternative hypothesis as $\beta_i \neq 0$ (i refers to the variable "age").

Table 2: Responses for hypothesis statement

Item	Answer for Both Items	Correct Hypothesis	
		Yes	No
(a)	$H_1: \beta < 0$ (The depression level decrease for every one hour increases in time spent sleeping of a person, keeping other variables constant.)	35 (17.8%)	162 (82.2%)
(b)	$H_1: \beta \neq 0$ (The variable age is significant to the model.)	176 (89.3%)	21 (10.7%)

Further analysis was conducted to compare the total test score obtained by these two groups of students – those who were able to give the correct hypothesis and those who provided incorrect answers, for both items. The p-value for Levene's test for item (a) was 0.481, indicating the true assumption of equal variances. The independent sample t-test (see Table 3) shows that there was a significant difference in total test score for students who were able to write the correct hypothesis (M = 75.18, SD =17.05) and those who failed to do so [M = 61.83, SD = 16.56; t (195) = 4.302, p < 0.001]. On the second item (b), the p-value for Levene's test was 0.880, which means again the assumption of equal variances holds true. The independent sample t-test (see Table 4) indicates that there was a significant difference in total score for students who could write the correct hypothesis (M = 65.59, SD = 16.60) and who could not do so [M = 52.60, SD = 19.73; t (195) = 3.331, p = 0.001]. Results from Table 3 and 4 indicate that students who could state the hypothesis correctly for both questions, had a higher total score compared to students who were not able to do so.

Table 3: Comparison of mean total of test scores between the two groups of students for item (a)

Variable	Mean (SD)		t-Statistics (df)	p-Value
	Can Write the Correct Hypothesis	Can't Write the Correct Hypothesis		
Total score	75.18 (17.05)	61.83 (16.56)	4.302 (195)	0.000

Table 4: Comparison of mean total of test scores between the two groups of students for item (b)

Variable	Mean (SD)		t-Statistics (df)	p-Value
	Can Write the Correct Hypothesis	Can't Write the Correct Hypothesis		
Total score	65.59 (16.60)	52.60 (19.73)	3.331 (195)	0.001

Table 5: The association between students' ability to write correct hypothesis for both items (N = 197)

Variable	Ability to Write Correct Hypothesis for Item (b)		χ^2 (df)	p-Value
	Yes	No		
Ability to write correct hypothesis for item (a)			1.816 (1)	0.178
Yes	34 (97.1%)	1 (2.9%)		
No	142 (87.7%)	20 (12.3%)		

A chi-square test with Yates' continuity correction shows that the association between ability to write correct hypothesis for item (a) and (b) was not significant, χ^2 (1, N = 197) = 1.816, p = 0.178 (Table 5). 97.1% of the students who could state the hypothesis for item (a) correctly could also state the hypothesis for item (b) correctly while 2.9% of them failed to do so. For students who failed to write the correct hypothesis for item (a), 87.7% were able to write the correct hypothesis for item (b). This finding was expected since the hypothesis for item (a) is more difficult to write as compared to item (b).

From the hypothesis testing performed on item (a), the conclusion may be written as "At 5% significance level, the depression level decreases for every one hour increase in time spent sleeping of a person, keeping other variables constant", since the null hypothesis is rejected. Only 15.2% of the students (Table 6) managed to give the proper conclusion for item (a). Most of them provided incorrect answers (84.8%) as they could not provide the correct hypothesis (82.2%) (Figure 2).

Table 6: Responses for conclusion on item (a)

Item	Answer	Students' Answer	
		Correct	Incorrect
(a)	At 5% significance level, the depression level decrease for every one hour increases in time spent sleeping of a person, keeping other variables constant.	30 (15.2%)	167 (84.8%)

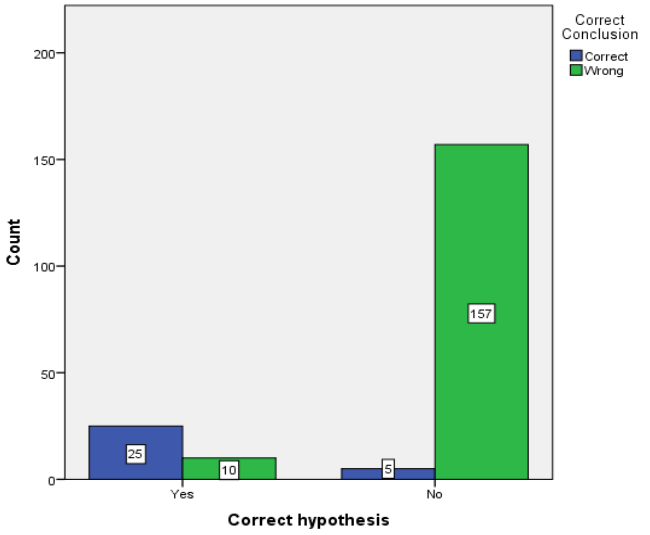

Fig. 2: Graphical comparison between ability to write the correct hypothesis and ability to write the correct conclusion for item (a) (N = 197)

Meanwhile, for item (b), since the null hypothesis is not rejected, the conclusion of "The variable age is not significant to the model at 5% significance level" should be applicable. Even though 89.3% of the students managed to write the correct hypothesis for this item successfully, only 56.3% of them were able to give the correct and complete conclusion for the same item (Table 7 and Figure 3). The most common mistake made by the students was mistreating β_i in the hypothesis as the parameter in a simple linear

regression model, hence they came out with the conclusion such as "the regression (or the model) is not significant"; which is considered as an incorrect conclusion. Some of them also concluded, "β_i is not significant to the model" – showing their incapability to relate the regression coefficient with the respective variable. Any conclusion without stating the significance level or simply using the symbol *X* was considered as partially correct, and 13.2% of the students provided this partially correct answer. However, this response is not going to be discussed further in this article.

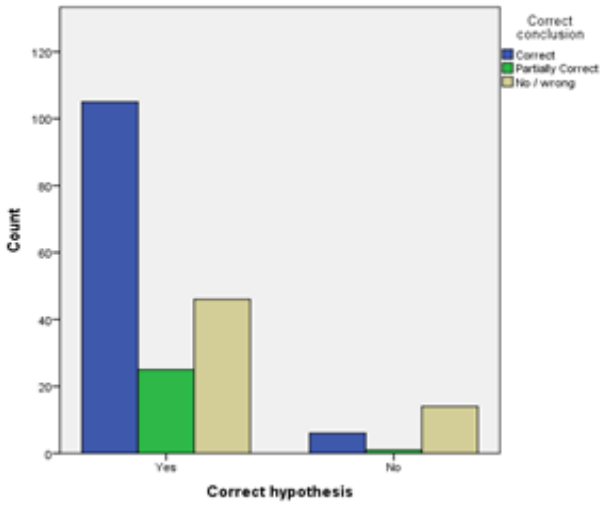

Fig. 3: Graphical comparison between ability to write the correct hypothesis and ability to write the correct conclusion for item (N = 197)

Table 7: Responses for conclusion on item (b)

Item	Answer	Students' Answer		
		Correct	Partially Correct	Incorrect
(b)	The variable age is not significant to the model at 5% significance level.	111 (56.3%)	26 (13.2%)	60 (30.5%)

4. Conclusion

In the hypothesis testing procedure, the ability to write a proper hypothesis statement as well as the ability to write the conclusion precisely are important, as the conclusion should correspond to the hypothesis statement. This study suggests that students are able to convert a simple and direct statement of regression parameters to an accurate hypothesis statement with less difficulty when they can easily relate the terms used in the question with a suitable notation. However, they revealed great difficulty in writing a proper hypothesis statement when the statement is given indirectly such as the definition of the slope in the context of the problem rather than clearly asking the students to test the slope of any respective variable. This finding appears to be consistent with the earlier findings by [15] that students have a lack of understanding on the definition of regression coefficients; therefore, they are unable to represent the statement referring to slope with an appropriate statistical symbol.

This study also showed that the ability of students to write a meaningful conclusion based on their decision was less than their ability to write the hypothesis statement. This is probably due to their language difficulties, as the medium of delivery is the second language. Nevertheless, the study suggested an interesting finding to all educators in searching for better methods of teaching delivery particularly in statistics courses. Many students were actually able to provide a correct conclusion for item (a) despite their incorrect hypothesis statement. One of the reasons was probably because they quoted the conclusion directly from the statement in the question, not realizing that the statement did not represent the hypothesis statement stated earlier.

Hence, this study provides some insights to statistics' educators in particular in finding ways to improve the students' learning and understanding of basic regression theory so as to apply the theory in a proper manner.

Acknowledgement

The study is financially funded by the Academic and Research Assimilation Grant, Universiti Teknologi MARA, 600-IRMI/DANA 5/3/ARAS (0180/2016). Special thanks are also extended to those participated in this study.

References

[1] Montgomery DC, Peck EA, & Vining GG (2015), Introduction to linear regression analysis. *John Wiley and Sons.*

[2] Haapala A (2003), Concept map as a tool for meaningful learning and assessment in an introductory statistics course. http://www.leeds.ac.uk/educol/documents/00002388.htm.

[3] Batanero C, Godino JD, Vallecillos A, Green DR & Holmes P, (1994). Errors and difficulties in understanding elementary statistical concepts. *International Journal of Mathematical Education in Science and Technology* 25(4), 527-547.

[4] Garfield J & Ben-Zvi D (2007), How students learn statistics revisited: A current review of research on teaching and learning statistics. *International Statistical Review* 75(3), 372-396.

[5] Henriques A (2016), Students' difficulties in understanding of confidence intervals. In D. Ben-Zvi, & K. Makar (Eds.), Teaching and Learning of Statistics: International Perspectives. Basel: Springer International Publishing, pp. 129–138.

[6] Lovett MC (2001), A collaborative convergence on studying reasoning processes: A case study in statistics. In S. Carver and D. Klahr (Eds.), Cognition and Instruction: Twenty-Five Years of Progress. New Jersey: Erlbaum, pp. 347-384.

[7] Sotos AEC, Vanhoof S, Noortgate W & Onghena P (2009), How confident are students in their misconceptions about hypothesis tests. *Journal of Statistics Education*, 17(2), 1-21.

[8] Batanero C (2000), Controversies around the role of statistical tests in experimental research. *Mathematical Thinking and Learning* 2(1-2), 75-97.

[9] Lecoutre MP, Poitevineau J & Lecoutre B (2003), Even statisticians are not immune to misinterpretations of null hypothesis significance tests. *International Journal of Psychology* 38(1), 37-45.

[10] Delmas G, Joan G, Ooms A & Chance B (2007), Assessing students' conceptual understanding after a first course in statistics. *Statistics Education Research Journal*, 6(2), 28-58.

[11] Mills JD (2002), Using computer simulation methods to teach statistics: A review of the literature. *Journal of Statistics Education* 10(1), 1-20.

[12] Bliwise NG (2005), Web-based tutorials for teaching introductory statistics. *Journal of Educational Computing Research* 33(3), 309-325.

[13] Moore DS (1997), New pedagogy and new content: The case of statistics. *International Statistical Review* 65(2), 123-137.

[14] Meyer O & Lovett M (2002), Implementing a computerized tutor in a statistical reasoning course: Getting the big picture. *Proceedings of the 6th International Conference on Teaching Statistics*, pp. 1-4.

[15] Fadzilah AR, Baharun N, Deraman NA, Ismail NR (2017), Assessing students' abilities in interpreting the correlation and regression analysis. *Journal of Fundamental and Applied Sciences* 9(5S), 644-61.