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The Application of Binary Logistic Regression Analysis on Transferability of Mathematical Knowledge amongst Science Students

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Abstract

Science students are required to apply mathematical knowledge at various levels. However, many students could not really relate what they have learned in mathematics classes in solving problems to another context. As such, this paper explore the factors that influence the ability of university science students to transfer their mathematical knowledge to a range of scientific contexts. The instrument was designed and comprised of mathematics and transfer questions. There are 255 university science students involved in this study. The performances of the students have been identified by determining the overall transfer score. The Binary Logistic regression model was used to identify the possible factors associated with students that would influence the knowledge transfer. The factors are namely Cumulative Grade Point Average (CGPA), gender, age, educational qualification, faculty and mathematics score. In this study, CGPA, faculty and mathematics score were found to be significantly affected the overall transfer score.

Keywords: *Knowledge transfer, Binary Logistic Regression, Transfer score, Transfer questions;*

Introduction

Knowledge is very important in our life as it is the only way for someone to become more successful, able to give opinions, prevent people from getting manipulated and highly respected by other people. Science knowledge is a subject to the reformation of new evidence and new ways of thinking [1]. Educators claimed that understanding the scientific knowledge constructed should be done by every students. This is because, understand the scientific knowledge make people to be more careful on public scientific issues [2]. In addition, people will get better understand on science especially through structure and the nature of sciences practically [3]. Mathematical knowledge on the other hand, is essential for all science students' success regardless of the choice of discipline. Understanding mathematics is important in daily life as it is needed in the process of problem-solving and also mathematics subject is a major subject used widely as the foundation to another subject [4].

Knowledge transfer can be defined as the application of knowledge that can be applied in one situation to a different situation [5]. The transfer of knowledge can be applied to everyday activities as the students used the knowledge they learned in their classes. In addition, transfer can occur if the students can relate and recognize the previous learning task to the need of current task [5]. Science students in particular are required to use the knowledge that they have learned in mathematics classes to another context [6]. Randahl [7] found that there is some difficulties of engineering students when applying mathematical knowledge in engineering subjects. This is because students from engineering are not necessarily used that knowledge successfully in their subjects while mathematics students are able to perform well in mathematics subject. She stated that engineering students that learned mathematics are essential to understand the conceptual and procedural knowledge. Indeed, there is a clear difference between the way in which procedural students approach the transfer problems, compared to conceptual students [8].

However, many students could not really relate what they have learned in mathematics classes in solving problems to another subject [9]. The inability to transfer mathematical knowledge to other context makes them difficult to successfully pursue their study [4]. Thus, there is a need to know the factors associated with students that affect students in transferring their mathematical knowledge to another context. Consequently this study investigate factors such as CGPA, gender, age, educational qualification, faculty and mathematics score.

Methodology

There are 255 (182 female and 73 male) third semester undergraduate students from seven (7) science based faculties from Universiti Teknologi MARA (UiTM) Selangor Campus Malaysia involved in this study and is display in Table 1. The students were selected because they have learned the differentiation topic and their applications.

A set of questions was designed for the instrument. A pilot study was taken place with thirty one (31) students from third semester undergraduate Chemical Engineering Faculty in order to determine their ability to transfer mathematical knowledge from a mathematical context to other science context. The results from the pilot study showed that students could solved correctly the mathematical context but were unable to solve the transfer contexts. Thus, some changes were made on the transfer questions to make them much simpler and relevant to mathematical context. Also the questions were validated by peer group. Finally, there are four (4) mathematics questions and six (6) transfer questions in this study. An example of Transfer Question is shown in Figure 1 [10].

> The temperature, T, is given in Fahrenheit, of a cold potato in a hot microwave, is given in terms of the equation T=f(t), where t represents the time in minutes after the potato was put in the microwave.
> (a) What is the sign of f ’(t)? Why?
> (b) What is the unit of f ’(20)? In practical terms, what do you mean by the statement f ’(20) = 2?

Fig. 1 The Sample of Transfer Question

This survey consists of 3 sections. Section A is on biographical information. Section B and section C comprised of mathematics questions and transfer questions respectively. The students need to answer section B first and the answer scripts were collected once they finished answered them. Finally, section C were distributed to the same students to answer. The answer scripts were collected and marks were given based on their answer.

Coding of Marks for Mathematics Questions and Transfer Questions

For each mathematics and transfer questions, the total marks for each question is 4 marks. In this study, the marks for each question were then be coded as below:
If the total marks for each mathematics or transfer question is between 0 – 2 marks, it will be coded as “0”, which indicates that the student was unable to solve the question. If the total marks for each question is between 3 – 4 marks, it will be coded as “1” which indicates that the student was able to solve the question.

Coding for Mathematics Score and Transfer Question

For mathematics score, if the total of four mathematics questions is between range 0-2, it will be coded as “0”, and if the range is between 3-4, it will be coded as “1”.
For transfer question, if the total of six transfer questions is between range 0-3, it will be coded as “0”, and if the range is between 4-6, it will be coded as “1”.

CalculatingTransfer Score (TS)

In this paper, Transfer Score (TS) is defined as the ability of each student to transfer the mathematics knowledge to the scientific questions. The calculation of transfer is based on the total questions answered by the students by comparing the coded marks obtained for mathematics score with those coded marks obtained for the transfer questions.

	Mathematics Score (MS)	Transfer Question (TQ)	Transfer Score (TS)
Coded Marks	1	1	1
	1	0	0
	0	1	1
	0	0	0

Fig. 2 Transfer Score

Figure 2 shows that if a student can answered correctly for both mathematics question and transfer question, the transfer score (TS) will be coded as 1. It shows that the transfer has occurred. But, if a

student answered mathematics question correctly but could not answer the transfer questions, then the transfer score (TS) will be coded as 0 which indicates that transfer does not occur. However, if a student answered mathematics question incorrectly but answered transfer questions correctly, the transfer score (TS) will be coded as 1 as it indicates the transfer still occurs. Finally, if a student answered incorrectly for both mathematics and transfer questions, the transfer score (TS) will be coded as 0 which indicates that transfer does not occur.

BINARY LOGISTIC REGRESSION

The results obtained were analysed using descriptive statistics and inference. Binary Logistic regression is used in this study to find the factors that affect the knowledge transfer. The main goal is to find the best fit model to describe the relationship between the response variable and a set of independent explanatory variables as displays in Table 1. This study considers transfer score as a dependent variable Y, whereas CGPA, gender, age, educational qualification, faculty and mathematics score as the independent variables.

Table 1 Coding of variables that influence the knowledge transfer of students

Variable	Explanation	Data Type	Condition Used
Dependent Variable			
Transfer Score	The student fails to transfer the knowledge	Binary	No = 0
	The student succeeds to transfer the knowledge		Yes = 1
Independent Variable			
CGPA	CGPA of student	Categorical	4.00 – 3.50 = 1
			3.49 – 3.00 = 2
			2.99 – 2.50 = 3
			2.49 – 2.00 = 4
			1.99 – 1.50 = 5
Gender	Gender of student	Categorical	Male = 1
			Female = 2
Age	Age of student (years)	Categorical	19 = 1
			20 = 2
			21 = 3
			22 = 4
			23 = 5
			24 = 6
			25 = 7
Educational Qualifications	Level of Education Attained	Categorical	Diploma = 1 Matriculation = 2 Foundation = 3
Faculty	Study Field	Categorical	Chemical Engineering (FChemE) = 1
			Electrical Engineering (FEE) = 2
			Civil Engineering (FCE)= 3
			Mechanical Engineering (FME)= 4
			Computer & Mathematical Sciences (FCMS) = 5
			Applied Sciences (FAS) = 6
			Education (FE) = 7
Mathematics Score	Student's score on mathematics questions	Binary	Score between 0 – 2 marks = 0 Score between 3 – 4 marks = 1

The logistics regression model is given by

$$z = log\ it(p(Y=1)) = ln\left(\frac{p(Y=1)}{1-p(Y=1)}\right) = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \ldots + \beta_m X_m$$

$$p(Y=1) = \frac{e^z}{1+e^z}$$

$$p(Y=1)=\frac{e^{\beta_0+\beta_1X_1+\beta_2X_2+\cdots+\beta_mX_m}}{1+e^{\beta_0+\beta_1X_1+\beta_2X_2+\cdots+\beta_mX_m}}$$

where;

YY Transfer score

$p(Y=1)p(Y=1)$ The probability of student succeeds to transfer the knowledge

$1-p(Y=1)1-p(Y=1)$ The probability of student fails to transfer the knowledge

$X_1,X_2,\ldots,X_mX_1,X_2,\ldots,X_m$ *m* independent/dummy variables

$\beta_0\beta_0$ Constant

$\beta_1,\beta_2,\ldots,\beta_m\beta_1,\beta_2,\ldots,\beta_m$ Logistic regression coefficients

Results and Discussion

In checking the association between overall transfer score and other variables, the Pearson Chi-square test indicates that there is a significant association between the overall transfer score versus faculty, mathematics score and CGPA (shown in Table 2). This is because the p-values for the three factors is significant since the value is less than α=0.05. On the other hand, there is no significant association between overall transfer score versus gender, age and educational qualification since their p-value is greater than α=0.05. In summary, CGPA, faculty and mathematics score are the factors that significantly associated with the overall transfer score.

Table 2 Cross Tab of Overall Transfer Score

Variables	Pearson Chi-Square	df	Assumption (2-sided)	Phi and Cramer's V
Faculty	67.935	6	0.000	0.516
Mathematics score	24.811	1	0.000	0.312
CGPA	14.021	4	0.007	0.234
Gender	0.429	1	0.512	0.041
Age	10.692	6	0.098	0.205
Educational qualification	0.304	2	0.859	0.035

The Omnibus test and Hosmer-Lemeshow test of model in Table 3 show the overall indication of how well the model performs. This is referred to a 'goodness of fit' test. For Omnibus test, the chi-square value is 116.840 with 20 degrees of freedom. In this case, the model is statistically significant because the p-value is less than .05.

Table 3 Overall Transfer Score Model Tests

	Chi-square	df	Sig.
Omnibus Test	116.840	20	0.000
Hosmer and Lemeshow Test	9.475	8	0.304

According to Hilbe [11], the best way to get the fit of logistic model most of statistician developed goodness-of-fit test by using Hosmer-Lemeshow test. Specifically, the Hosmer-Lemeshow test calculates if the observed events rates match the expected event rates in population subgroups. Based on the Hosmer-Lemeshow test, the value of chi-square is 9.475 and the significant value is 0.304. The significant value is greater than 0.05. It shows that the model is better and supported.

Table 4 The results of binary regression model for Overall Transfer Score

	B	S.E.	Wald	df	Sig.	Exp(B)
faculty			44.942	6	.000	
FChemE	.717	.548	1.711	1	.191	2.047
FEE	-.266	.547	.237	1	.626	.766
FCivilE	-.693	.565	1.503	1	.220	.500
FME	-.531	.608	.764	1	.382	.588
FCMS	3.121	.669	21.786	1	.000	22.678

FAS	-.468	.594	.621	1	.431	.626
math_score(1)	-1.807	.402	20.246	1	.000	.164
Constant	-.032	.399	.007	1	.936	.968

Therefore, from Table 4 the fitted model is given by:

$$p(Y=1)=\frac{e^{z}}{1+e^{z}}$$

$$z=-0.032+0.717FChemE-0.266FEE-0.693FCivilE-0.531FME+3.121FCMS-0.468FAS \\ -1.807math\_score(1)$$

The results from Wald test, as presented in Table 4, were useful for estimating which coefficients were statistically significant (Sig. < 0.05) and which were not statistically significant (Sig. > 0.05). The significant value of overall transfer score in the model are FCMS and Mathematics Score. This shows that the odds of able to transfer knowledge whose students are from FCMS is 3.12 times higher than those from other faculties. For the Mathematics Score, if the students are able to solve the mathematics questions, it can contribute to the transferability of mathematical knowledge to other context by odds of 0.032 times higher compared to students who are unable to solve the mathematics questions. In summary, FCMS and Mathematics Score are the variables that affect the overall transfer score.

Conclusion

The results demonstrated that CGPA, faculty and mathematics score are the variables that significantly associated with the overall transfer score by using Pearson Chi-square test. However, in using BLR, only FCMS and Mathematics Score are the variables that affect the overall transfer score. Out of seven science-based faculties, only FCMS significantly satisfied the model. This is due to students from FCMS are able to solve both mathematics and transfer questions. Besides, the other significant factor in the model is Mathematics Score. This is because having a strong fundamental background of mathematics help students better in transferring mathematical knowledge to other contexts.

References

[1] Nickels, M. (1998). The Nature of Modern Science & Scientific Knowledge.

[2] Rudolph, J. L. (2005). Epistemology for the masses: The origins of “the scientific method” in American schools. *History of Education Quarterly*, *45*(3), 341-376.

[3] Sandoval, W. A. (2005). Understanding students' practical epistemologies and their influence on learning through inquiry. *Science Education*, *89*(4), 634-656.

[4] Mynbaev, D. K., Cabo, C., Kezerashvili, R. Y., & Liou-Mark, J. (2008). Support of study on engineering technology from Physics and Mathematics. *arXiv preprint arXiv:0807.1950*.

[5] Adams, K. (2014). The Effect of Students' Mathematical Beliefs on Knowledge Transfer.

[6] New, P., Britton, S., Sharma, M., & Brew, A. (2012, November). Researching the transferability of mathematical skil. In *Proceedings of The Australian Conference on Science and Mathematics Education (formerly UniServe Science Conference)* (Vol. 7).

[7] Randahl, M. (2016). Engineering students approaching the mathematics textbook as a potential learning tool – opportunities and constraints.

[8] Zakaria, N. (2004). *A study of the nature of knowledge transfer across subject boundaries: comparing procedural students and conceptual students at university level*. (Unpublished doctoral dissertation). Warwick University, UK.

[9] Britton, S., New, P., Roberts, A., & Sharma, M. (2007). Investigating students’ ability to transfer mathematics. Sydney University Press.

[10] Hughes-Hallett, D; Gleason, A. M.; Flath, D. E.; Lock, P. F.; Gordon, S. P.; Lomen, D. O.; Lovelock, D; McCallum, W. G,; Quinney, D.; Osgood, B. G.; Pasquale, A.; Tecosky-Feldman, J.; Turosh, J. B.; Thrash, K. R.; Tucker, T. W.; Bretscher, O. K. (1998). *Calculus Single Variable*. John Wiley and Sons, Inc.

[11] Hilbe, J. M. (2011). Logistic regression. In *International Encyclopedia of Statistical Science* (pp. 755-758). Springer Berlin Heidelberg.