Web-based Spreadsheet in Malaysian Matriculation Physics Labs

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Bronze Award, Presented Borneo Innovation Festival 2024

Abstract. The world is undergoing the Fourth Industrial Revolution (IR 4.0) and this means that large scale machine-to-machine communication and the Internet of Things are starting to be integrated into the current system. To match with the demands of this internet-based future, we are proposing the integration of a web-based spreadsheet, Google Sheets into the Malaysian Matriculation Physics Laboratory. Linearity in the equations pertaining to the Malaysian Matriculation Physics curriculum allows us to easily build such spreadsheet for students' use in data analysis. In this paper, we report the structure in which we have built the spreadsheet of the experiments in the Malaysian Matriculation curriculum, the integration of the web-based spreadsheet into a Physics laboratory sessions and the students' response, which are generally encouraging.

1. Introduction

Since the introduction of modern computers, the application of it in the field of physics is well known. In fact, in Los Alamos in the 1940s, simulations of many physical systems were carried out on computers. This included, but is not limited to, the nuclear bomb and ballistics simulation [1], Monte Carlo simulations [2], and hydrodynamic simulations [3]. Even today, the cornerstone of the Industrial Revolution 4.0, of which the internet is the backbone of it, was a contribution of physicists, through the European Organization for Nuclear Research (CERN) [4]. As such, it is undeniable that the fields of physics and computer science goes hand-in-hand together.

Computational physics is well founded in Malaysia, with the likes of Professor Wan Ahmad Tajuddin of University Malaya (UM), Associate Professor Yoon Tiem Leong of *Universiti Sains Malaysia* (USM), Associate Professor Zamri Zainal Abidin (UM), it shows that the Malaysian computational physics scene is a thriving scene. In fact, Malaysia is a member of the CERN, the biggest physics experiment in the world, through the *National Centre of Particle Physics*. This is done through collaboration with CERN by students of UM. The most recent involvement of a Malaysian PhD physics student was Dr Adlyka Annuar, in her contribution to the discovery of a supermassive black hole [5]. This discovery was achieved through her contribution in the data analysis team, which is in fact a branch of computational physics.

For a Pre-University student, the idea of programming with little to no basic of it might seem intimidating. However, spreadsheets are relatively easy to get a grasp on and may act as a stepping stone to learning programming [6]. Excel, or its alternative *Google Sheets*, are readily accessible to any Pre-University student in Malaysia through its digital endeavour, DELIMa [7]. Through the use of spreadsheet softwares, the integration of the three domains of physics (theoretical, experiment and computational) is made possible and their overlap made apparent. Taking into consideration that 11 out of 12 of the experiments in the Matriculation Physics curriculum results in linear graphs[8], it is easy to see that data analysis in Excel is not at all a daunting task.

With that, it is the proposal of this author for computational physics to be considered its inclusion in the Malaysian Matriculation curriculum, particularly in the data analysis section of the laboratory sessions. This paper describes the utilization of spreadsheets, through the use of *google sheets*, in the data analysis part of the second physics experiment (free fall and projectile motion) in the first semester of the one-year Malaysian Matriculation Program.

This paper is structured as follows. In chapter 2, we describe the spreadsheet built on *Google Sheet* and was planned to be applied in the laboratory sessions. In chapter 3 we summarize the student response, via questionnaire as well as through interviews, to the usage of the spreadsheet in their laboratory sessions, and in chapter 4 we provide a brief summary of this work and some conclusions.

2. Spreadsheet: Build and Application

To determine how the spreadsheet should be built, it is important for one to refer to the manual provided and ask "What is required for the data analysis part of the lab report in the Malaysian Matriculation physics curriculum?". Referring to the Laboratory Manual provided by the Malaysian Matriculation Division [8], we deduced that the spreadsheet will require a number of components:

(i) The tabulation of collected data, which is the table the students will fill in as they run the experiment.

(ii) The theoretical data set, of which is records the values expected from theory.

(iii) The value of centroid, gradient and y-intercept of the best fit line.
The value for the centroid replaces the need to include $\oplus$ on the graph produced, the y-intercept and gradient is used to calculate the experiment parameters (for example the gravitational acceleration constant in a simple pendulum experiment) to be compared to the theoretical value.

(iv) Uncertainty calculations, data of which determines the uncertainty of gradient and the y-intercept.

(v) Data visualization through the use of a graph, most commonly 1 dimensional (linear) graphs.

Once this has been established, we can proceed with building the spreadsheet. For the purpose of this project, the experiment chosen here is the second experiment of the SP015 module in the Malaysian Matriculation Physics programme. This experiment studies the gravitational acceleration constant of $g = 9.81ms^{-1}$ in a free fall set up and then uses that calculated value in the *Projectile motion* part. The free fall set up is a standard set up in which a steel ball is released and the time taken for the steel bass released from varying heights are recorded. The projectile motion part of the experiment, obtained from the laboratory manual, is illustrated as below: In this part

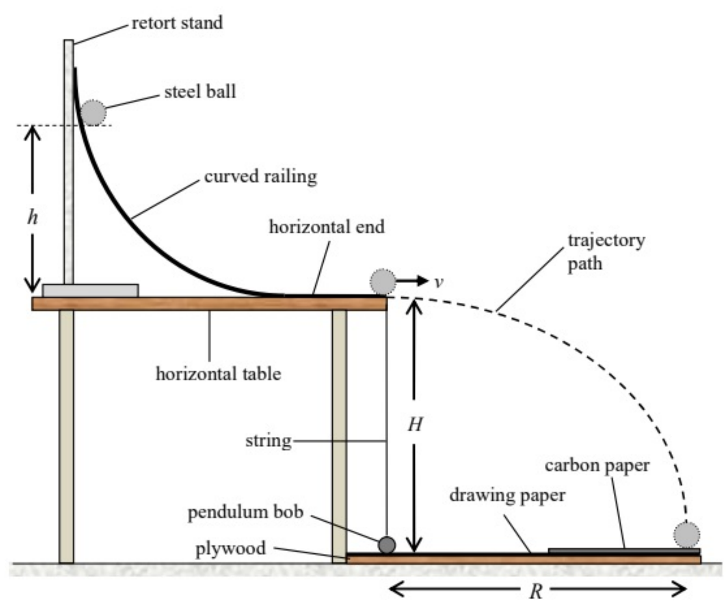

Figure 1. Projectile motion Experiment Set Up

of the experiment the g value is used to relate the height H and range R.

2.1. Tabulation of collected data

Figure 2 shows the data tabulation section of the spreadsheet for free fall experiment. In this experiment, students records the predetermined release height and the time taken for the steel ball to fall in the shaded/coloured area of the spreadsheet. 3 main columns were built - *Height h*, *Time taken T* and *average of the time taken squares* T^2. Since multiple reading reduces the uncertainties, the *Time taken* column is further split into 3 columns - *Reading 1, Reading 2* and *Average Reading.* The calculation of the average reading as well as its square value was programmed into the spreadsheet using the *"=AVERAGE()"* function in *Google sheets.*

Experimental Data Tabulation

Height, h(m)	Time taken (s)			T^2 (m^2)
	Reading 1	Reading 2	Average Reading, T	
0.1	0.1428	0.1428	0.1428	0.0204
0.2	0.2019	0.2019	0.2019	0.0408
0.3	0.2473	0.2473	0.2473	0.0612
0.4	0.2856	0.2856	0.2856	0.0815
0.5	0.3193	0.3193	0.3193	0.1019
0.6	0.3497	0.3497	0.3497	0.1223
0.7	0.3778	0.3778	0.3778	0.1427
0.8	0.4039	0.4039	0.4039	0.1631

Figure 2. Data Tabulation: Free Fall

Experimental Data Tabulation

Height	Range, R(m)			R^2
	Reading 1	Reading 2	Average Reading, R_{ave}	
0.1	0.5345	0.5345	0.5345	0.2857
0.2	0.7559	0.7559	0.7559	0.5714
0.3	0.9258	0.9258	0.9258	0.8571
0.4	1.0690	1.0690	1.0690	1.1429
0.5	1.1952	1.1952	1.1952	1.4286
0.6	1.3093	1.3093	1.3093	1.7143
0.7	1.4142	1.4142	1.4142	2.0000
0.8	1.5119	1.5119	1.5119	2.2857

Figure 3. Data Tabulation: Projectile motion

In the spreadsheet for the second part of the experiment, *Projectile motion experiment*, as shown in figure 3, the variables were changed. Column *Height* remained the same as before but instead of *Time taken*, we have there *Range*. This signifies the range of the falling steel ball acting as a projectile motion in the experiment. Again, the calculation of *Average Reading*, R, and the square of that value is programmed into the spread sheet.

2.2. Theoretical data set

Figure 4 shows the table of theoretical data set, unlike the figures before, we can see that no such shaded/coloured in these tables as the students did not need to input the values. This is because the values were generated by the programmed spreadsheet. The theoretical data set is linked directly to the determined height column found in the collected data tables. The determination of theoretical values was based on the

Theoretical Data	
Height (m)	T^2
0.1	0.0204
0.2	0.0408
0.3	0.0612
0.4	0.0815
0.5	0.1019
0.6	0.1223
0.7	0.1427
0.8	0.1631

Theoretical Data	
Height of release, h (m)	R^2
0.1	0.1527
0.2	0.3054
0.3	0.4582
0.4	0.6109
0.5	0.7636
0.6	0.9163
0.7	1.0690
0.8	1.2218

Figure 4. Sample theoretical data Set

equations found in the Laboratory Manual. Those equations are:

$$h = \frac{1}{2}gT^2$$

and

$$h = \frac{7}{10gt^2}R^2$$

This may act as a guideline as to the values the students are looking for as they performed the experiments. Too big of a deviation may suggest an expected error.

2.3. Centroid, gradient and y-intercept

Calculation :		
Centroid :	(x, y)	
	0.051	0.325
Gradient :	6.433	
y - axis :	-0.002	

(i)Free Fall Experiment

Calculation :		
Centroid :	(x, y)	
	0.41	0.19
Gradient :	0.460	
y - axis :	-0.0008	
t^2 :	0.140	

(ii) Projectile Motion

Figure 5. Sample of Centroid, gradient and y-intercept calculation for: (i) Free Fall Experiment and; (ii) Projectile Motion Experiment

Figure 5 shows the tables for the calculation of centroid, gradient and y-intercept of the 2 experiment, all of which are programmed into the spreadsheet. The calculation of centroid was fairly direct utiling the "*=AVERAGE()*" function for both x and y axes. THe calculation of gradient on the other hand utilized the "*=SLOPE()*" function, with all the values of x and y axes as its input. The y-intercept, on the other hand, makes use of "*=INTERCEPT()*" function in of *Google sheet*.

2.4. Uncertainties

			FREE FALL DATA ANALYZE			
x-axis :	t^2					
y - axis :	h					
x	x - xavg	(x - xavg)^2	y	y cap	y - y cap	(y - y cap)^2
0.080	0.029	0.00082	0.50	0.510	-0.010	0.000091
0.068	0.017	0.00030	0.45	0.436	0.014	0.000191
0.062	0.011	0.00011	0.40	0.394	0.006	0.000041
0.055	0.004	0.00002	0.35	0.350	0.000	0.000000
0.048	-0.003	0.00001	0.30	0.308	-0.008	0.000063
0.041	-0.010	0.00010	0.25	0.260	-0.010	0.000109
0.030	-0.021	0.00044	0.20	0.191	0.009	0.000090
0.024	-0.027	0.00073	0.15	0.152	-0.002	0.000002
0.051		0.00252				0.000587
xavg		Σ (x - x avg)^2				Σ (y - y cap)^2
Δm =	0.00050					
Δg =	0.00099					

Figure 6. Sample of uncertainty calculation for Free Fall Experiment

PROJECTILE MOTION DATA ANALYZE						
x-axis :	R^2					
y - axis :	h					
x	x - xavg	(x - xavg)^2	y	y cap	y - y cap	(y - y cap)^2
0.568	0.517	0.26721	0.26	0.2603	0.000	0.000000
0.465	0.414	0.17163	0.24	0.2131	0.027	0.000722
0.489	0.438	0.19225	0.22	0.2242	-0.004	0.000018
0.440	0.389	0.15111	0.20	0.2014	-0.001	0.000002
0.394	0.343	0.11759	0.18	0.1803	0.000	0.000000
0.410	0.359	0.12871	0.16	0.1876	-0.028	0.000761
0.304	0.253	0.06417	0.14	0.1391	0.001	0.000001
0.250	0.199	0.03947	0.12	0.1140	0.006	0.000037
0.415		1.13215				0.001541
xavg		Σ (x - x avg)^2				Σ (y - y cap)^2
Δm =	0.01705					

Figure 7. Sample of uncertainty calculation for Projectile Motion Experiment

Figures 6 and 7 shows the uncertainty calculations for the free fall set up and the projectile motion set up respectively. As before, the students will only need to key in the data for the x and y axis values of each experiment and that the rest of the table was programmed to take those values as input and use the programmed equations to give an output. This table for uncertainty calculation was obtained from the Laboratory Manual in which it shows the determination of gradient and y-intercept uncertainty. These values are important as they are the variables that are directly compared to the theoretical value of gravitational acceleration, g.

Alternative calculation of uncertainties Aside from the uncertainty calculation based on the Laboratory Manual, *google sheets* offer such analysis through its "*=LINEST()*" function. The authors would like to note here that the comprehension of this level of statistical analysis is not required in the Malaysian Matriculation Physics curriculum, however it serves as an exposure to students with regards to further analysis of linear regression models. The function of "*=LINEST()*" was applied to give an output as shown in figure 8 and figure 9. Ten items were observed to as product product, six of

Slope	4.905	5.55112E-17	intercept
std dev of slope	6.31668E-16	6.50309E-17	std dev of intercept
R^2	1	8.34593E-17	std dev of y
Fisher F stats	6.02976E+31	6	degrees of freedom
regression ss	0.42	4.17927E-32	unexplained variation

Figure 8. Sample of uncertainty calculation for Free Fall Experiment throught LINEST

which are relevant to to a Matriculation student. These six are the slope and its standard deviation, the y-intercept and its standard deviation, the R^2 value, and the standard

Slope	0.35	5.55112E-17	intercept
std dev of slope	1.03185E-16	1.48874E-16	std dev of intercept
R^2	1	1.91061E-16	std dev of y
Fisher F stats	1.15055E+31	6	degrees of freedom
regression ss	0.42	2.19026E-31	unexplained variation

Figure 9. Sample of uncertainty calculation for Projectile Motion Experiment using LINEST

deviation of the y-values of the observed data set. The remaining four items produced are beyond the Matriculation Physics Curriculum, they are the Fisher statistics, the number of degrees of freedom, the regression sum of squares (”*regression ss*”) and the residual sum of squares (”*unexplained variation*”). The remaining four items are crucial only in further analysis, e.g. the Fisher statistics provides insight for the significance of the contingency between the x and y variables.

2.5. Graph plotter

As with any data, visualization is a powerful tool. As such, the spreadsheet was built with the inclusion of a automatically generating graph. This was made possible using ”*Chart editor*” function on *google sheet* where the data range was selected from x and y axis columns of the collected data tables.

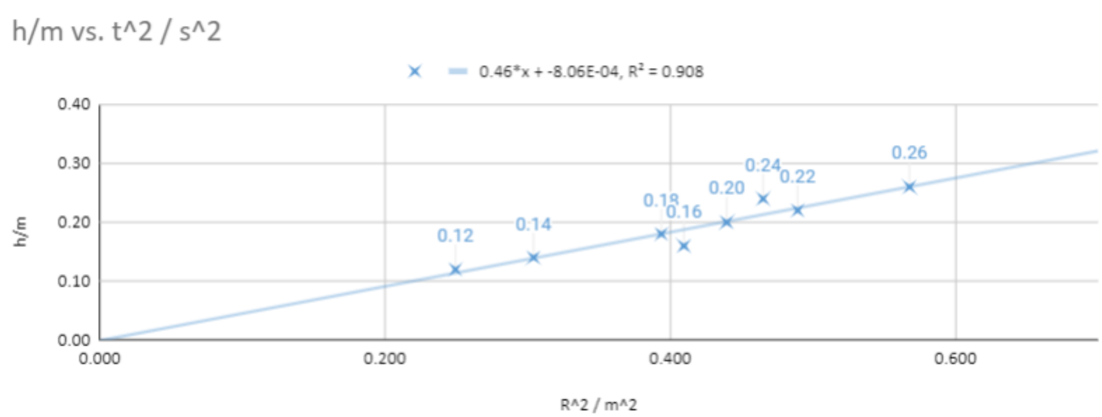

Figure 10. Sample of spreadsheet-generated graph for free fall experiment

A point of interest on this graph plotter is that the we have include within it, the trend line. This gives a visual representation of the gradient as well as the y-intercept. The equation of this trendl ine is also programmed to be generated automatically following the presence of the trend line. In translation, this trend line acts as a substitute of the more traditional ”line of best fit” which is obtained manually, drawn by hand. The algorithms that generates the trend line reflects upon linear regression model

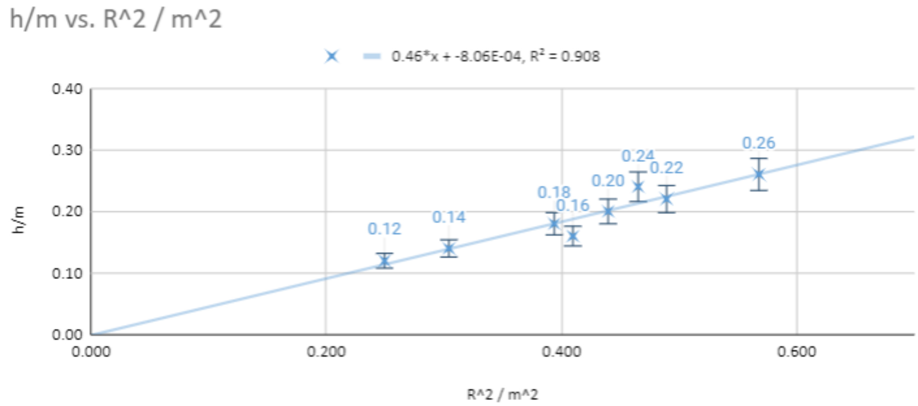

Figure 11. Sample of spreadsheet-generated graph for projectile experiment

analysis through *Google Sheets*in the language of *Javascript* rather than depending on the subjectivity of the traditional case a hand-plotted trend line, or "line of best fit".

2.6. Application of the spreadsheet

Figure 12 shows the flow chart for the execution and the deliverance of the spreadsheet to be utilized by the students. It begins with the building of the spreadsheet by the lecturer, followed by the sharing of the *google drive* link through the smartphone application *Whatsapp*. The results of the experiments are updated in real time as the students are carrying out the experiment. This allows the lecturer to monitor result tabulation via the spreadsheet. The data tables and graphs are then automatically generated and plotted via the spreadsheet. provided. This minimizes the need for the lecturer's presence during the experiment, giving the students more liberty in their experiments. In line with IR 4.0, *google drive*, *google sheets* and *Whatsapp* acts as internet-based platforms that allows the execution and deliverance of the spreadsheet possible.

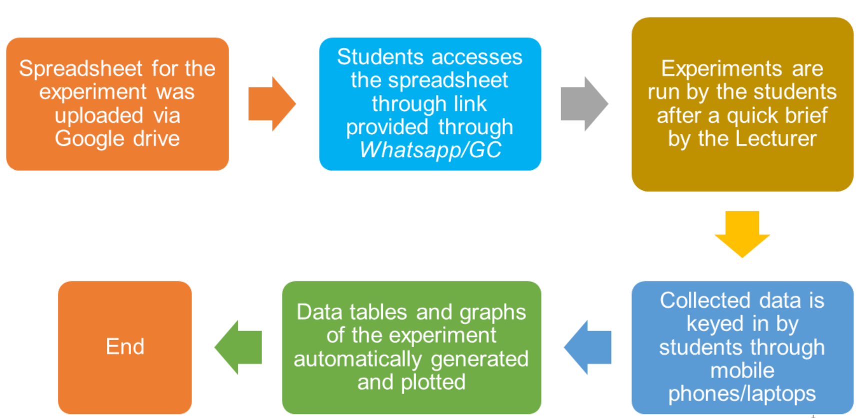

Figure 12. General flow chart in the application of the spreadsheet

3. Student Response

In this section, we summarise an interview and a questionnaire consisting of 4 parts - *Demography, Tabulation of Data, Graph plotting* and *Data Interpretation*. The first part involves the students' gender and prior academic performance. The remaining three part of the questionnaire involves the data tabulation, graph plotting and data interpretation (analysis) using the provided spreadsheet.

The data obtained for these parts of the questionnaire were done in accordance to the Likert Scale [9] , as it seems best fitting. The indicator is provided and the students will respond by choosing which of the given response anchor, where we have chosen to follow "My Beliefs" found in [10]. This 5-point response anchor choice were chosen to be Bipolar. The choice of using a 5-point format was made as it was reported in [11] that the choice of scale showed no difference in terms of standard deviation, skewnness of kurtosis. Data obtained from the 5-point scale is readily transferable to a 7-point format by simple re-scaling methods. This means that using a 7-point or a 10-point format in the future is still possible, if needed in the future.

3.1. Demography

The application of the built spreadsheet was carried out amongst 19 students from Kolej Matrikulasi Kelantan, involving 12 females and 7 males. Within the group of test subjects, their achievement in *Sijil Pelajaran Malaysia* (SPM) in the subject of Physics were recorded. It was found the 26.3% of the students achieved Distinction level merit (A+, A, or A-), 31.6% were low academic performers (C+ or C) and 42.1% were intermediate in their results (B+ or B).

Their achievements in the Mathematics subjects during SPM was also inquired and it was found that, 78.9% of the students were high achievers (A+, A, or A-), the remaining 21.1% saw an equal split of intermediate- and low-level performance. The choice of including SPM Mathematics and Physics results was carried out as effect of the studies relating poor performance in physics and poor prior mathematics knowledge, seen in [12, 13, 14] and [15].

3.2. Tabulation of collected data

In this part, 4 indicators were presented. The first assesses the student's knowledge in using *Google Sheet* as a database for the collected data in the experiment. Of the 19 students who responded to the questionnaire, all of them knows how to use *Google Sheet* as a database., despite the fact (fourth indicator) that 18 out of 19 of them was using *Google Sheet* for the first time for data collection and tabulation. This may suggest that there exist a prior knowledge with regards to the matter.

The most common score for the second and third indicator is in agreement with the statement "Recording data through *Google Sheet* is more systematic" and "Recording data through *Google Sheet* is easier and faster". One student, however, disagreed with

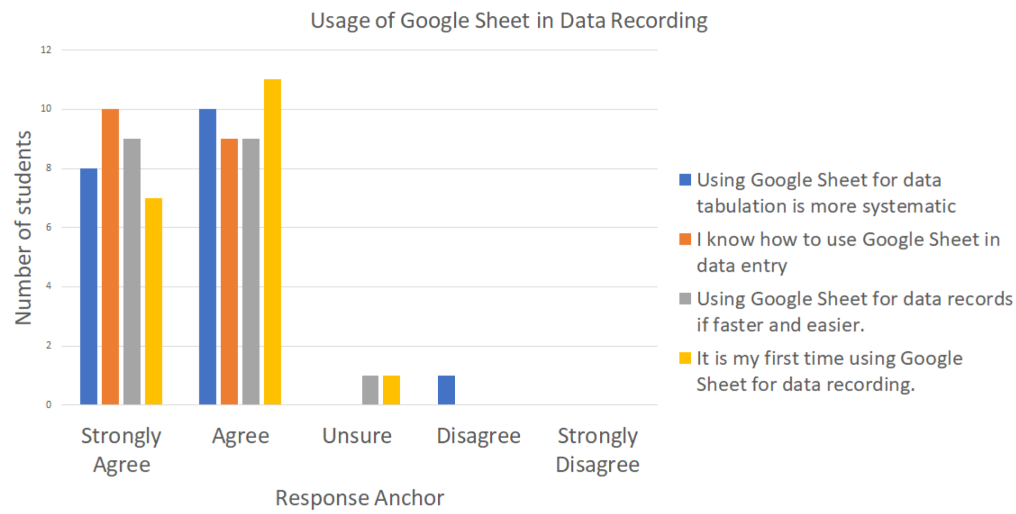

Figure 13. Data Tabulation: Students' response

the second indicator and one student was unsure of their belief if recording via *Google Sheet* is faster and easier. One could of course say that using a *Google Sheet* spreadsheet for the first time may involve a learning curve of some gradient.

3.3. Graph Plotting

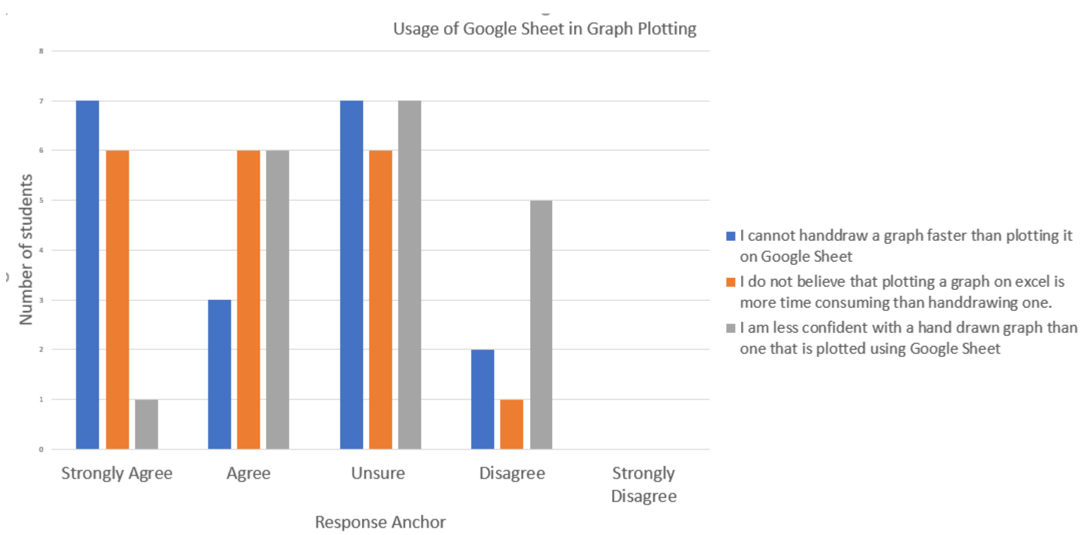

Figure 14. Graph Plotting: Students' response

Referring to figure 14, we can see that there is quite a distribution in terms of response towards the ease of use and the speed of graph plotted. For example, the item of confidence with the plotted graph through Excel has the most students saying that they are unsure with respect to that item. This may be due to their lack of exposure to the algorithms involved in the built of the spreadsheet.

Speaking of speed, the number of students peaked at 2 point on the Likert scale, once at the "Strongly agree" and once at "Unsure". One can deduce that the students are unable to form a strong opinion on the matter. But those who able to, seems to agree that they are unable to plot a graph in the traditional manner faster than, through *Google Sheets*.

On the matter of time consumption, it seems that majority of the students agree that they do not consume more time by plotting graphs on *Google Sheet*, instead of handdrawing them. 7 of the students responded that they are unsure with the time consumption factor but one student disagree, claiming that they unable to save more time by plotting graphs using *Google Sheet*.

3.4. Data interpretation

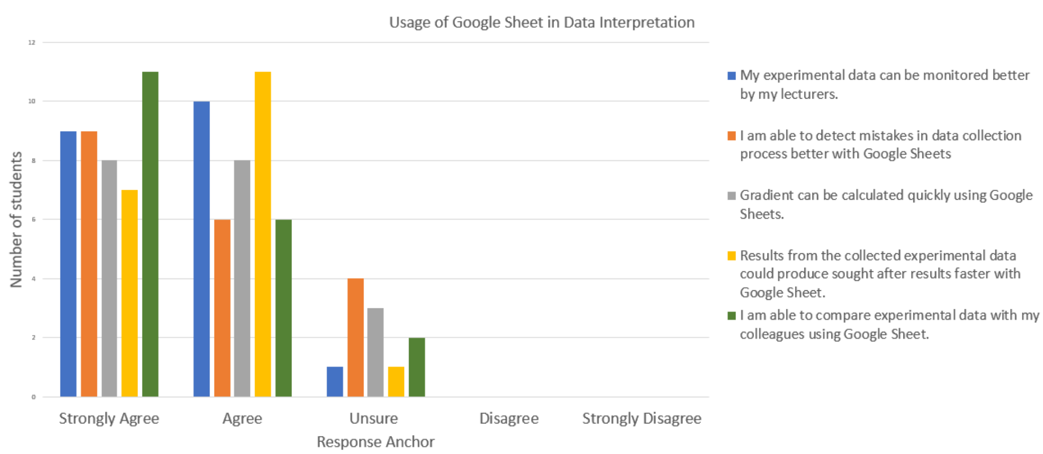

Figure 15. Graph Interpretation: Students' response

On the part of *Data Interpretation*, it is found that majority of the students are supportive in that the use of *Google Sheet* does help them in data interpretation. . For all items, the number of students that is marked "*unsure*" is insignificant, accounting for only 14% of the whole sample. The highest number of "*unsure*" students (at 4 out of 19 students) was found in for the item of "detecting mistakes in the data collection process".

3.5. Interview

The interview was carried out on 10 students. Overall, positive response were received from all the students. As a result of the interview, two points are to be reported.

One, the students reported the steep learning curve of learning to analyse data using *Google Sheet*. According to 7 out of 10 of the students interviewed, This steep learning curve was the reason of that they spent more time on being unsure if the spreadsheet in *Google Sheet* was time-saving. But overall, they agreed that with frequent use, time consumption will be reduced significantly.

Two, the use of *Google Sheet* provides them with a higher level of awareness with the readily available tools for data analysis that were not exposed to them prior to using *Google Sheet*.

4. Conclusion

In this paper, we have demonstrated the spreadsheet structure for the experiment of *Experiment 2: Free Fall and Projectile Motion*. The richness of built-in functions and plotting capabilities found *Google Sheet* has made it a attractive choice in the data analysis section of the lab report preparation process. It is shown that it is not a daunting task for a Physics lecturer to build such spreadsheet for the students' use. To add to that, the ability of linking *Google Sheet* to the cloud service *Google Drive* further extends the advantages of utilizing it in the Malaysian Matriculation environment. The students' response to the usage of *Google Sheet* has also been positive. It it easy to see the advantages of the utilization of *Google Sheet* in the Malaysian Matriculation Physics Laboratory Sessions:

(i) The browser-based software is readily available for free,

(ii) In the case of an internet connection failure, it is easily adaptable to MS Excel.

(iii) The same objective can be achieved, considering the short period of time in a student's Matriculation study.

(iv) The skills obtained from learning *Google Sheet* and spreadsheet software alike can be translated into the real world, considering that the world is undergoing the fourth Industrial Revolution.

(v) It acts as a stepping stone for the programming,especially considering that Object Oriented Programming has become a compulsory subject in Malaysian Universities [16], especially for those in module 1 who does not undergo any programming lessons.

The adoption of such methodologies in the Malaysian Matriculation Physics Program potentially goes a long way, not just for future undergraduate physics students of the future, but for all.

References

[1] Thomas Haigh, Mark Priestley, and Crispin Rope. Los alamos bets on eniac: Nuclear monte carlo simulations, 1947-1948. *IEEE Annals of the History of Computing*, 36(3):42–63, 2014.

[2] Nicholas Metropolis and Stanislaw Ulam. The monte carlo method. *Journal of the American statistical association*, 44(247):335–341, 1949.

[3] RD Richtmyer. Proposed numerical method for calculation of shocks. *LANL Report, LA*, 671:1–18, 1948.

[4] Tim Berners-Lee. The original http as defined in 1991. *World Wide Web Consortium (W3C)*, 1991.

[5] George B Lansbury, DM Alexander, J Aird, P Gandhi, D Stern, Michael Koss, I Lamperti, M Ajello, A Annuar, RJ Assef, et al. The nustar serendipitous survey: Hunting for the most extreme obscured agn at¿ 10 kev. *The Astrophysical Journal*, 846(1):20, 2017.

[6] Zsuzsanna Szalayné Tahy. How to teach programming indirectly–using spreadsheet application. *Acta Didactica Napocensia*, 9(1):15–22, 2016.

[7] Microsoft Malaysia. Kementerian pendidikan lancar pelantar pendidikan digital baharu dengan kerjasama google, microsoft dan apple. *https://news.microsoft.com/*, Jun 2020.

[8] Matriculation Division. *Physics Laboratory Manual SP015 & SP025*. Matriculation Division of the Ministry of Education Malaysia, twelfth edition, 2020.

[9] Rensis Likert. A technique for the measurement of attitudes. *Archives of psychology*, 1932.

[10] Wade M Vagias. Likert-type scale response anchors. 2006.

[11] John Dawes. Do data characteristics change according to the number of scale points used? an experiment using 5-point, 7-point and 10-point scales. *International journal of market research*, 50(1):61–104, 2008.

[12] HT Hudson and Ray M Rottmann. Correlation between performance in physics and prior mathematics knowledge. *Journal of Research in Science Teaching*, 18(4):291–294, 1981.

[13] Jaime Maerten-Rivera, Nicholas Myers, Okhee Lee, and Randall Penfield. Student and school predictors of high-stakes assessment in science. *Science Education*, 94(6):937–962, 2010.

[14] Ömer Delialioğlu and Petek Aşkar. Contribution of students' mathematical skills and spatial ability of achievement in secondary school physics. *Hacettepe Üniversitesi Eğitim Fakültesi Dergisi*, 16(16), 1999.

[15] Warren Wollman and Frances Lawrenz. Identifying potential "dropouts" from college physics classes. *Journal of Research in Science Teaching*, 21(4):385–390, 1984.

[16] Norazlina Khamis and Sufian Idris. Investigating current object oriented programming assessment method in malaysia's universities. *Proceeding of ICEEI*, 2007.