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EFFECTIVENESS OF GRAVI-STEM MODULE TOWARDS HIGHER-ORDER THINKING SKILLS (HOTS) IN GRAVITATION TOPIC

KEBERKESANAN MODUL GRAVI-STEM TERHADAP KEMAHIRAN BERFIKIR ARAS TINGGI (KBAT) BAGI TOPIK KEGRAVITIAN

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Abstract: The Gravi-STEM module integrates STEM teaching and learning based on an Inquiry-Based Learning (IBL) strategy that can assist the students in improving Higher Order Thinking Skills (HOTS) which was developed by employing Sidek's Module Development Model. The aim of this study is to determine the effectiveness of the Physics Gravi-STEM module in improving HOTS of Form Four students in the state of Perak, Malaysia, specifically in Gravitation topic. The study employs a quasi-experimental design of non-equivalent groups pre-post tests design involving 61 students from two different schools by utilizing the Pre and Post-HOTS tests as the instruments of this study. The finding from the independent sample t-test indicates a significant difference in the post-test scores between the treatment and control groups, with an effect size of 1.804 (very strong). Further analysis by comparing the pre-test and post-test for each group using paired sample t-test supports the above finding that the students of the treatment group have significantly improved their HOTS in the topic with an effect size of 1.191 (strong). Hence, there is a possibility that the Gravi-STEM Module could be used in other secondary schools in Malaysia to effectively improve students' HOTS in Physics, specifically in Gravitation topics.

Keywords: STEM, module, physics, gravitation, HOTS

***Abstrak**: Dibangunkan menggunakan Model Pembangunan Modul Sidek, Modul Gravi-STEM mengintegrasikan pengajaran dan pembelajaran STEM berdasarkan strategi Pembelajaran Berasaskan Inkuiri (PBI) yang dapat membantu pelajar dalam meningkatkan Kemahiran Berfikir Aras Tinggi (KBAT). Tujuan kajian ini ialah untuk menentukan keberkesanan modul Fizik Gravi-STEM dalam meningkatkan KBAT murid Tingkatan Empat di negeri Perak, Malaysia, khususnya dalam topik Kegravitian. Kajian ini menggunakan reka bentuk kuasi-eksperimen dengan reka bentuk ujian pra-pasca kumpulan yang tidak setara yang melibatkan 61 pelajar dari dua sekolah yang berbeza dengan menggunakan Ujian Pra dan Ujian Pasca KBAT sebagai instrumen kajian ini. Dapatan daripada ujian-t sampel bebas menunjukkan perbezaan yang signifikan bagi min skor pasca ujian antara kumpulan rawatan dan kawalan, dengan saiz kesan 1.804 (sangat kuat). Analisis lanjut dengan membandingkan ujian pra dan pasca ujian untuk setiap kumpulan menggunakan ujian-t sampel berpasangan menyokong dapatan di atas menerusi peningkatan KBAT yang ketara bagi murid kumpulan rawatan dengan saiz*

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kesan 1.191 (kuat). Justeru itu, Modul Gravi-STEM amat berpotensi untuk digunakan di sekolah menengah yang lain di Malaysia bagi meningkatkan KBAT murid dengan efektif khususnya dalam topik Kegravitian.

Kata kunci: *STEM, modul, fizik, kegravitian, KBAT*

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INTRODUCTION

Science education and technology are inextricably linked as a result of technological advancements that have unavoidably influenced education. Globally, it is widely acknowledged that science plays a significant part in promoting technological innovation and preparing competitive and innovative future students. This includes Malaysia, which has seen a series of radical and dynamic reforms in its educational system, including a freshly redesigned curriculum specification for science topics tailored to local students.

However, the poor level of performance in Science and Mathematics, as well as the decreasing enrollment of students in STEM majors in Malaysia, are indicators of students' lack of grasp of basic concepts in Science topics, particularly Physics (Lilia Halim & T. Subahan Mohd Meerah, 2016; MOE, 2016; MOE, 2020), whereby a substantial percentage of secondary school students regard physics to be a boring and difficult subject (Farrell & Ventura,1998). Furthermore, students' misconceptions and poor levels of HOTS have been a major problem for them in solving problems, especially those that involved mathematical equations that gradually led to a loss of interest in the subject (Khalijah et al., 1995). This finding is backed by Chiu (2016), who argues that physics disciplines are frequently characterised as difficult since they include complicated mathematical analysis among outstanding, medium, and weak students. Students must be able to explain the gravitation concept with the inclusion of an "invisible" force, adding the severity for them to comprehend the concepts of gravity (Kavanagh & Sneider, 2007; Halloun & Hestenes,1985). Moreover, concerns such as a lack of effective teaching and learning (T&L) approach (Edy Hafizan Mohd Shahali et al., 2019) are among the causes that impede students from getting interested in the gravity topic, leading to a low level of HOTS among Malaysian students in general.

While according to an IEA report by Neidorf et al. (2020), the level of students' ability in solving problems related to HOTS questions has been exposed, particularly in the gravitation topic, where the Trends in International Mathematics and Science Study (TIMSS) data shows Malaysia is among the countries where at least one-third of students have been unable to solve problems, including questions that were categorized as HOTS. This analysis supports the findings of the MOE (2012), which stated in the PPPM 2013-2025 that Malaysia's learning strategy embracing HOTS has not yet achieved adequate levels. While to complicate things, according to Mohd Yusri Kamarudin et al. (2016), Tze et al. (2017), Norlizawaty Baharin et al. (2018), and Maruthai (2017), most educators do not fully understand how to integrate HOTS into their pedagogy and have very limited the time to do so. This perfectly illustrates that teachers lack the capacity to include both hands-on and mind-on activities in their teaching,

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and most students could miss out on the chance to enhance their innovation, creativity, and HOTS.

Thus, in this study, the researcher took the initiative to develop and study the effectiveness of the Gravi-STEM Module by incorporating the Inquiry-based Learning (IBL) approach and STEM T&L strategy. Utilising the second stage of the module development in the Sidek Module Development Model, this study was conducted to determine the effectiveness of the module towards improving students' HOTS, specifically in the Gravitation topic.

Objectives of the Study

The purpose of this study was to assess the effectiveness of the Gravi-STEM Module in enhancing form four students' HOTS in the state of Perak. The following research questions are being addressed by this study:

1) Is there any significant difference in the mean score of the post-test between the control and treatment groups?
2) Is there any significant difference in the mean score between the pre-test and post-test of the control and treatment groups?

Scope And Limitations

A sample size of 61 students from two secondary schools, which are both located in different districts of Perak, was chosen as the population in this study to reflect the proportion of Form Four students in Perak, Malaysia. Only the Gravitation topic in Physics was explored in this research, which included two subtopics of Newton's Law of Universal Gravitation and Kepler's Law. These subtopics were selected as fundamental yet crucial elements in understanding a more complex concept in the Gravitation subtopics. Furthermore, the study is restricted to only two secondary schools in Perak.

METHODOLOGY

Developed through rigorous phases utilising the Sidek Module Development Model in which both the IBL and STEM strategy were well incorporated, the Gravi-STEM Module has good content validity and excellent reliability based on the experts' consensus and pilot study. Comprising with subsections such as IBL guidelines, teachers' daily lesson plan (RPH), illustrations of STEM-based models' construction, worksheet and formative assessment, teachers could utilise this module in implementing Classroom Assessment (PBD) to evaluate the students' Performance Level (TP) in Content Standard (BP) 3.0 Gravitation as enclosed in the Curriculum and Assessment Standard Document (DSKP) KSSM Physics Form 4.

A post-test was administered on the students for both groups one week after each intervention ended. Data gathered were analyzed using SPSS through an independent sample t-test and paired sample t-test.

Instruments

The instruments used in this study were pre and post-tests, namely the Pre and Post-HOTS Test. Items in the test were adapted from PISA examination under the gravitation theme as well

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as adapted from the Physics Form 4 textbook published by MOE of Malaysia. The instruments have been validated by three content experts and one language expert prior to evaluate whether the module objectives could be achieved.

RESULTS AND DISCUSSION

Descriptive Analysis of HOTS Tests for Treatment and Control Groups

As referred to Table 1, based on the values of the mean score and the standard deviation obtained, the treatment group's statistical data shows that the mean score was higher (M=10.30, SD=3.975) compared to the control group's mean score for the Pre-HOTS test (M=17.20, SD=2.987).

Table 1: Statistical Data for the Treatment Group's Pre-Post HOTS Test

Test (HOTS) Treatment	N	Mean	Standard Deviation (SD)
Pre	30	10.30	3.975
Post	30	17.20	2.987

Meanwhile, based on the values of the mean score and the standard deviation obtained in Table 2, the mean score for the Post-HOTS test also shows an increase (M=10.81, SD=3.807) compared to the mean score for the Pre-HOTS Test (M=10.90, SD=3.919) for the control group.

Table 2: Statistical Data for the Control Group's Pre-Post HOTS Test

Test (HOTS) Control	N	Mean	Standard Deviation (SD)
Pre	31	10.81	3.807
Post	31	10.90	3.919

In addition, Table 3 shows the mean score and standard deviation of the Pre-HOTS Test between the treatment group and the control group, with the lower mean pre-test score of the treatment group (M=10.30, SD=3.975) compared to the mean score of the control group (M=10.71, SD=3.770).

Table 3: Statistical Data for Treatment and Control Group’s Pre-HOTS Test

Pre Test (HOTS)	N	Mean	Standard Deviation (SD)
Treatment	30	10.30	3.975
Control	31	10.81	3.807

Meanwhile, Table 4 shows the mean score and standard deviation of the Post-HOTS Test between the treatment group and the control group, with the higher mean score of the treatment group (M=17.20, SD=2.987) when compared to the control group's mean score (M=11.16, SD=3.813).

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Table 4: Statistical Data for Treatment and Control Group's Post-HOTS Test

Post Test (HOTS)	N	Mean	Standard Deviation (SD)
Treatment	30	17.20	2.987
Control	31	10.90	3.919

Independent Sample t-Tests for Post-HOTS Tests of Treatment and Control Group

The results of the Levene Test for Equality of Variances against the Post-HOTS Test showed no difference in variance between the treatment group and the control group with $p = .128$ ($p > .05$). Thus, the t-test analysis is selected from the Equal Variants Assumed in Table 5.23 with sig. (2-tailed) $p = .000$. From the independent sample t-test analysis of the Post-HOTS Test, there was a significant difference ($p < .05$) in the mean of Post-HOTS Test scores between the two groups. The mean score of the treatment group ($M=17.20$, $SD=2.987$) was higher than the mean score of the control group ($M=10.90$, $SD=3.919$) with $t(59) = 7.040$, $p < .05$, $d = 1.804$, that is, the Effect Size that showed a very strong magnitude based on Cohen (1988) and Sawilowsky (2009).

Therefore, the indicators showed that the performance of the treatment group in solving problems involving HOTS was significantly better than the control group after undergoing the intervention using the Gravi-STEM Module. Effect Size with very strong magnitude (Cohen, 1988 and Sawilowsky, 2009) for the Post-HOTS Test between treatment and control groups became an indicator of the high efficacy of using the Gravi-STEM Module in improving students HOTS compared to conventional T&L methods. Table 5 shows a descriptive analysis of the Post-HOTS Test for the treatment and control groups.

Table 5: Independent Sample t-Tests for Post-HOTS Tests of Treatment and Control Group

	Levene Test for Equality of Variances		t-test for Equality of Means		
	F	**Sig.**	**t**	**df**	**Sig. (2-*tailed*)**
Equal variances assumed	2.384	.128	7.040	59	.000
Equal variances not assumed			7.072	55.969	.000

Paired Sample t-Test for the Treatment and Control Group's Pre-Post HOTS Test

Analysis of paired sample t-test was conducted on Pre and Post-HOTS Test of the treatment group showed that there was a significant difference between the Pre-HOTS Test scores ($M=10.30$, $SD=3.975$) compared to Post-HOTS Test ($M=17.20$, $SD=2.987$) and $t(29) = -6.526$, $p < .05$, $d = 1.191$, showing the Effect Size in a strong magnitude based on Cohen (1988) and Sawilowsky (2009) as shown in Table 6.

Table 6: Paired Sample-t-Test for the Treatment Group's Pre and Post-HOTS Test

Treatment Group	Paired Differences		t	df	Sig. (2-tailed)
	Mean	**Standard Deviation (SD)**			
Pre-Post Test (HOTS)	-6.900	5.791	-6.526	29	0.000

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However, for the control group as shown in Table 7, there was no significant difference between the Pre-HOTS Test scores (M=10.81, SD=3.807) compared to the Post-HOTS Test scores (M=10.90, SD=3.919) with t (30) = -1.793, p > .05, d = 0.322, with the Effect Size showing a weak magnitude based on Cohen (1988) and Sawilowsky (2009).

Table 7: Paired Sample-t Test for the Control Group's Pre and Post-HOTS Test

Control Group	**Paired Differences**		**t**	**df**	**Sig. (2-tailed)**
	Mean	**Standard Deviation (SD)**			**Mean**
Pre-Post Test (HOTS)	-0.097	0.301	-1.793	30	0.083

Thus, based on the descriptive analysis of Pre and Post-HOTS Tests obtained from the treatment and control groups as shown in Table 6 and Table 7, this analysis shows a significant improvement in post-HOT test scores compared to the Pre-HOTS Test scores for the treatment group after undergoing the intervention using the Gravi-STEM Module compared to the control group, which also supported the previous analysis done using an independent sample t-test. The Effect Size for the treatment group showed a strong magnitude (Cohen, 1988; Sawilowsky, 2009) compared to the Effect Size of the control group, which showed a weak magnitude, thus indicating that the Gravi-STEM Module exposure was very effective at improving students' HOTS in Gravitation topic compared to conventional T&L methods.

From the findings, the exposure of the Gravi-STEM Module to students showed a positive and significant impact in effectively improving the students' HOTS. After Pre-HOTS Tests were performed on the treatment group and control group before the two groups underwent the intervention through the use of the Gravi-STEM Module and conventional T&L, an independent sample t-test analysis showed no significant difference between the mean of Pre-HOTS Test scores for the two groups. The findings from the analysis also showed that the HOTS levels for both groups were moderate, and both groups had equivalent levels of HOTS. These findings are important in ensuring that both groups have the same level of cognitive before the two groups are exposed to their respective interventions.

Based on an independent sample t-test analysis to compare the mean of post-test scores between the treatment and control groups, there was a significant difference in the mean score between the two groups after the group was exposed to their respective interventions, with Effect Size showing a very strong magnitude. Through analysis of paired sample t-test of the Post-HOTS Test compared to the Pre-HOTS Test, the mean score for the treatment group was found to increase significantly ($p < .05$) as well as the Effect Size in a strong magnitude range compared to the control group. Thus, the findings bring empirical evidence that the intervention through the use of the Gravi-STEM Module is able to effectively increase the level of students' HOTS, specifically in the Gravitation topic. Figure 1 shows the graph of the mean scores for Pre and Post-HOTS Tests for both groups.

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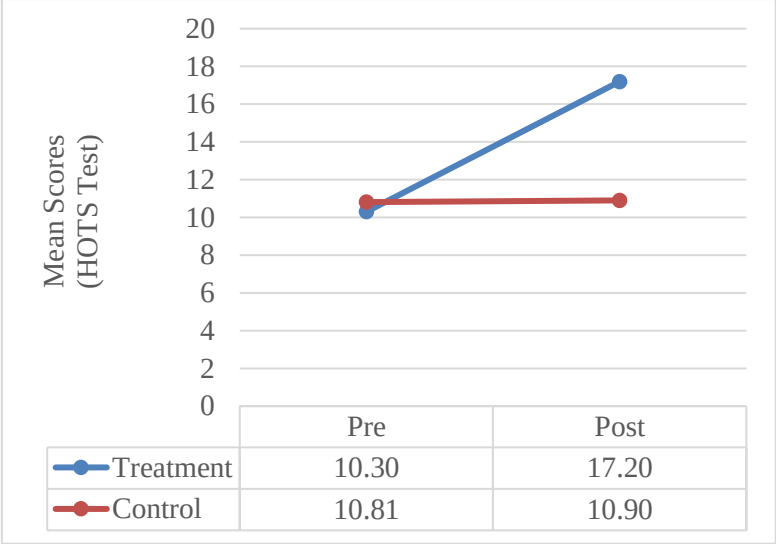

Figure 1: Mean scores for Pre and Post-HOTS Test

When compared to previous studies, there are similarities in terms the increase of HOTS in which the students of the treatment group underwent the intervention using the Gravi-STEM Module. The similarity can be seen in terms of the effectiveness of the IBL-based T&L method in the improvement of students' HOTS, even though the scope of the studies is beyond the topic of Gravitation. Among the previous studies are by Mohamed (2008) through the POGIL method, a study by Nur Fadhila Baharudin (2016) through the use of PBM-SC2 Module and also a study by Nurashikin Muzafar (2015), which implemented the inquiry phases in the Bio Three Module. In addition, the findings of this study also confirm the findings by Vidergor (2017) that through the integration of the IBL in T&L, students were given the opportunity to apply productive thinking skills, problem-solving skills and activities that promote creativity, thus leading to the improvement of HOTS. These findings also confirmed the findings by Kwan and So (2008), Hofstein et al. (2004) as well as Hofstein and Marnlok-Naaman (2007) that the integration of IBL indirectly changed the learning environment to active learning, thus having a positive impact on improving the cognitive, affective and psychomotor of students that are translated through a significant improvement in students' HOTS.

In addition, the findings of this study have expanded further the idea in terms of the improvement of students' HOTS through T&L exposure with the IBL and STEM approach as proposed by Slough and Milam (2013), which supports that the STEM approach is indirectly capable of nurturing students' HOTS. From the aspect of the effectiveness of STEM-based modules on HOTS, the findings of this study have supported the findings of past studies despite differences in the scope of subjects, but the findings of this study have brought emperical evidence of the effectiveness of STEM-based modules for physics subjects specifically in the topic of Gravitation. Among them are the findings by Nurul Huda Kasim (2019) through the use of PRO-STEM Modules, findings by Ahmad Adnan Mohd Shukri, Che Nidzam Che Ahmad, and Norhayati Daud (2019) through the use of STEM Celik Module, findings by Reni Dwi Puspitasari, Kartini Herlina and Agus Suyatna (2020) through the use of STEM-based E-Modul as well as findings by Sri Retnowati, Riyadi and Sri Subanti (2020) through the use of Rectangular Module with a STEM approach. As stressed by Parno, Yuliati & Ni'mah (2019)

as well as Purwaning Budi Lestari, Wijayanti Point and Tri Asih Wahyu Hartati (2020), STEM-based PdP is able to make a significant impact in nurturing students to problem-solving skills through the skills of interpreting, analyzing and sorting problems according to priority. Thus, this finding also opens up a new dimension in considering IBL and STEM integration in physics T&L as an alternative yet effective strategy to students' HOTS, specifically in the topic of Gravity.

CONCLUSION AND RECOMMENDATIONS

In general, students are given the ability to shape their learning by participating actively in each phase of the T&L session through the implementation of the Gravi-STEM Module, as teachers merely serve as facilitators. As a result, the impact of integrating learning based on the approach of learning with the integration of STEM and IBL has enabled students to foster their HOTS by providing space and opportunities for them to apply productive thinking skills, problem-solving skills, and activities that promote creativity.

It is hoped that the findings of this study, which shows that the T&L approach with the integration of IBL and STEM applied through this module has a positive and effective impact on students' HOTS, will benefit all stakeholders in the national education system, particularly the MOE, teachers, and students. The findings of this study are crucial, particularly in developing educational policy in which educators and stakeholders should take the lead in investigating educational challenges so that urgent improvements can be achieved.

Following to the perspective of this study, the curriculum that emphasised full dependence on teacher-centered dynamics left little possibility for meaningful conversation among students or between students and instructors, resulting in students acting exclusively as recipients by retaining all the information. Apart from ensuring that the students are able to grasp all the concepts, critical considerations should be considered to examine the best learning approaches and strategies so that meaningful learning is successfully produced every time T&L is implemented to bring out new changes to the science curriculum. With this, students' HOTS, as well as their keen interest in science subjects, especially physics, can be nurtured to have a positive impact on the future of the country's human capital in the field of science and technology.

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