STEM PROJECT-BASED APPROACH IN ENHANCING CONCEPTUAL UNDERSTANDING AND INVENTIVE THINKING SKILLS AMONG SECONDARY SCHOOL STUDENTS

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ABSTRACT

Background and Purpose: Formal learning in schools generally does not provide enough engagement for students to grasp the science concepts and skills taught to them. Therefore, the structured informal learning activities such as STEM (Science, Technology, Engineering, Mathematics) integrated project-based learning is vital for students to partake in the more meaningful science learning process as it involves interdisciplinary activities. Hence, this paper discusses the study that underlies the structured informal learning activity, the STEM project-based approach, in enhancing conceptual understanding and inventive thinking skills among secondary school students.

Methodology: A quasi-experimental research design concerning treatment and control groups with pre-test as the covariate was employed in this project. The sample was selected based on the purposive sampling approach. Seventy Form Four students (33 male students and 37 female students) from a secondary school in Kedah, Malaysia were divided into 35 students of a controlled group (received conventional approach) and 35 students of the treatment group (followed STEM project-based approach). Data collected via the Newtonian Conceptual Understanding Test (NCUT) and Inventive Thinking Skills Test (ITST) were then analysed descriptively and inferentially.

Findings: The structured informal learning activity, the STEM project-based approach, was found effective in enhancing conceptual understanding and inventive thinking skills among secondary school students. Further analysis showed that the elements of thinking skills (management and adaptation to

complexity, self-regulation, curiosity, creativity, risk-readiness, and high-order thinking skills and sound reasoning) were also improved among students who followed STEM project-based approach.

Contributions: The study highlighted the importance of a structured informal learning activity, such as the STEM project-based approach in assisting students to grasp the science concepts and develop the required 21st-century learning skills besides formal learning in schools.

Keywords: Conceptual understanding, inventive thinking skills, Newtonian physics, physics education, secondary school students.

1.0 INTRODUCTION

The Industrial Revolution 4.0 (4IR) has brought about tremendous transformation in a new wave of global technology economy. STEM education is part of the education policy remodelled in the new Malaysia Education Blueprint (2013-2035) to fuel the science and technology-driven economy challenges in the era of 4IR. STEM education has been advocated as a comprehensive interdisciplinary learning approach via real-world problem-solving by nurturing the 21st-century competencies (Bell, Morrison-Love, Wooff, & McLain, 2018; Reeve, 2014) and enhancing the conceptual mastering of STEM (Galand, Raucent, & Frenay, 2010).

STEM education is generally practised in the forms of either formal, informal, or non-formal. Formal education has structured characteristics, a compulsory curriculum, clear goals, clear assessment mechanisms, recognised educators, and practised in a formal premise such as schools and colleges (Colley, Hodkinson, & Malcom, 2003). Informal and non-formal education occur when one chooses to acquire further knowledge or skills in a particular field, whether in structured or unstructured settings such as attending courses, workshops, and seminars (European Commission, 2001). Informal learning is different from formal and non-formal learning because it is unstructured, voluntary-based engagement, offers choices and tends to be non-transmissive, non-judgemental, occurs spontaneously, and takes place with complete individual control (Eraut, 2004; Rennie, 2007). An effective STEM learning may extend beyond the formal and non-formal settings. Informal STEM learning could offer a

contextual experience and interacts in reminiscence for an extended time in individual minds (McCreedy & Dierking, 2013), is realistic with a hands-on and minds-on activities, and could offer free learning from a rigid curriculum to comply with. Furthermore, it is able to occur anywhere regardless of time constraints (Cuinen et al., 2012). However, informal learning is often neglected in educational studies despite the fact that almost 85% of the time is spent by students outside a formal classroom (Ainsworth & Eaton, 2010).

Project-Based Learning (PBL), on the other hand, is a student-centred instructional model that promotes diverse specific skills within the process of creating an authentic prototype, product, or artefact (Bell, 2010; Grant, 2002; Thomas, 2000). The manifestation of prototype, product, or artefact provides a learning environment, scaffolding students' learning process as a way of gaining the ultimate goals of robustly comprehending the learnt concepts and fostering various skills among them. Past empirical studies asserted that a PBL product is not necessarily defined as a real model. A video produced by students, artwork, reports, photography, music, model, live performances, action plans, digital stories, and websites are all examples of products or artefacts (Holubova, 2008; Ocak & Uluyol, 2010; Yalcin, Charlet, Freund-Mercier, Barrot, & Poisbeau, 2009). It is recognised to be advantageous in all face-to-face learning mediums as well as a blended learning environment (Baines et al., 2015; Ozcan, 2013; Ravitz & Blazevski, 2014). An open and collaborative PBL in STEM education was validated to support students in constructing vital 21st-century skills inclusive of inventive thinking skills, which encompass creative and innovative thinking that is crucial in the development of higher-order thinking skills (HOTS) (Barak & Asad, 2012; Hassan & Osman, 2014; Lesseig, Slavit, & Nelson, 2017).

In this study, the STEM project-based approach known as 1,2,3 Newton STEM Project which incorporated both the STEM activities and PBL approach was a project developed to enhance the Newtonian conceptual understanding and inventive thinking skills among students in a secondary school. The project integrated student-centred, enquiry-based, and contextual learning approaches with multiple disciplines for genuine or authentic problem-solving (Mayer et al., 2012) strategies, which were expected to contribute to lucrative and effective STEM learning. Therefore, the purpose of the study was to answer the following questions:

1. Is there any significant difference in terms of Newtonian conceptual understanding between students who are exposed to the 1,2,3 Newton STEM Project and those who received conventional approach in informal science learning?

2. Is there any significant difference in terms of inventive thinking skills between students who are exposed to the 1,2,3 Newton STEM Project and those who received conventional approach in informal science learning?

2.0 LITERATURE REVIEW

Physics is well known as a fundamental component subject in STEM education, especially for future engineers. However, an abundant number of studies suggested that most physics conceptual understanding requires a high degree of abstraction, which frequently imposes serious difficulties for students to grasp, specifically Newtonian concepts (Mellors-Bourne, Connor, & Jackson, 2011; Resbiantoro & Nughara, 2017). This will contribute to a mental burden for the students as they ought to learn the subject even though they were unable to digest the concept well. Eventually, this scenario will form a negative perception in students' view as if physics is boring, difficult, and irrelevant to their life.

The same argument is confronted by the Malaysian students whereby findings from the previous studies pointed that the level of understanding of Newtonian concepts among Malaysian students is considerably low (Ismail & Ayob, 2016; Saleh, 2008; Saleh & Ahmad, 2015). Conceptual understanding refers to students' ability to identify concepts involved in a variety of situations and questions. It is best to demonstrate such understanding when the students are able to relate to their newly acquired knowledge with prior knowledge as well as relating them to real-world situations (Baroody, Feil, & Johnson, 2007). Henceforth, Newtonian's conceptual understanding can be understood as the ability to relate the first, second, and third Newton's laws with real daily phenomena. The concept is closely related in explaining the daily natural phenomena, mainly about the kinematic problems, collision, forces, momentum, and so forth in daily life (NAEP, 2005; Saleh, 2008).

According to Treagust and Duit (2008), students attend classes in their preconscious state and concepts usually contradicted its actual scientific conception. The problem in the field of physics usually includes basic concepts of velocity, acceleration or force, and Newton's laws, particularly the second Newton's law. Moreover, students are frequently confused with the informal terms used in daily life with the scientific terms applied in a formal physics classroom. For example, the term 'work' in everyday life is an act done by a person or an occupation but in a scientific context, it means the force imposed on a system multiplied by the distance

travelled or system. The general terms such as force, weight, mass, velocity, work, and energy have given particular meaning in the daily life activity but quite contrary to the use in scientific contexts (Stein, Larrabee, & Barman, 2008). In order to gain a better understanding, students must be able to differentiate and understand clearly the terms used (Vosniadou, 2003). These are among the few factors identified that have contributed to the deterioration of students' Newtonian conceptual understanding.

It appears that the issue becomes the worst-case scenario when the complexity and abstraction of the Newtonian concept itself is exacerbated by passive teaching approach rather than cognitive flexibility which is dominantly teacher-centred emphasis on memorisation, hindering the adoption of concept, principles, and evidence-based ways of thinking (Dehaan, 2009; Hong, Chen, Wong, Hsu, & Peng, 2012). As a result, it leads to ill-spirited and monotonous learning atmosphere instead of intellectual excitement that apparently results in low achievement in creative and innovative students, particularly in problem-solving skills due to the lack of hands-on activities. Finally, this will lead to demotivating students in learning physics, hence contributing to an alarmingly declining numbers of student enrolment in science stream for secondary education level as well as STEM-related career for their future. As a further matter, PISA 2015 reported only 33% of students are found to be into STEM-related careers in the future (OECD, 2015).

Apart of the shortage of STEM graduates, Malaysian graduates are also depicted as incompetent for highly skilled workforce, lacking high-level thinking skills especially in problem-solving, having low innovative thinking, and weak communication skills (MOE, 2013). Adopted reports from World Design Rankings: 2010–2018 published by A 'Design Award and Competitions, a world-renowned prestigious award that recognises innovators of worldwide innovation products, revealed that Malaysia was ranked 53 out of 100 countries in producing innovative inventive products. Surprisingly, Malaysia is ranked lower than other Asian countries such as Singapore (19), Thailand (35), Vietnam (38), and Indonesia (51).

This scenario reflects the level of inventive thinking skills among Malaysians which is considered crucible and alarming. It implies that the thinking abilities that the mainstream education system recognises and celebrates such as creativity and critical thinking skills are still inadequate to meet the standards appointed for skilful and knowledgeable workers as demanded in this 21st century. The Partnership for 21st Century Learning (NCREL & Metiri, 2003) declared that an inventive thinking skill is one of the components of the 21st-century skills ought to be fostered for the future workforce. Inventive thinking skills is a form of application of new dimensionally comprehensive creative and critical thinking infused with

multiple innovative traits with high self-regulation and management skills (Barak, 2009; Barak & Mesika, 2007; Abdullah & Osman, 2010; NCREL & Metiri, 2003). It incorporates specific elements which are management and adaptation to complexity, self-regulation, curiosity, creativity, risk-readiness, and high-order thinking skills and sound reasoning (NCREL & Metiri, 2003).

Thus, it is a wake-up call for stakeholders to determine a key solution to an effective strategy or programmes from the grassroots to catalyse the students' empowerment of an inventive thinking skill with regard to developing creative and innovative human capital to meet the needs of the country in the 21st century. Eventually, by possessing the inventive thinking skill, one is expected to be capable of dealing with problems with a creative, innovative, and positive mind as well as positive attitude management. Despite ample evidence presented by previous empirical research on innovative thinking skills which positively impacted students' thinking proficiency (Omar Ali, 2014; Abdullah & Osman, 2010; Ngaewkoodrua & Yuenyong, 2018; Abdul Samad & Osman, 2017), there is limited research documented according to inventive thinking skills, particularly in physics education from the literature.

A profound result from the literature suggested that out-of-school setting inclusive as co-curricular activities encourages the cognitive, effective, and social aspects of development among students. A variety of generic skills and inventive thinking cultures that practise creativity and innovative skills among students may be nurtured via co-curricular activities (MOE, 2013). Early exposure to numerous challenging activities inclusive of participation in innovation competitions, science festivals, and robotics competitions is an ideal platform to inculcate the culture of inventive thinking and spark students' interest in the direction of the STEM pipeline in the future (Feinstein & Meshoulam, 2014). Looking into these and espoused to the national educational policy of STEM education in the 4IR, the 1,2,3 Newton STEM Project which is a project-based learning approach was developed to enhance Newtonian conceptual understanding and inventive thinking skills among students in a secondary school.

2.1 The 1,2,3 NEWTON STEM PROJECT

The 1,2,3 Newton STEM Project learning process began with a guided driven question that serves as a 'heart' of the project (Flemming, 2000). It is a problem statement with regard to current issues presented to challenge and stimulate students' inventive thinking skill to find solutions (Larmer, Mergendoller, & Boss, 2015). Along the process, enquiry and curiosity related to a principle or theories might be gained by means of the students in actual experience

and exploratory activities through seeking in-depth information during project-based learning (Thomas, 2000). Students possess an autonomy to self-learning, choose the preferred method they are inquisitive about, liable for making their project planning as an effective scaffolding (Ali, 2014; Thomas, 2000).

There are various PBL models designed with exclusive implementation strategies such as suggested by Flemming (2000), Katz and Chard (2000), Markham, Larmer, and Ravitz (2003), and Larmer et al. (2015). In essence, the BIE (Buck Institute for Education) model was adopted in this study, due to its comprehensive framework model, with a clear and well-developed instructional model. It was guided with seven-phase models initially started with the driven questions, project challenges, developed expert skill, project execution, project presentation, reflection, and evaluation. Basically, the 1,2,3 Newton STEM PBL is comprised of three distinctive STEM projects primarily based on the three different driven questions given, which are associated with Newton's laws of first law N1, second law N2, and third law N3 consecutively. It was purposely designed with an intention to ease students' difficulty in the conceptual understanding with a fun learning activity. A step-by-step activity in the project is believed to impart a significant long-term memory of what they have garnered in the process. In addition, the project itself was named as 1,2,3 Newton to give an impression how easy it is to grasp the Newton's concepts, as easy as 1,2,3.

The first project, Newton 1: Inertia Movie-Making Challenge, implies the Inertia concept. Students were assigned to produce their own video related to Newton's first law (Newton 1). They were encouraged to act or direct a short movie in the task to exhibit their understanding of Inertia Newton's first law concept. Students were capable of sharing and presenting to other students online via VLE Frog application. Technological skills that were integrated into the project had empowered the students' technology literate. Furthermore, previous empirical studies affirmed that a PBL product is not necessarily defined as a real touchable model. Subsequently, a video produced by students, artwork, reports, photography, music, modelling, live performances, action plans, digital stories and websites are all examples of product or artefacts (Holubova, 2008; Ocak & Uluyol, 2010; Yalcin et al., 2009).

The second task is N2: Mission Possible. The second Newton's law defines the law of relationship between force, acceleration, and mass, and eventually, students were able to derive an equation of $F = ma$ and relate to the concept of impulse, changes of momentum, and time of impact $F = mv - mu/t$. Students were assigned to egg-drop challenges using recycled straws throughout the course of the activities and they were given assignment to measure the velocity obtained by the egg during the activity. Integration of fundamental mathematics skills and

concrete understanding of Newton's second law related to free fall concept is the key idea to solving this task.

Finally, the third assignment, N3: F1 Challenge, concerned the invention of an F1 racing car balloon. It was grounded with the third Newton's law, which defines that every motion will form a reaction but in a different direction. Thus, the end product is a creation of a simple handmade creative car from recycled plastic bottles for the purpose of competing for the fastest car among the groups. The fun-play learning approach which is recommended in PBL STEM will not only enhance students' interest and motivation towards STEM but will additionally increase the mastery of the concept of science gradually (Amir & Subramaniam, 2009; Petersen & Nassaji, 2016).

The project was orchestrated to embrace the three laws of Newton consecutively to consolidate the new scientific conceptual understanding systematically. The implementation of the task assigned will nurture the development of the new concept and overcome the alternative framework which contributes to misunderstanding among students earlier than some stages in the process, and students gain meaningful experience in dealing with challenges and uncertainty. This may inspire the students to fulfil their curiosity, enhance their creativity and innovation skills, induce the HOTS ability in an effective self-management, and prepare for the risk consequence in a positive way towards managing challenges while completing the project. The infusion of digital technology and Internet of Things (IoT) will definitely serve as an advantage for the students to self-regulate their study and potentially transform into experts in undertaking the content area with a complete guide by an expert teacher.

3.0 METHODOLOGY

A quasi-experimental research design concerning treatment and control groups with pre-test as the covariate (Shadish, Cook, & Campbell, 2002) was employed on this project. The sample selected was based on the purposive sampling approach which included 70 Form Four students (n = 33 male students and n = 37 female students) in a secondary school in Kedah. The samples were divided into 35 students of a controlled group and 35 students of a treatment group. Two experienced female teachers who acquired a similar qualification in physics education and teaching experience were selected to conduct the control group with their conventional common teaching technique while the treatment group was exposed to the 1,2,3 Newton project-based teaching approach.

The NCUT which was adapted from Force Concept Inventory [developed by Hestenes, Wells, and Swackhamer (1992)] and Physics SPM questions [developed by the Malaysian

Examination Board] consisted of 20 multiple-choice items and three open-ended questions. The reliability of the instrument gained from the KR-20 test was 0.76. The instrument was piloted and validated by experts together with the 1,2,3 Newton module. The ITST instrument was adapted from Kuratko and Hodgetts (2001), NCREL and Metiri (2003), and Ali (2014). It was administered with a five-point Likert scale with a reliability test indicating Cronbach's alpha of 0.89, which presented a reliable and high validity instrument to be implemented in this study.

Example of the Intervention Phase: Newton 2: Mission Possible is shown in Figure 1 below:
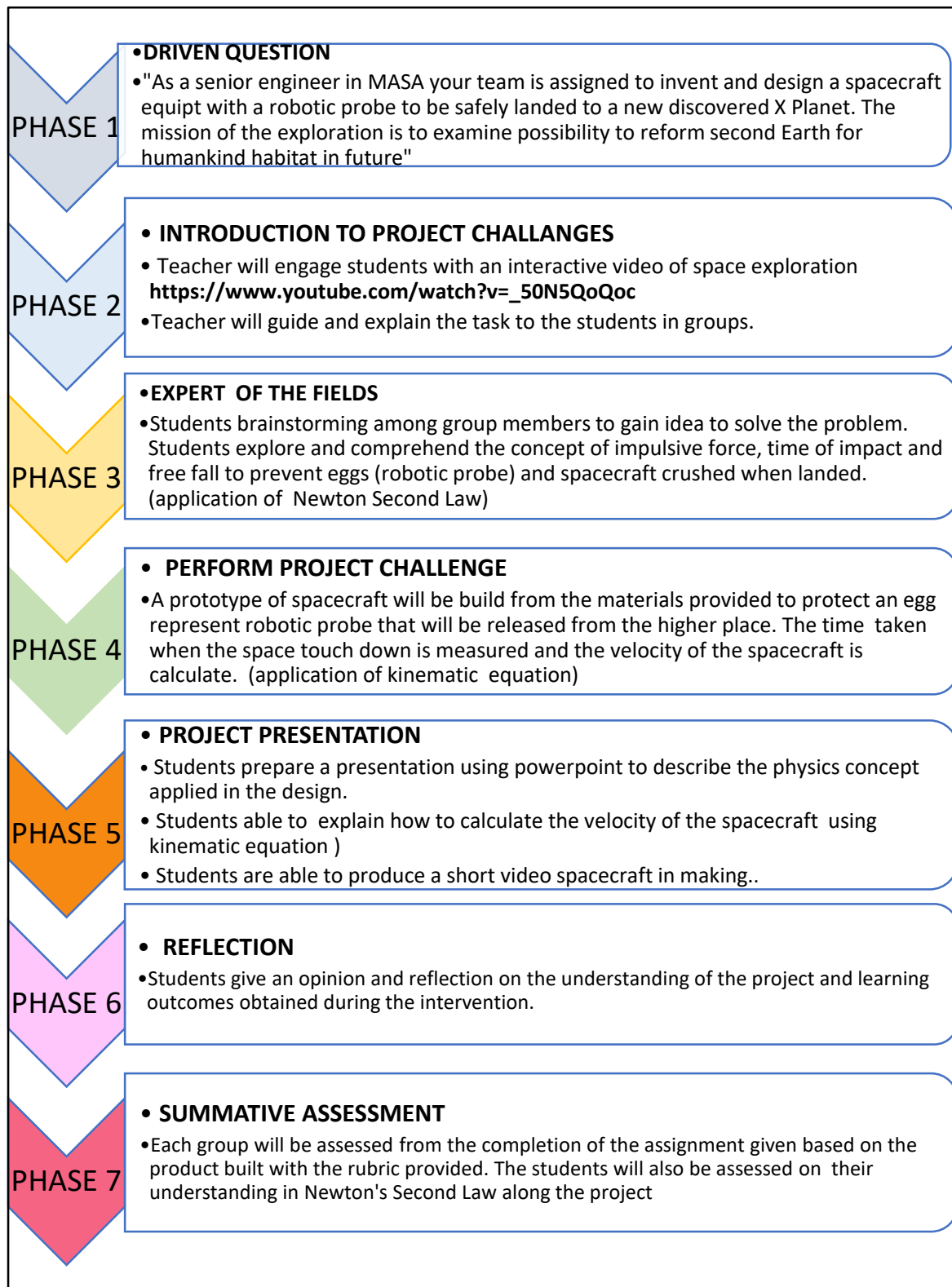
PHASE 1
- **DRIVEN QUESTION**
- "As a senior engineer in MASA your team is assigned to invent and design a spacecraft equipt with a robotic probe to be safely landed to a new discovered X Planet. The mission of the exploration is to examine possibility to reform second Earth for humankind habitat in future"

PHASE 2
- **INTRODUCTION TO PROJECT CHALLANGES**
- Teacher will engage students with an interactive video of space exploration
 https://www.youtube.com/watch?v=_50N5QoQoc
- Teacher will guide and explain the task to the students in groups.

PHASE 3
- **EXPERT OF THE FIELDS**
- Students brainstorming among group members to gain idea to solve the problem. Students explore and comprehend the concept of impulsive force, time of impact and free fall to prevent eggs (robotic probe) and spacecraft crushed when landed. (application of Newton Second Law)

PHASE 4
- **PERFORM PROJECT CHALLENGE**
- A prototype of spacecraft will be build from the materials provided to protect an egg represent robotic probe that will be released from the higher place. The time taken when the space touch down is measured and the velocity of the spacecraft is calculate. (application of kinematic equation)

PHASE 5
- **PROJECT PRESENTATION**
- Students prepare a presentation using powerpoint to describe the physics concept applied in the design.
- Students able to explain how to calculate the velocity of the spacecraft using kinematic equation)
- Students are able to produce a short video spacecraft in making..

PHASE 6
- **REFLECTION**
- Students give an opinion and reflection on the understanding of the project and learning outcomes obtained during the intervention.

PHASE 7
- **SUMMATIVE ASSESSMENT**
- Each group will be assessed from the completion of the assignment given based on the product built with the rubric provided. The students will also be assessed on their understanding in Newton's Second Law along the project

Figure 1: The implementation of 1,2,3 Newton STEM Project

4.0 ANALYSIS AND DISCUSSION

Table 1 shows the descriptive statistics of the students' Newtonian conceptual understanding and inventive thinking skills before they were exposed to the 1,2,3 Newton STEM Project.

Table 1: Descriptive statistics of the students' Newtonian conceptual understanding and inventive thinking skills before the implementation of 1,2,3 Newton STEM Project

Variable	Group	N	Mean	Std. Deviation	Std. Error
Conceptual Understanding	Control	35	16.26	3.109	.526
	Treatment	35	17.94	2.589	.438
	Total	70	17.10	2.964	.354
Inventive Thinking Skills	Control	35	182.71	16.160	2.732
	Treatment	35	166.46	13.307	2.249
	Total	70	174.59	16.822	2.011

It is found that there was a significant difference between the mean score for inventive thinking skills between control group and treatment group. For the control group, Mean control = 182.71, SD = 16.16 while for the treatment group, Mean treatment = 166.46, SD = 13.307. As for the Newtonian conceptual understanding, there were only slight differences between both groups (Mean control = 16.26, SD = 3.109 and Mean treat = 17.94, SD = 2.589). Based on this, the analysis of covariance (ANCOVA) was conducted to further analyse the data.

Table 2: Descriptive and inferential statistics (ANOVA) analysis of tests of between-subjects

effects dependent variable: Post-test Newtonian concepts

Group	Mean	SD	Covariate	Source	Type III sum of squares	Df	Mean square	F	Sig.(p)	Partial Eta Square
Control n=35	16.49	3.128	Pre conceptual	Pre conceptual	570.428	1	570.428	213.443	.000	.761
Treatment n=35	23.91	3.501		Group	525.978	1	525.978	196.811	.000	.746
				GROUP * PRE CONCEPTUAL	.919	1	.919	.341	.561	.005
				Error	179.058	67	2.673			

ANCOVA provides direct estimates of treatment differences even if the groups are different prior to the study (Shadish et al., 2002). It is indeed used to determine whether the project (IV) has an effect by controlling the influence of covariate (pre-test) on the post-test on Newtonian conceptual understanding (DV). Table 2 shows the output indicated $F(1,67) = 196.811$, $p = .000 < 0.05$. Statistically controlling the pre-test scores showed that there was a significant difference in the mean score for post-test on Newtonian conceptual understanding among the treatment group and control group. According to the descriptive statistics provided in Table 1, the treatment group (Mtreat = 23.91, SDtreat = 3.501) outperformed the control group (Mcont =16.49, SDcont = 3.128), suggesting that the students managed to enhance their Newtonian conceptual understanding after they were exposed to the 1,2,3 Newton STEM Project. A total of 74.6% (effect size $\eta = 0.746$) is considered as a moderate effect of the total variance in the post-test scores. This might be due to the group differences while controlling the effect of the students' pre-test scores.

The results of inventive thinking skills were then analysed for each element, namely management and adaptation to complexity, self-regulation, curiosity, creativity, risk-readiness, and high-order thinking skills and sound reasoning (see Table 3).

Table 3: Descriptive and inferential statistics (ANCOVA) analysis of tests of between-subject effects dependent variable: Post-test inventive skills

Group	Mean	SD	Covariate	Source	Type III sum of squares	df	Mean square	F	Sig.(p)	Partial Eta Square
Control n=35	31.29	2.966	Pre Management & adaptability	Pre Management & adaptability	717.089	1	717.089	983.722	.000	.937
Treatment n=35	30.00	3.819		Group	.223	1	.223	.306	.582	.005
				Group* Adaptability	1.274	1	1.274	1.748	.191	.026
				Error	48.111	67	.729			
Control n=35	31.69	4.157	Pre Self-regulation	Pre Self - regulation	1093.260	1	1093.260	1279.348	.000	.950
Treatment n=35	32.17	4.069		Group	120.489	1	120.489	140.998	.000	.678
				Group* Pre Self-Regulation	.354	1	.354	.410	.524	.006
				Error		67				
Control n=35	28.34	3.757	Pre Curiosity	Pre curiosity	773.276	1	773.276	360.838	.000	.843
Treatment n=35	31.17	3.585		Group	195.976	1	195.976	91.449	.000	.577
				Group*Pre Curiosity	8.012	1	8.012	3.900	.052	.287
				Error	194.780	67	2.951			
Control n=35	30.06	3.725	Pre Creativity	Pre creativity	815.357	1	815.357	322.293	.000	.828
Treatment n=35	32.17	3.884		Group	355.193	1	355.193	140.400	.000	.677
				Group * Pre creativity	7.865	1	7.865	3.212	.078	.046
				Error	169.500	67	2.530			
Control n=35	31.00	4.073	Pre	Pre Risk readiness	1175.039	1	1175.039	2094.235	.000	.969

			Risk readiness							
Treatment n=35	32.03	4.389		Group	2.551	1	2.551	4.547	.037	.064
				Group * Pre Risk-readiness	.656	1	.656	1.169	.283	.017
				Error	37.031	67	.561			
Control n=35	28.71	2.295	Pre HOTS& reasoning	Pre HOTS& reasoning	513.151	1	513.151	628.137	.000	.904
Treatment n=35	30.51	3.381		Group	78.104	1	78.104	95.605	.000	.588
				Group*Pre HOTS& reasoning	425.942	1	425.942	3.087	.084	.045
				Error	54.735	67	.817			

From Table 3, ANCOVA shows that by statistically controlling the pre-test scores, there was a significant difference in the mean score for post-test on self-regulation element [F (1,67) = 140.998, *p* = .000 < .05]. The treatment group exhibited more positive attitudes towards self-regulation (Mtreat = 32.17, SDtreat = 4.069) than the control group (Mcont = 31.69, SDcont = 4.157) with a total of 67.8% effect size (η = 0.678) in the post-test scores, suggesting that some or all aspects of the treatment positively change in self-regulation better than in the control group.

Table 3 also shows that there was a significant difference in the mean score for post-test on curiosity [F(1,67) = 91.449, *p* = .000 < .05] with a total of 57.7% effect size (η = 0.577) in the post-test scores, suggesting moderate effect of the treatment on the research sample. Compared to the conventional teaching approach (Mcont = 28.34, SDcont = 3.757), it was found that the 1,2,3 Newton STEM Project has significantly impacted the students' curiosity (Mtreat = 31.17, SDtreat = 3.585). The treatment group which was exposed to the 1,2,3 Newton STEM Project also improved in creativity (Mtreat = 32.17, SDtreat = 3.884) better than the control group, which received the conventional teaching approach (Mcont = 30.06, SDcont = 3.7255) with a total of 67.7% effect size (η = 0.677) in the post-test scores, suggesting that some or all aspects of the treatment positively change students' self-regulation in the treatment group better than in the control group.

The findings also indicate the 1,2,3 Newton STEM Project has increased students' HOTS and reasoning skill that are shown by Table 2 [F(1,67) = 95.605, *p* = .000 < .05] with 58.8.7% effect size (η = 0.588), which is referred to as moderate effect of the total variance in the post-test scores. It is proved by the difference in mean score of the treatment group (Mtreat= 30.51, SDtreat = 3.381) which performed better than the control group (Mcont = 28.71, SDcont = 2.295).

Henceforth, the analysis of risk readiness shows a slightly significant difference but with a low effect size [see Table 2, F(1,67) = 4.547, *p* = .037 < .05] and consist only 6.4% effect size (η = .064) of the total variance in the post-test scores. The mean score of the treatment group which was exposed to the 1,2,3 Newton STEM Project (Mtreat = 32.03, SDtreat = 4.389) is higher than the control group which received the conventional teaching approach (Mcont = 31.00, SDcont = 4.073). However, in management and adaptability aspects, it was found that there was no significant difference between both groups with a total of 5% effect size (η = 0.05) of the total variance in the post-test scores. This showed that the treatment group (Mtreat = 31.29, SDtreat = 2.966) scored slightly higher than the control group (Mcont = 30.00, S cont = 3.819) in the post-test administered. This means that some aspects of the treatment were not significant in enhancing the management and adaptability element among the students. They were probably because of the duration of the project and other technical problems.

The overall results show that the 1,2,3 Newton STEM Project has a positive impact on students' Newtonian conceptual understanding and inventive thinking skills. The findings of this study are consistent with the research of Abdullah and Osman (2010), Omar Ali (2014), and Ngaewkoodrua and Yuenyong (2018), which found that inventive thinking skill is likely increased when the students are exposed to the problem-solving task and are also parallel with the research from Galand et al. (2010) and Ali (2014), which revealed that project-based learning approach has succeeded in enhancing students' conceptual understanding, particularly Newtonian conceptual understanding.

It is believed that this project which was designed with step-by-step activity based on Newton's law N1, N2, and N3 leads to an easy approach to better understand the Newtonian concepts and impart a longer lasting memory for students. The activity focused on a problem-solving task, supported with hands-on activities, and finally, produced an artefact or a product as their manifestation of their ultimate understanding of the Newtonian concepts as well as enhancement of the inventive thinking skills among the students. Perhaps the postulate of Piaget's constructive (Piaget, 1953) and Papert's constructionist theory (Papert, 1991) was

applicable, which proved that the students were able to construct their new knowledge from abstract to concrete in learning by doing. As a result, this encourages the students to employ a new way of thinking and attitude management towards managing problem-solving. Furthermore, the project which was run in a curriculum-free and stress-free informal learning environment led to a fun and enjoyable learning atmosphere. This encourages the students to be open and free-minded as well as enables them to produce more creative and innovative ideas apart from in-depth learning of the Newtonian concepts itself.

5.0 CONCLUSION

As a conclusion, throughout the learning process, students were able to focus on dealing with the complex challenges in completing the task. Hence, this will develop their curiosity, creativity, and higher order skills as well as reasoning skills, which enhance their inventive thinking skills. Nevertheless, some parts of the treatment should be improvised in order to enhance students' skills of management and adaptability aspects. The 1,2,3 Newton STEM Project is viewed as an alternative approach for teachers to apply in the teaching and learning process of student development towards diversity of the 21st-century skills, precisely from the aspect of inventive thinking and enhancement of student comprehension of Newtonian concepts rather than an ordinary 20th-century teaching approach.

However, an effective PBL approach has to be designed with an ideal plan. Consideration ought to be put on several crucible factors together with suitability of challenge and content-matter, materials, students' level, project complexity, facilities and support, students' prior- knowledge, and competence appropriateness for group work. Moreover, the tendency of teachers to evaluate only the end products may inflict the teachers to overlook the social dynamics and the students' soft skills throughout the process of completing the task. An occurrence of 'social loafing' problem due to less commitment among group members needs to be notified. As a mastermind, a teacher needs to be sensible, creative, and proactive to play a significant role in facilitating, encouraging, and engaging the students to get involved in active learning as well as gain the advantages of PBL approach. This can therefore transform the learning atmosphere into an enjoyable and fruitful learning in an effort to sustain the students' interest and enthusiasm towards knowledge.

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