

Visual and Kinesthetics Learning Adopting Student as Trendsetter via 3D Printing Kits to Enhance Understanding of Physics Theorem

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Abstract: Physics is a branch of science that often difficult for students to visualize the concepts hence deteriorate their interest in learning science. Adopting 3D printing technology in providing better visualization and interaction with three-dimensional models can ease the learning experience. Hence, the aim of this study was to develop 3D printed models as tool to help students understand the physics concepts through trendsetter-student approach and consequently the impact was investigated. The results showed that this approach demonstrated significant positive impact on the student's critical thinking and learning gain through visualizing the abstract concepts and enhanced their understanding. Ergo, the project is expected to greatly revolutionize educator-coordinated learning of physics through engaging education for the framework of 10-10 MySTIE Socio-economic drivers.

Keywords: *3D printing; gifted student; rapid prototyping; student-oriented; teaching aid*

1. Introduction

Expertise, modernization, cyber security, Internet of things (IOT), advance knowledge, are the key factors in Industry 4.0 which regulate a developing country like Malaysia to become a developed nation. In the year of 2020, Malaysia requires at least 500,000 registered scientists and engineers to achieve the demand in Industry 4.0 according to the National Council for Scientific and Research Development. However, currently, only 17% of the figure were registered engineers. Therefore, demands of human capital for high-tech economy must be prepared and thus the Malaysia education system must be in line with the needs of Industry 4.0 and apparently for science, technology, engineering and mathematical (STEM) education [2].

The revolution of education system is unavoidable to preserve an economic expansion and stimulate investment in

a country. The framework of education industry will exemplify the stakeholder's role in education that will portray the success of the goals and the output [3]. The concern of the world and including in Malaysia also facing the same issue and currently even though variety of endeavors have been done to enhance their STEM education practitioners, students' interest in STEM is diminishing throughout their schooling period. Consequently, the numbers of students deviated from the STEM fields when pursuing tertiary education has decreased [2,4].

This occurs even though the substantial role of our educators and their method of delivery are proportionate with the international level. However, the complexity in understanding the basic principles of science and mathematics even at the inception or early introduction of STEM has demotivated and disinterest students in engage with STEM education [5-9]. Besides, the interest of the new

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generation is not even remotely coherent with the educators' expectations which creates more dilemma in delivering complex topics in the classroom [4].

Being the most basic and essential part of sciences field, Physics is all about study on energy and conversion of energy, properties of matter and interaction of matter to solve many problems related to society and consequently contribute to the development of knowledge applications for science and technology [5, 10-12, 14]. It is also a natural occurrence study that manages with the behavior of the universe from the smallest particles of cosmology [12-13]. In learning physics, students are required to have a preliminary understanding on mathematics and science conception as physics as it aims to apply the theory and concept in the form of scientific method that involves problem solving skills towards everyday life [11, 13-14].

However, the deteriorating interest of school students in Physics becomes alarming sign the Physics stakeholder and the nation to take actions to resolve this matter. Previous study has been conducted to investigate the elements that affect students' interest in Physics. The finding showed that the highest augmentation towards this paradox was the pedagogical approaches used by the educators and followed by the complexity of the subject itself. It demonstrated that inadequacy of pedagogical design and delivery expedite to student's inferior performance in physics [4, 15-16]. This also due to the teacher-centered approach applied by the educators that creates negligence among the students without the involvement of students in class [17]. Therefore, an immediate plan and force are necessary to establish a new teaching strategy and consequently improve the educator's performance in delivering the knowledge. A leader in education practices student-to-student bonding which is an exceptional teaching method found to have great achievement in understanding the STEM elements in secondary schools.

The dullness of the physics subject can also be improved by implementing a distinct learning style which corresponds to the students' needs. In parallel, students also must commit to revamp their embracement in physics that is proportional to the educator's approaches. Therefore, this will help in constructing a fun teaching-learning routine for both educators and students [18]. It is too complex theory and concept to be grasp for the students as they cannot visualize the concept and eventually resulting in amplification the problem of student's disinterest in Physics. Meanwhile. An excellent student they also require an effective teaching strategy inside the classrooms for them to grow their knowledge to higher level [4-5].

Integration of three-dimensional printing (3DP) technology in Physics class may serve as an alternative method to improve teaching delivery among the educators. This unique approach can be the key in attract student's diligent to the topic discussed while engaging and encouraging them to embrace an exceptional comprehension

of the topic. In this strategy, students must equip and prepare to explore, interpret and assess any argument in the subject via project-based learning by applying 3DP technology as teaching tool to encourage the students in think critically which leads to their great performance. An alternative learning strategy for implementing 3DP in physics for secondary school students is the conceptual theory in associated with in-depth knowledge through designing process that encourage an active learning. Thus, this approach will expedite a student-centered learning embarkment [19-20].

Meanwhile, 30 National Science, Technology, Innovation and Economy (STIE) Niche Areas for the 10 Socio-economic Drivers (10-10 MySTIE) framework has addressed 10 drivers which include 3D/4D/5D printing technology as one of the main drivers that can be integrated with other sectors such as innovation in education by virtual reality 3D/4D/5D-design and printing for rapid prototyping in engineering and creative arts [19]. Therefore, to meet the industrialized world, the education field must also be in line with the needs in technology and equip these students for better skills and improve their comprehension without extra cost and rapid prototyping through implementation of 3DP and Industry 4.0 into the STEM curricular as an initiative for encouraging students' interest to learn STEM in a fun way [21].

Consequently, the embracement of 3D printing (3DP) technologies in education is expanding as a tool that is found to take advantage of their functionalities to imitate for the wider adoption in technology [20, 22]. Hence, the study focused on determining the difficult topics in physics through a survey among secondary school students which were then used to develop the 3DP kits based on the difficult topics. Subsequently, a module was developed and used as a classroom activity by applying a trendsetter-student approach to investigate the impact of trendsetter and activity effectiveness through 3D printing kits and module.

2. Methodology

2.1 Survey Questions Development

A set of survey questions was chartered to investigate the complexity level in physics chapter based on the National Curriculum of Malaysia. The levels were categorized into easy, normal, hard, and challenging, and the questions were disseminated to 90 students of Kolej GENIUS Insan between the ages of 16 to 17 years old using Google form. Consequently, the difficult chapters on physics were determined after an analysis from the survey was performed. After the analysis was carried out, a few models were selected to be used as kits for classroom activity which suits the chapters and topics such as battery concept for electricity, light and waves phenomenon and cathode ray oscilloscope (CRO) for electronic. A detailed summary of the respondents is shown in Table 1.

Characteristics of respondents

Gender		Age	
Female	Male	16 years old	17 years old
41	49	42	48

2.2 Designing and 3D Printing Process

2D Sketching was done on the selected models as a draft before undergoing 3D designing to create a 3D model. TinkerCAD software was used in designing process of the 3D model. This software is a free, accessible, and straightforward for 3D model design, electronics, and coding which commonly used by educators, school students, hobbyists, and designers to conceptualize, construct and assemble the 3D model.

A stereolithography (.stl) file was engendered from the 3D design and was sliced using prusaslicer to convert the file in a g-code form for printing purposes as the setting and information of the model was stored in the file for printing process was done and it can be read by the 3D printer for the extrusion and movement of the print head which corresponding to the required model.

3D printing process was carried out using Original Prusa MINI with incorporation of polylactic acid (PLA) filament where it is a low-cost polymer-based material to lithograph the 3D model at temperature of 210 °C [23-25]. The 3D model was in a big size and therefore, the model was divided into few components and the printing process was carried out in few stages accordingly. The flow process of designing and printing were incorporated with students.

2.3 Module Development

A module was developed according to the 3D printed models which was used as a hands-on activity in the classroom. Content of the module involving lesson summary, learning objective, methodology including preparation of materials, parts needed and assembly method on the 3D model, designing student activities (theory or concept, history, problem, tasks, testing and evaluation, activity schedule and reflection) and assessment (formative and summative). Subsequently, the 3D printed (3DP) kits module was performed as a tool for the teaching module.

2.4 Trendsetter-student Activity

Implementation on the 3DP kits module was carried out by selecting the trendsetter among the students. The trendsetter acted as an educator for their peers in delivering the knowledge. There were two stages of activity which consist of mentoring and delivering, respectively.

In the mentoring stage, a series of in-depth training was executed for the trendsetter so that they can perform an excellent delivery during the trendsetter-student activity. In addressing the concept in the 3DP kits module. The next stage was the implementation of the 3DP kit module delivered by the trendsetter towards their peers of 90 students.

The module consists of two types of activities, i.e., a) Knowledge transfer by the trendsetter as in Electricity

(concept of parallel and series resistance) and Light and Waves (diffraction and interference), and b) Hands-on activity as in Electronic (component and functions of CRO).

In the knowledge transfer, the trendsetters delivered their knowledge based on the selected topics by addressing the concept through the demonstration of the Electricity and Light Waves kit to their peers. Meanwhile, for the hands-on activity, the peers were divided into groups, and they must complete their task given by the trendsetter, i.e., connecting the component of CRO and explaining their functions followed by a treasure hunt (finding the components of CRO). Each group must modify the CRO component according to their concept and creativity to improve their problem-solving skills. Consequently, reflection of the activity was done by presenting each group finding to the other groups. The flow process of the trendsetter-student activity is presented in Fig. 1.

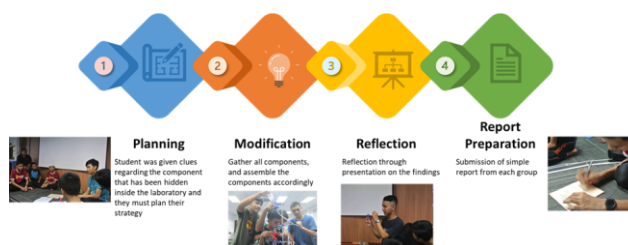


Fig. 1 - Flow process of the trendsetter-student hands-on activity

2.5 Data Collection Procedure

2.5.1 Survey execution

A survey was performed after the trendsetter-student activity to acquire the insight into the learning objective of the module developed which evaluate via 5-point scale (Likert-type) survey questionnaire. The questions asked contains of program effectiveness, trendsetter approaches, effectiveness of the topic and student self-evaluation. Each item in the questionnaire were evaluated to establish its connotation towards in the vicinity of respondents. Responses to the instrument items were deliberated using a construct of 5-point Likert scale. The mark of “5” designated the ‘Strongly Agree’ (SA) response, meanwhile “1” designated to the ‘Strongly Disagree’ (SD) response, respectively. The total instrument items the questionnaire were 36 which divided into four sections which can reflect the leverage of student’s viewpoint towards the trendsetter approach via the 3D printed kits modulated activity. All the results from the assessment and survey were analyzed to acquire the correlation between each item. The summary of the whole process is shown in Fig. 2.

2.5.2 Data Analysis

The survey questionnaire was given to 90 students who participated in the activity. The result of the test was analysed by each question. Quantitative analysis data was applied to obtain the descriptive statistics which was a description or presentation of data in a big number inclusive of mean,

median, and standard deviation [26].

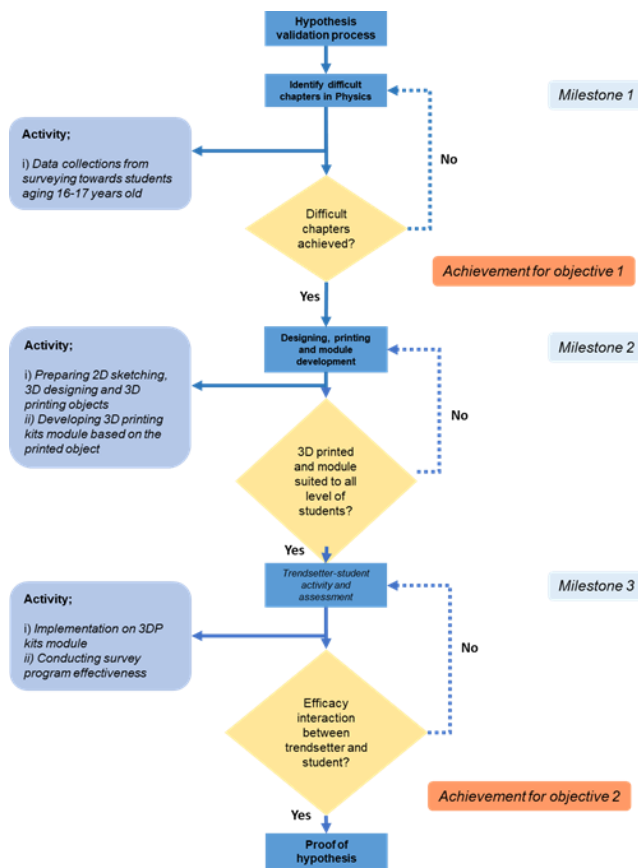


Fig. 2 - Method in applying TPD for finger test

3. Results and Discussion

3.1 Complexity Level of Physics

Fig. 3(a) shows the findings obtained from the survey conducted subject to each Physics chapter and sub-chapter's complexity level by referring to National Curriculum of Malaysia. The results demonstrated that the most pleasant chapter in Physics was Chapter 1 where 52.4% of students selected "easy" as their complexity level and very little percentage of "Challenging", which is 1.6%, was chosen. Meanwhile, the most complex dan difficult chapters in Physics are represented by Chapter 7, 8 and 9 which are Electricity, Electromagnetism and Electronics (3E). These chapters showed the highest percentage for "Challenging" amongst other chapters. This finding can be justified with the result shown in Fig. 3(b) where it showed that the 3E chapters were the highest chapters selected by students at 15-18% that need to be focused and improved. This reflected that these chapters were challenging, hence the students selected these chapters for them to study and focus more on these chapters

for them to excellent in Physics [4]. In addition, Chapter 5 and 6 were also selected as amongst the higher complexity level whereby the percentage of "Hard" and "Challenging" chosen by students were parallel to the greater percentage of improvement must be executed by students.

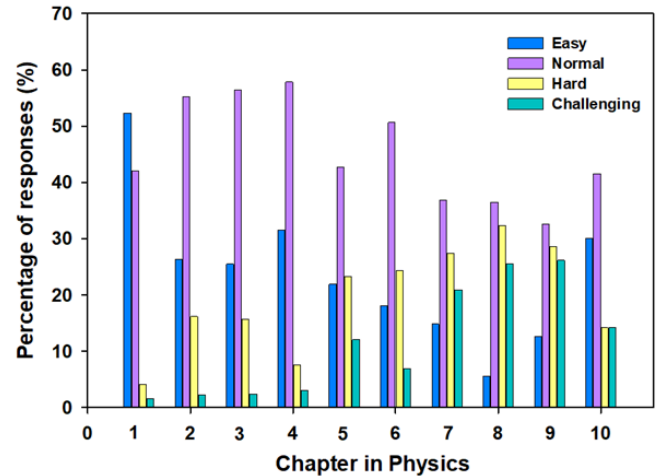


Fig. 3(a) – Complexity Level of Physics chapters

Fig. 3(c) shows student's self-assessment based on their own performance. The percentage was "Poor" which exhibited that the students still need a lot of improvement, probably in all chapters. This correlated with the result shown in Fig. 3(b) where for the easiest chapter (Chapter 1), there were 1.93% students who needed to improve their knowledge. This means that the "Poor" performance students contributed to the improvement to be done on Chapter 1 and to the 1.6% of "Challenging" level in the Complexity Level for Chapter 1; this was vice versa to the outstanding students of 2.3%. This group of students contributed to the 5.6% of "Easy" level in Chapter 8 respectively as shown in Fig. 3(a).

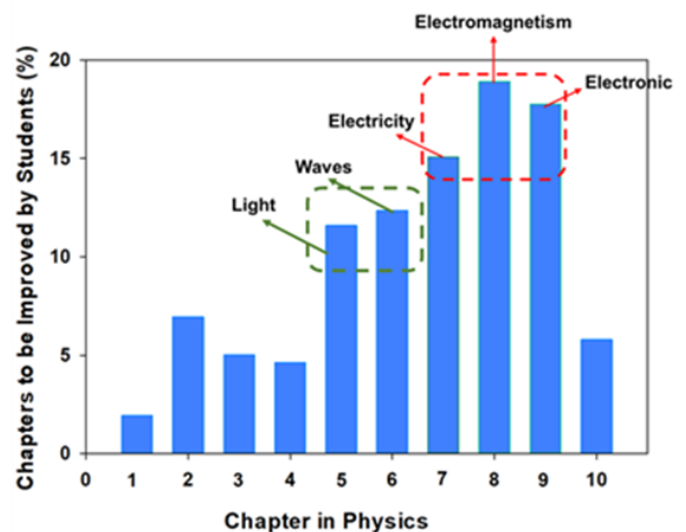


Fig. 3(b) - Percentage of chapter to be improved by students

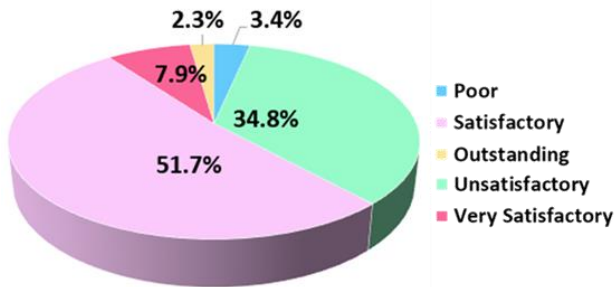


Fig. 3(c) - Percentage student's performance based on student's self- assessment

3.2 3D Models

Fig. 4(a) shows the 2D sketch of one of the models selected, which was CRO, to be developed. The 2D sketching is an important step before designing the 3D model to establish the precise dimension of the models that will be designed and consequently printed. TinkerCAD is a simple 3D software that was utilized in designing the 3D model of CRO in the form of illustration based on the 2D sketch designed. Consequently, the 3D model file was extracted in the form of stereolithography (.stl). Slicing process of the .stl was conducted via Prusaslicer software to alter the setting of the model to be printed including solid content, mesh pattern, position and orientation of the 3D model. Thereupon, the file was then converted into g-code file where only g-code file can be read by 3D printer. [23, 27, 28]. Each of the assembled models were too big to be printed using a 3D printer, hence the models were split into several parts for easier printing. The components of the 3D printed parts and the assembled model of CRO can be seen in Fig. 4(c).

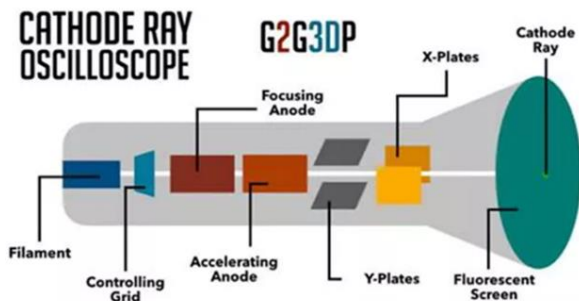


Fig. 4(a) - Illustration model of CRO

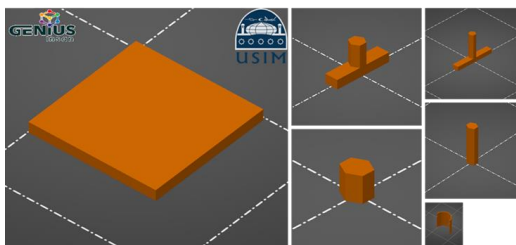


Fig. 4(b) - g-code file for 3D modelling of components in CRO



Fig. 4(c) - 3D printed model parts and assembled model of CRO

3.3 Trendsetter-student Modulated Activity

A teaching module was developed (Fig. 5) as a reference for the modulated trendsetter-student activity which consisted of lesson summary, learning objectives, and details of each activity and assessment. This module was used as a guideline for the trendsetters to transfer their knowledge and convey the modulated activity effectively in the classroom.

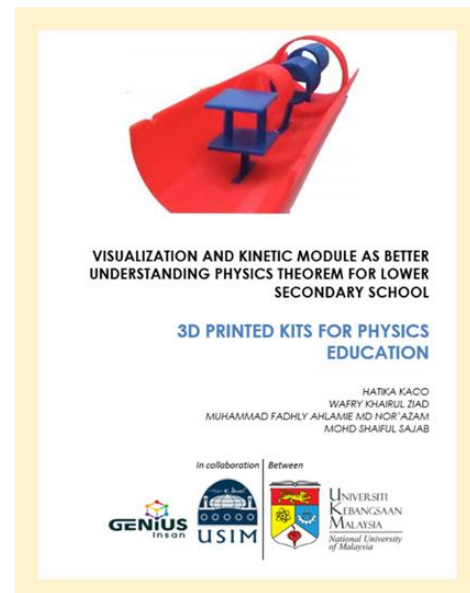


Fig. 5 - Front view of 3D printed kits module

3.3.1 Effectiveness of modulated activity

Fig. 6 shows the results based on the survey questions on the effectiveness of the 3D printed kits modulated activity by referring to the 5-point Likert scale items. 'Strongly Agree' and 'Agree' options presented the highest percentage chosen by 91.4% and only a percentage of 0.14% had chosen 'Strongly Disagree'. Amongst the questions given in Part 1, the highest percentage of "strongly agree" was 1(a) and 1(b), followed by 1(c) where these questions obtained more than 30% of "Strongly Agree". This finding demonstrated that the modulated activity was successfully executed and demonstrated that it is a fun approach towards student's interest in learning physics and eventually conceptual gains when students could use the printed models [29]. However,

only 1 student selected “Strongly Disagree” for question 1(g) which contributed to the 0.14% while there was 0% “Disagree”. This may be because this student did not actively participate in the activity, hence he/she found that the activity did not encourage active learning.

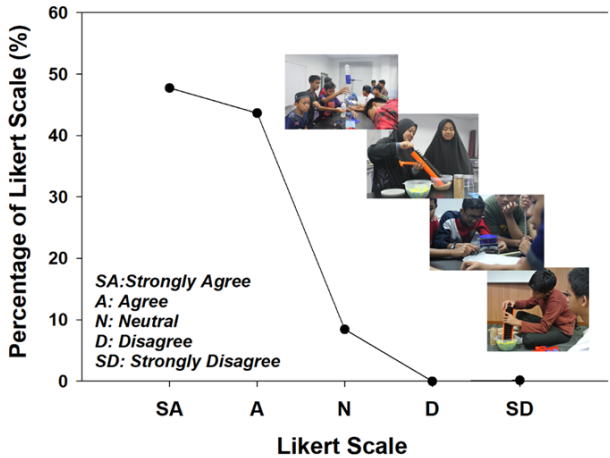


Fig. 6 - Effectiveness of 3D printed kits modulated activity

3.3.2 Effect of trendsetter approach

Trendsetter refers to the first person or group that create a new teaching method in this; and in this context, the trendsetter applied the 3D printing prototyping technology in Physics education. They had been studying Physics since they started secondary school at the age of 13. Fig. 7(a) shows the results for the survey questions on the trendsetter approach by referring to the 5-point Likert scale items. It shows that the students gave positive feedback towards the trendsetter approach where 88% of the students chose “Strongly agree” and “Agree” while only 12% of the students selected neutral. Three main key items emerged from the data collection on the total of “Strongly Agree and Agree”, which were Approachability (n=13.6%), Variety instructional methods (n=13.6%), and Interest (n=13.9%), out of 8 items of the survey questions anticipated by the students towards their trendsetter.

Students’ perceptions towards the trendsetter approach are summarized in Fig. 7(b) which shows the main key items. In “approachability”, the fact that the students established a compatibility or rapport between trendsetter and students which was proven from the results. The students acknowledged in the comment section as the trendsetters were “easy to interact”, “approachable”, “fun”, “friendly”, “informal class”, and “different opinion and view”. More importantly, no student labelled the trendsetter as aggravating, ignorant, or arrogant. The students stated that this trendsetter approach created a variety of instructional methods since there were activities with a few instructions to be followed especially in the hands-on activity involving the 3D printed models. Their comments also referred to the various methods applied where students gained experience to “learn together”, “two ways learning”, “communication with friend”, “enjoy and comfortable”, and “can correct each

other”.

Furthermore, the trendsetter approach enhanced students’ interest in learning physics because they can visualize the concept in the form of 3D models, and they can touch the models as they try to understand the theorem. The trendsetter also created an environment where they have the charisma to attract students to learn the topics. This viewpoint was perceived as forward-looking to learn and enroll the students in a supportive learning environment [30-32]. Likewise, students aware that having a trendsetter is beneficial to them who was have both remarkably knowledgeable than themselves but not too much of an expert that they had distinct experiences [33-35]. Eventually, the key item from the qualitative data likely explains in that manner that trendsetter relationship affected student’s understanding in the physics theorem with the assistance of 3D printed models [35].

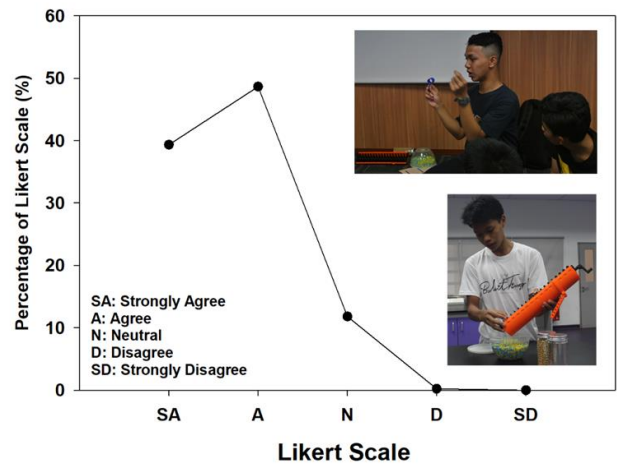


Fig. 7(a) - Percentage of Likert scale of trendsetter approach



Fig. 7(b) - Student’s comments on trendsetter approach

3.3.3 Insight into student’s performance

Fig. 8(a), 8(b) and 8(c) show the findings on the students’ performance based on topic effectiveness with respect to “Understanding”, “Application” and “Answering”, respectively. It was found that the students valued each topic with “Agree”, “Neutral” and “Strongly Agree” on the Understanding and Application elements after having experienced the trendsetter approach in 3D printing technology. Students’ understanding improved after the implementation of the 3D printed models with a positive

response by the students. The students also demonstrated a constructive response towards the implementation by selecting “Strongly Agree”, “Agree” and “Neutral” on the Likert scale for “Application” based on the concept in real life [4].

However, for “Answering”, the highest percentage on the Likert scale selected was “Neutral” for the Waves, Electricity and Electronic topics. This finding correlates with the nature of the topics itself, where students found that the topics were difficult, as can be seen in Fig. 3(a). These topics need to be further improved for most of the students (refer to Fig. 3(b)). In addition, the Electricity and Electronic topics were associated with the concept of mathematics. Therefore, if the students possessed low mathematical thinking, they might find it difficult to answer the questions given [4-5]. For the three elements for all topics, a small number of students selected “Disagree” and “Strongly Disagree”, at a total of less than 5%. This shows that the executed learning approach served as a fun method towards increasing student’s interest in learning physics [5].

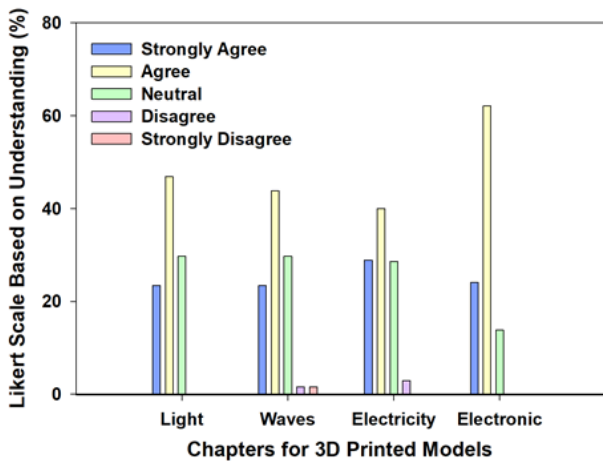


Fig. 8(a) - Topic effectiveness based on question with respect to “Understanding”

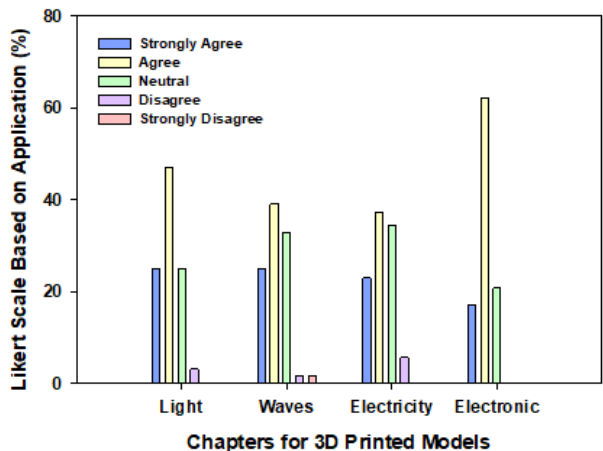


Fig. 8(b) - Topic effectiveness based on question with respect to “Application”

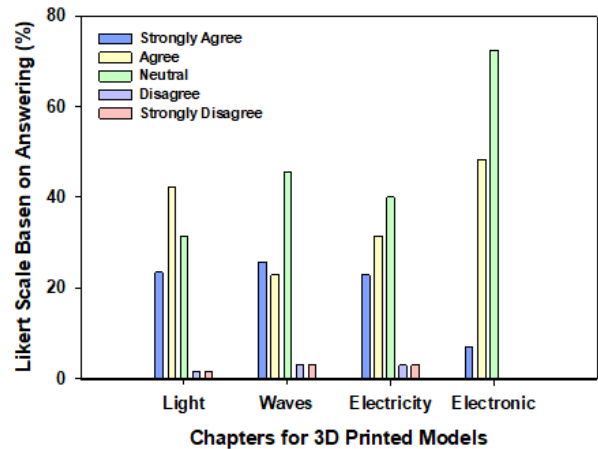


Fig. 8(c) - Topic effectiveness based on question with respect to “Answering”

An analysis was performed on the activities approach based on knowledge transfer and hands-on activity. Both shows positive feedback where 99.9% of the students were favorable towards both activities, as can be seen in Fig. 9. This means that during the modulated activity in the classroom, the students participated well in both activities.

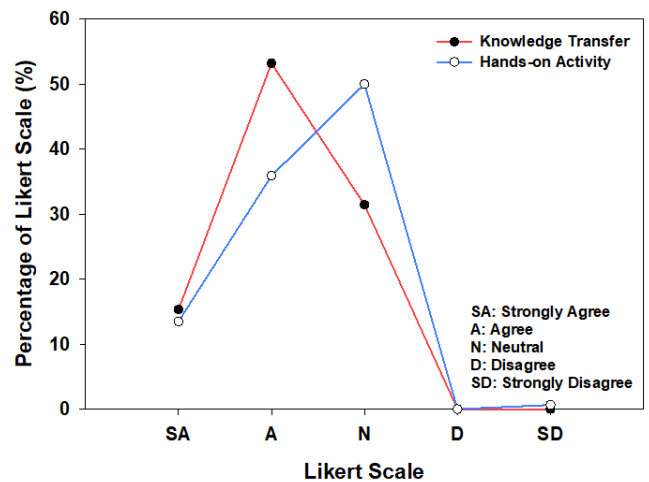


Fig. 9 - Percentage of Likert scale of knowledge transfer versus hands-on activity

3.3.4 Student’s self-evaluation

Fig. 10 shows the percentage of Likert scale on the student’s self-evaluation regarding their contribution in class activity, their feelings in gaining the learning objectives and on learning to adopt the trendsetter approach. The result shows that the highest percentage selected from the Likert scale was for “Agree” followed by “Strongly Agree” and “Agree”, respectively. Meanwhile, 0% selected “Disagree” and “Strongly Disagree”. The finding portrayed that all the students were satisfied with the approach.

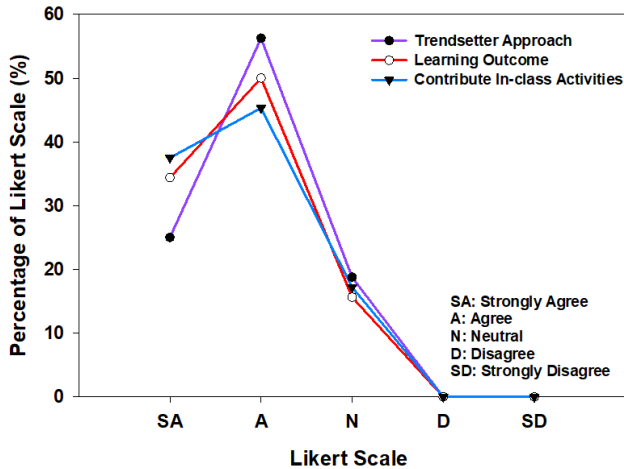


Fig. 10 - Percentage of Likert scale of student's self-evaluation

However, this kind of learning approach and learning environment still require some improvement as suggested by the students, as can be seen in Fig. 11. Students were eager to widen the scope involving more topics in Physics with the complement of more activities and frequent classes. They also suggested that the trendsetter should be friendly and passionate in their approach by using simple explanations. However, the selection of the trendsetter must be done where the selected trendsetters must be students with a high level of confidence besides being well-prepared before starting the activities.

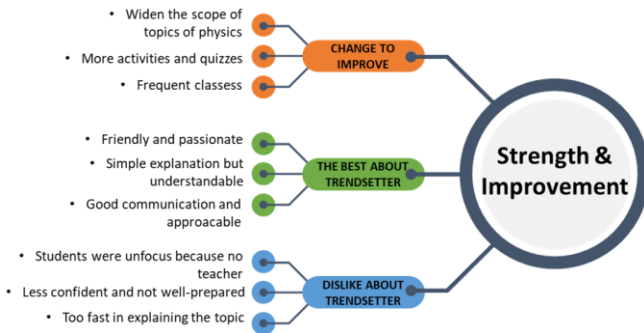


Fig. 11 – Student's reflection and suggestion

4. Conclusion

In summary, the employment of 3D printing technology has been integrated with physics syllabus in secondary education level for a vast range of applications to improve educators teaching approach and parallel with the attraction of students' interest in physics. In addition, 3D printer also can be applied to create any custom tools and equipment for better in any subject especially for hands-on related topic. This study has successfully determined the complexity level of the topics in Physics which led to educators' concern in improving their teaching approach. Throughout the development of 3D models based on the difficult topics, the established module has enhanced students' understanding in the selected topics which is complemented with trendsetters

among the students themselves. Consequently, the effectiveness of this program is expected to in line with Malaysian Blueprint 2013-2025 and thus engaging education for the framework of 10-10 MySTIE Socio-economic drivers through enhancing the nature and excellence delivery in teaching and learning of physics.

4. Acknowledgements

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