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Omani Student's Differentiated Performance on University's Mathematics Placement Test as Mediated by the Exposure to the National Learning Management System

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Abstract

The explosion of technology-related modality of teaching had increased exponentially in commercial and in open-source arena. The importance and implication of having such technology-related modality had been magnified ten-folds by the emergence and longevity of COVID-19 pandemic. All over the world, education institutions and academic excellence providers inevitably shifted to these 'new normal' way of teaching. This paper proposed the innovation of a centralized National Learning Management System for Omani students. Initial evidence was based on the differentiated performance of students in Mathematics Placement Test result as mediated by engagement scores obtained the National LMS transactional database. The highly positive correlation between the engagement made by the students in the course contents and the placement test score proves that the exposure in the National LMS is a noteworthy advocacy. This paper provides evidence and proofs that the concept of having a centralized National LMS is doable in smaller number of courses such as in General Foundation Program and expected to bring about a worthwhile learning experience to new intakes in pre-Higher Education courses in the entire Sultanate.

Keywords: National Learning Management System; Pre-Higher Education Program; Educational Data Mining; e-learning; MOODLE.

1. Introduction

The burst of technology-related modality of teaching had increased exponentially in commercial and in opensource arena. The importance and implication of having such technology-related modality had been magnified ten-folds by the emergence and longevity of COVID-19 pandemic [2]. All over the world, education institutions and academic excellence providers inevitably shifted to these 'new

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normal' way of teaching [6]. The same case had been exercised in University of Technology and Applied Sciences (UTAS). Open-source MOODLE and commercially available Blackboard platforms dominated the learning management systems (LMS) in the entire University. With these advancements in technology, most academic institutions specifically the higher education institutions leaned towards capitalizing these developments [3]. In Sultanate of Oman, a common set of curricula has been used for the entire country in the General Foundation Program (GFP). As a legal basis, the decision of the Higher Education Council No.13/2008, HE the Minister for Higher Education issued Ministerial Decision No.72/2008 stating that the GFP should be adopted by all public and private higher education institutions operating in the Sultanate of Oman [8,9]. GFP in Oman are training programs commenced by students preceding to admittance to Post-Foundation Programs (PFP). Most secondary school graduates in Oman are required to successfully complete GFP to ensure that the new student intakes acquired sufficient knowledge and capabilities to effectively undertake PFP levels (diploma to bachelor levels). Higher Education Institutions (HEI's), which involves UTAS, are required to provide a GFP that comprises of the following core areas of study: English Language, Mathematics, Computing and General Study Skills [8]. These courses are being delivered in each of the satellite campus of UTAS using their respective open-sourced LMS's.

Over the last few years, there has been a strategic shift to standardize the course delivery in GFP specifically, in mathematics disciplines across campuses of the University. This objective has not been realized due to some limitations. Consistency with course delivery is inevitably the expected common concern since every campus (which currently stands at 13) had their own respective LMS. To be more poignant, the problem arises when an Omani student had been exposed to a set of different learning objects in the main campus as compared to the other satellite campuses, equating everything else (course delivery plan, assessment plan, etc.) as constant. This leads to numerous differentiations in academic preparedness among post-Foundation intakes from different satellite campuses (e.g., intakes from Salalah vs intakes from Muscat). In addition, the student 'cognitiveengagement-rich' log files from the LMS transactions had been neglected and just lives and dies in the database server.

To address these shortcomings, a National Learning Management System (National LMS) is conceptualized [3]. Direct impact of the innovating a National LMS is in financial framework. The University will be saving a huge chunk of money since only one National LMS is needed to execute the GFP math (1 National LMS vs 13 independently served LMS station across Oman). The National LMS will benefits Omani student by just giving them a common platform, common learning objects to pre-start and post-start their journey going to post-Foundation or higher- level programs. This National LMS is expected to provide an inclusive, flexible and a very engaging transformative learning for all foundation students. The existence of this centralized LMS will ensure that every single Omani student will have adequate, up-to-date resources across the University's 13 campuses. More importantly, the availability of a joint catch basin for student's learning transaction from the LMS log database will promote evidence-based learning and data-driven policy-making due to the

availability of primary resources which directly reflecting the students' engagements to the course and its contents. Leveraging Educational Datamining (EDM) using these log files in the National LMS database server can convert raw dataset in to meaningful and significant insights about the student, the course and the course delivery that are vastly needed in policy-making and decision-making paradigms. This conceptualization emanates from a Proof-of-Concept (PoC) that was successfully executed in December 2021 to January 2022, where the idea of a National LMS is very feasible specially if courses involve are very few to begin with (2 mathematics courses only in GFP curriculum).

This technical paper provides scientific evidence to the impact and importance of student engagement on the National LMS as reflected in differentiated Mathematics Placement Test (MPT) results. The paper is organized into several sections: Introduction - this part; Methodology - design, sampling techniques, statistical procedures used; Results and Discussions - presents the empirical evidence and relative implications and importance of the findings generated by the statistical evidence; Supplemental Reports – a priori reports made as the implementation of the project progresses.

2. Methods

The paper's main problem statements are related to the engagement of the students on the National LMS and its impact to Mathematics Placement Test results. In addition, an independent pre-assessment test score from mock MPT was used to serve as continuous covariate of MPT result. Differentiated performance was presented in the succeeding section by disaggregating the MPT result by gender and by category of engagement score.

A commonality in learning objects used to deliver a mathematics course with the capitalization of their raw learning transactions will generate the basic requirements to execute an Educational Data Mining (EDM) technique. EDM is very valuable in the field of learning analytics particularly when assessing student behavior in an online learning situation. This paper generally proposes to generate a unified National LMS that will be used for the entire university if not for the country and explore the learning behavior of the students using EDM techniques and principles to determine their future academic performance, quantify the student-at-risk and other educational statistics that would trigger and influence a new policy that is driven by the data generated by the students themselves; and, not by human emotion which is proven to be inconsistent in many academic applications.

This section presented the samples used in the study and their significant demographic characteristics. In addition, the Online Learning Framework (OleF) [1] used as the developmental design of the National LMS were discussed. The National LMS was created on December 11, 2021, where Basic Math and Computing Skills courses were made available for the students online on December 19, 2021. The course backups of these two courses were requested from UTAS-Muscat eLearning Team and were uploaded to the National LMS. These backup files served as the initial content of the two

courses. In addition, Nizwa College of Technology through their own Educational Technology Center (ETC) provided a question bank for Basic Mathematics that was later added to the existing lists of questions. The OLeF served as the online learning structure that provided the learners with the conducive learning environment to help them gain knowledge in the most efficient way; and, on assessing the student's learning gain as measured by Mathematics Placement Test (MPT) score and cognitive engagement with the online assessments before the MPT schedule.

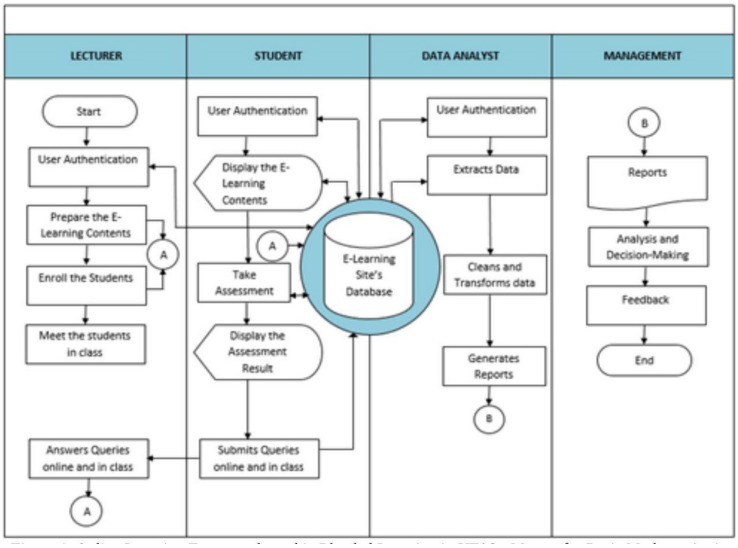


Figure 1: Online Learning Framework used in Blended Learning in UTAS - Muscat for Basic Mathematics in IT Department and Probability and Statistics in Engineering Department

Figure 1 serves as the Online Learning Framework (OLeF) used for delivering a fully online course in Basic Mathematics. This whole framework involves four important pieces: Lecturer, Student, Data Analyst and Management. As an internal practice, the Lecturers, through the leadership of the course coordinator, are responsible in enhancing the contents and substance of their courses' e-Learning pages. However, the National LMS administrator was authorized to register all the potential students to provide the latter an access to the contents such as texts, videos, links, forums, and test yourself assessments [1].

The content-rich pages are expected to be utilized by the students for the entire duration of the course. That is while they are still at home and waiting for the actual MPT schedule, the students may elect to use the resources available on the National LMS. At a regular interval or at any point that is deemed necessary, the Data Analyst extracts data from the e-Learning's database server for the sole purpose of preparing management-level reports. These reports served as a substantial reference in the management's planning and decision-making functions [1].

A total of 5,065 students were on the list of new intakes from the UTAS-Muscat's Student Affairs Department. An initial 5 editing teachers were enrolled and were responsible for upgrading the course content of the two foundation courses. Through a specialization meeting attended by all CoT's Heads of Mathematics sections, the number of teachers enrolled in the portal had increased to 40. This

includes all heads of Mathematics section along with at least 1 lecturer from their respective college.

Campus*	Frequency **	Percentage
Campus 1	880(478, 402)	17.4%
Campus 2	1384(811, 573)	27.3%
Campus 3	767(468, 299)	15.1%
Campus 4	530(363, 167)	10.5%
Campus 5	815(447, 368)	16.1%
Campus 6	243(174, 69)	4.8%
Campus 7	446(285, 161)	8.8%
University	5065(3026, 2039)	100%

*Source: Student Affairs Department, UTAS Muscat; Several students with incomplete details were not able to be added in the National LMS user database
**n (male, female)

Table 1: Distribution of Potential Student Intakes

The participants of this study were 5,065 students who just completed the School Level education and who are planning to take Placement Test (Math/Computing Skills) at UTAS. There were 3026 males and 2039 females. As for the pedagogical format, the Basic Mathematics course was designed to have several learning objects which mainly concentrated into two modules - LESSON and QUIZ. Lesson module contains the video lectures chapter-wise, and the video lectures were presented topic-wise. The quiz module, on the other hand, contains topic-wise exercises which can be unlimitedly taken by the students for practice and have immediate feedback about their submitted output. As the learning pedagogy of this project is self-paced, participants in this study were encouraged to complete several 'Test Yourself' assessment tasks through the Basic Mathematics eLearning pages in the National LMS portal.

To measure the impact of the engagement made by the participant on the National LMS to the MPT scores, several metrics have been defined and considered. Specifically, the amount of engagement in the National LMS will be categorized into three categories. 'Engaging' category will be participants who accumulated at least 100 times of interaction to the Basic Mathematics eLearning course contents. 'Less Engaging', on the other hand, are participants with accumulated interactions of less than 100; 'Not Engaging' were participants who never used the eLearning Portal at all.

Engagement Level*	Engagement Score (ES)**	Pass***
Engaging	179(4411, 100)	755(11.4%)
Less Engaging	29(99, 1)	3239(4.8%)
Not Engaging	–	1071(3.2%)
Total	37	5065(5.4%)

*$ES > 99$, 'engaging'; $ES > 0$, 'less engaging'; else, 'not engaging'
**Median(max, min)
***n$\left(\text{MPT Passing \% as } \frac{n_i}{N_i}\%\right)$

Table 2: Engagement Level and Mathematics Placement Test Passing Percentage Distribution

Table 2 presents the distribution of engagement level of the participants after categorization has been made based on the threshold set on their respective engagement score (ES). This initial result generates a promising difference between the impact of ES on the National LMS to passing the MPT. This, however, is not as consistent and conclusive as it represents since a huge imbalance in each category is observed in the contingency table. Further testing was presented to the next section.

Students' records on their participation in self-paced online learning on Basic Mathematics were recovered from the National LMS database server. Self-paced learning behaviors such as rate of logging-in, number of sent messages, frequencies of viewing messages, discussions, and reading course materials, attempting, submitting, and reviewing 'Test Yourself' assessments were extracted from the data. Next, the data were exported to an Excel spreadsheet to merge with the codes of cognitive engagement in the discussion scripts.

The complete dataset was used twice: the data was imported into R Programming 4.0.4 (Lost Library Book version) for further statistical analysis. Data mining of the complete dataset resulted in the construction of a predictive model for students' cognitive engagement in online learning. The overall variables involved are presented in succeeding tables in Section 4.

3. Results and Discussions

This section presents the significant findings of the study based on the different data analyses that was carried out to the dataset and subsequent sub-groups to arrive at conclusive evidence to support the impact of National Learning Management System to the Mathematics Placement Test Result of the participating students. Table 3 presents the distribution of the participants in terms of gender, engagement level and mock MPT result disaggregated by the outcome of the actual MPT.

Characteristic	Overall $N = 4939$	MPT Result*		p-value**
		Pass $N = 274$ (5.4%)	Fail $N = 4665$	
Gender, n (%)				$< .001$
Male	2936 (59%)	82 (30%)	2854 (61%)	
Female	2003 (41%)	192 (70%)	1811 (39%)	
Engagement, n (%)				$< .001$
Engaging	754 (15%)	86 (31%)	668 (14%)	
Less Engaging	3202 (65%)	154 (56%)	3048 (65%)	
Not Engaging	983 (20%)	34 (12%)	949 (20%)	
Mock MPT Result, n (%)				$< .001$
Pass	378 (7.7%)	48 (18%)	330 (7.1%)	
Fail	4561 (92%)	226 (82%)	4335 (93%)	

*Original overall case was 5,065. Due to filtering of MPT score > 0, total number of cases reduced to 4,939; MPT passing rate of 5.4% was based on the original and unfiltered total number of cases
**Pearson's Chi-squared test

Table 3: Engagement Level and Mathematics Placement Test Passing Percentage Distribution

Out of 274 passing students in MPT, majority are female in gender. To test this observation, a chi-square test of independence was performed to examine the relation between MPT Result and gender of the participants. The relation between these variables was highly significant $(p < .001)$. Female participants, in general, were likely to pass the MPT than the male participants. Among the number of passing students in MPT, majority belongs to either 'engaging' or 'less engaging' categories. To test this remark, a chi-square test of independence was performed to examine the relation between MPT Result and level of engagement on the National LMS of the participants [5].

There was a highly significant relationship between the two categorical variables $(p < .001)$. At least a 'less engaging' participants, on average, were likely to pass the MPT than the 'not engaging' participants. Consequently, majority of the passing students in the actual MPT failed in the mock MPT. A chi-square test of independence was performed to investigate the relation between MPT Result and mock MPT outcome. The relation between these categorical variables was highly significant $(p < .001)$. Most of the students passed the actual MPT failed the mock MPT.

Table 2 on the previous section presents a promising initial finding that 'engaging' students on the National LMS 'appeared' to be more likely to pass the MPT as compared to the two lower levels of engagement. In reference to Table 2, 11.4% passed the 'engaging' cohort as compared to 4.8% and 3.2% for the cohorts 'less engaging' and 'not engaging', respectively. To verify this finding, a greater than cumulative cut-off value of the engagement score had been introduced, n cohort. For each cut-off, say for instance, 20-cohort, would include students with engagement score 20 or more. In addition, a 100-cohort, would include students with engagement score 100 or greater.

The resulting cut-off score served as the stratum for a complete enumeration sampling which resulted to serial sub-groups of the original dataset. For each sub-group, a test of linearity between the MPT score and engagement score (setting MPT as the response variable while the ES is the predictor variable) using linear model given by equation (1) was serially undertaken.

$$\widehat{MPT} = HY \tag{1}$$

where, $\widehat{MPT}$ is $n \times 1$ matrix of estimated values of MPT score, Y is $n \times 1$ matrix of actual MPT score, H is the 'hat matrix' given by

$$H = X\left(X'X\right)^{-1}X' \tag{2}$$

where, X is $n \times 2$ matrix of 1's and 'engagement score', and H is $n \times n$ symmetric and idempotent matrix.

Linear Model No*	Cut-off Score**	% Variance Explained***
1	0	3.96
2	10	3.97
3	20	4.22
4	30	4.29
.	.	.
.	.	.
.	.	.
28	270	6.37
29	280	6.76
30	290	6.52

*30 linear models were generated for all datasets, another 30 for dataset involving male students only and 30 more linear models for female dataset
** Cut-off score of 10 means dataset with engagement score of 10 or more, etc.
***A total of 1,853 cases were included in this analysis. Dataset with MPT Mark of less than 10 and Mock MPT mark of less than 10 were excluded

Table 4: Serial Results of R-squared Value from 30 Linear Models from Sub-samples Generated from the Engagement Cut-Off Score

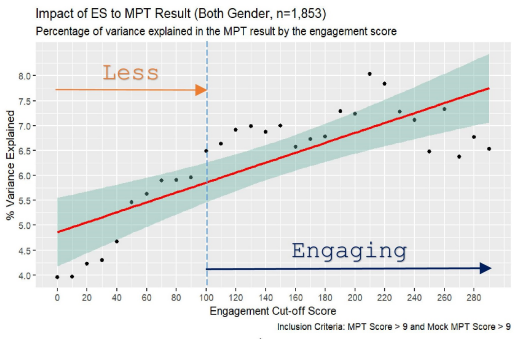
All assumptions had been tested for each running linear model and no serious violation was observed. The resulting coefficient of determination value given by equation (3) or the percentage of variance in the MPT score that is explained by the ES for each cut-off score had been noted and recorded in a new dataset (see Appendix for complete table) [5,10]. Sample of this dataset is presented on Table 4.

$$r^2 = 1 - \frac{\text{Unexplained Variation}}{\text{Total Variation}} \tag{3}$$

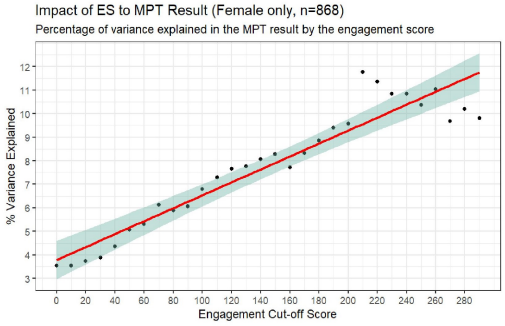
The impact metric, τ, is given by equation (4) which is the ratio between the benchmark r_0^2 and maximum r_{sup}^2 within the sub-group.

$$\tau = \frac{r_{sup}^2}{r_0^2} \tag{4}$$

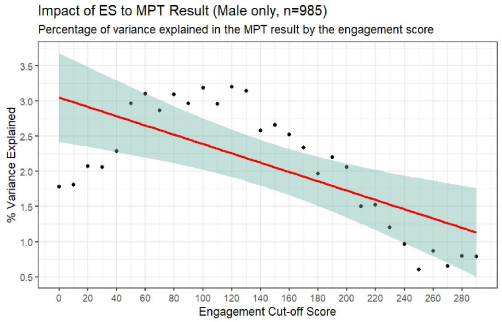
Table 4 presents the approximate percentage of variation in MPT score that is explained by the variation in the ES in varying n - cohort (multiples of 10). In simple terms, the coefficient of determination served as the proxy indicator of the effect size or important contribution of ES to the MPT score which can be directly interpreted as the higher the value of r^2 the more important it is. For context and benchmark, the first value in Table 4 represents the 0 - cohort group where the ES equal to 0 or more are included in the linear model.



(a)



(b)



(c)

Figure 2: Relationship between the R-Squared value (from Regressing the MPT Score to Engagement Score in 30 different sub-samples and Cut-off Scores) a) All students; b) Female students, only, and c) Male students, only

Figure 2 represents the scatter plot between the ES and MPT result. In addition, the best-fitting line with 95% confidence interval was also super-imposed on the same plot and a vertical line separating the 'less engaging' and 'engaging' regions of students.

Based on Figure 2a, there is a strong positive relation $(p < 0.001)$ between the ES cut-off scores and 'percentage of variance explained'. This suggests that as the ES cut-off score increases, the percentage of variance explained or the importance of ES to MPT score increases as well. The 0-cohort ES which represents all cases $(n = 1,853)$ from the 'less engaging' and 'engaging' groups obtained a 'percentage of variance explained' of about 3.96%. This value will represent our benchmark value, $r_0^2 = 3.96\%$, where the rest of the observed impact of ES on MPT score will be evaluated. Within the 'less engaging' region, the highest 'percentage of variance explained' was 5.96% at 70 -cohort.

Based on equation (4), the approximate supremum impact of ES on MPT score from 'less engaging' group is about $\tau = 1.51$. This suggests that the variation in MPT score is 51% better explained by the variation in ES with at least 70 engagement score than with at least 0 engagement score. In other words, the student impacted their MPT score positively by at most 1.51 times if they will engage in the course contents for at least 70 times. On the other hand, within the 'engaging' region, the highest 'percentage of variance explained' was 8.03% at 210-cohort. Based on equation (4), the approximate supremum

impact of ES on MPT score from 'engaging' group is about $\tau = 2.03$. This suggests that the variation in MPT score is 103% better explained by the variation in ES with at least 210 engagement score than with at least 0 engagement score. In simple terms, the student impacted their MPT score positively by at most 2.03 times if they used the course contents such as video lectures and 'Test Yourself' activities for at least 210 times.

Based on Figure 2 b and under female students' dataset, there is a strong positive relation $(p < 0.001)$ between the ES cut-off scores and 'percentage of variance explained'. This suggests that as the ES cut-off score increases, the percentage of variance explained or the importance of ES to MPT score increases as well. The 0 cohort ES which represents all cases $(n = 868)$ from the 'less engaging' and 'engaging' groups obtained a 'percentage of variance explained' of about 3.54%. This value will represent our female benchmark value, $r_0^2 = 3.54\%$, where the rest of the observed impact of ES on MPT score will be evaluated. Within the 'less engaging' region, the highest 'percentage of variance explained' was 6.13% at 70-cohort. Based on equation (4), the approximate supremum impact of ES on MPT score from 'less engaging' group is about $\tau = 1.73$. This suggests that the variation in MPT score is 73% better explained by the variation in ES with at least 70 engagement score than with at least 0 engagement score. In other words, the student impacted their MPT score positively by at most 1.73 times if they will engage in the course contents for at least 70 times. On the other hand, within the 'engaging' region, the highest 'percentage of variance explained' was 11.78% at 210-cohort. Based on equation (4), the approximate supremum impact of ES on MPT score from 'engaging' group is about $\tau = 3.33$. This suggests that the variation in MPT score is 233% better explained by the variation in ES with at least 210 engagement score than with at least 0 engagement score.

In simple terms, the female student impacted their MPT score positively by at most 3.33 times if they used the course contents such as video lectures and 'Test Yourself' activities for at least 210 times. Based on Figure 2c and under male students' dataset, there is a strong negative relation $(p < 0.001)$ between the ES cut-off scores and 'percentage of variance explained'. This suggests that as the ES cut-off score increases, the percentage of variance explained or the importance of ES to MPT score is anticipated to decrease. The 0 cohort ES which represents all cases $(n = 985)$ from the 'less engaging' and 'engaging' groups obtained a 'percentage of variance explained' of about 1.78%. This value will represent our female benchmark value, $r_0^2 = 1.78\%$, where the rest of the observed impact of ES on MPT score will be evaluated. Within the 'less engaging' region, the highest 'percentage of variance explained' was 3.10% at 60 -cohort. Based on equation (4), the approximate supremum impact of ES on MPT score from 'less engaging' group is about $\tau = 1.74$. This suggests that the variation in MPT score is 74% better explained by the variation in ES with at least 70 engagement score than with at least 0 engagement score. In other words, the student impacted their MPT score negatively by at most 1.74 times if they will engage in the course contents for at least 60 times. On the other hand, within the 'engaging' region, the highest 'percentage of variance explained' was 3.20% at 120 -cohort. Based on equation (4), the approximate supremum impact of ES on MPT score from 'engaging' group is about

$\tau = 1.80$. This suggests that the variation in MPT score is 80% better explained by the variation in ES with at least 120 engagement score than with at least 0 engagement score. In simple terms, the male student impacted their MPT score negatively by at most 1.80 times if they used the course contents such as video lectures and 'Test Yourself' activities for at least 120 times.

Comparing the results between the female and male students, the highest 'percentage of variance explained' was 11.78% from the female group and the lowest benchmark value was 1.78% which was from the male group. Based on equation (4), the approximate supremum impact of ES on MPT score from female group as compared to the male group is about $\tau = 6.62$. This shows that the impact of ES to MPT score is 6.62 times larger than to female students than male students.

4. Conclusion

The National Learning Management System is an innovative and unifying approach in handling a geographically challenged setting of delivering pre-Higher Education courses such as the Graduate Foundation Programs. The 17-day trial period is generally not a sufficient exposure in obtaining significant impact. But in contrast, the data gathered from this study conveyed a somewhat promising endeavor in the future delivery of pre-Higher Education in Oman. The highly positive correlation between the engagement made by the students in the course contents and the placement test score proves that the exposure in the National LMS is a noteworthy advocacy. This paper provides evidence and proofs that the concept of having a centralized National LMS is doable in smaller number of courses such as in General Foundation Program and expected to bring about a worthwhile learning experience to new intakes in pre-Higher Education courses in the entire Sultanate.

5. Future Research Direction

Successful implementation of this project is expected to bring about a huge shift on the management of the e-learning contents of the General Foundation Programs in the University. Creation of content managers from a pool of internal and external panel of experts are necessary to establish and then subsequent content and face validation studies will be inevitable to follow next in the process of standardizing the course contents. The student transaction from the centralized LMS database is expected to generate student data-driven policies and from there the techniques of Educational Datamining will be fully utilized and put in serial action and reproduceable research.

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