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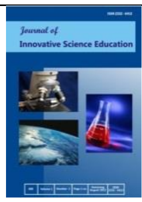

An Exploratory Study to Investigate the Implementation of Feynman Learning Method in a Physics Classroom Setting

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Abstract

In order to explore alternative methods to learn physics effectively, this research was inspired by a fundamental question: how did famous physicists use to learn and/or teach physics? Are there any recipies suggested by these physicists which are still relevant and can be imitated and applied to physics learning in a today classroom? This research aims at exploring the impact of the implementation of Feynman learning method on students' physics concepts understanding and describing their spontaneous responses about the implementation of this learning method afterwards. This research was an exploratory research conducted at one grade X science class of St. Gabriel Catholic Senior High School in Maumere city, Flores. Data regarding students' understanding were collected through pre and post test questionnairres and their spontaneous responses were obtained through unstructured interview. The results of N-gain pretest and post test score was 0.49. Apart from few non-positive responses, students' responses indicated that the method can encourage them to actively participate in the learning process, improve their communication skill, and train their abilities to explain things in simple ways. The results suggest that there was an improvement in students' physics concepts understanding with a medium N-gain score and that this learning method is positively appreciated by the participants.

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INTRODUCTION

It is generally believed that teachers' teaching method has a very prominent impact on students' learning process and achievements. Teachers' teaching methods meant here refer to the general principles, procedures, pedagogy and management strategies used by teachers for classroom instruction in order to achieve desired learning goals (Westwood, 2008). A huge number of researches about the implementation of teachers' teaching method in the classroom have been conducted by education researchers, university professors, lecturers, and even pre-service teachers. The themes of the research about teaching methods also vary, ranging from testing their effectiveness in the classrooms (Çalik at al., 2010; Farashahi & Mahdi, 2018; Ganyaupfu, 2013), investigating their impact on students' performance about certain topics being learnt (Abdi, 2014; Strelan at al., 2020), to testing their impact on students' motivation and learning attitudes (Cudney & Ezzell, 2017; Harandi, 2015; Vennix at al., 2018).

Teachers' ability to choose and implement appropriate teaching methods is highly recommended. In the context of physics learning, this is even more crucial due to the nature of the subject and the efforts to overturn the long existing negative notion about the subject. Physics is always associated with formulas, complicated mathematics, and is frequently ranked by students as one of the most difficult subjects (Angell at al., 2004; Williams at al., 2003; Ornek at al., 2008). While it is true that laws and theories of physics are expressed in the language of mathematics which is always considered too difficult to understand, there are actually other features of physics which are easily understandable and hence are interesting to explore. However, these interesting features are over shadowed by those negative views. The role of physics teachers to overturn these negative notions is extremely important. Physics teachers are responsible to make physics not only better understandable but also become a fun and interesting subject. This crucial role of physics teacher is encapsulated in professor Lewin's words, "*if you hate physics, it is because you have a very bad teacher"* (Lewin & Goldstein, 2011).

According to Suparno (2013), there are various learning methods which can be applied by physics teachers in their classrooms. The inquiry method, discovery method, experiment method, problem and project based learning methods (just to mention some) are examples of learning methods which can be used. Each of these learning methods has its own strengths and limitations. In terms of their effectiveness, all learning methods are generally location, materials and participants dependent. As a consequence, one cannot isolatedly generalize which learning method is the most effective method used to learn physics. And this is an important precursor for a continuous research regarding the exploration and implementation of effective physics teaching and learning methods.

In order to explore alternative methods to learn physics effectively, this research was inspired by a fundamental question: how did famous physicists use to learn and/or teach physics? Are there any recipies suggested by these physicists which are still relevant and can be imitated and applied to physics learning in a today classroom? While most famous physicists are illustrated as a smart-born person, our search of literatures led us to the story of Richard Feynman (1918-1988), an american physicist and 1965 physics nobel prize winner who personally described himself as "an ordinary person who studied hard". Feynman was famously known as a great explainerfor his ability to explain complicated physics formulas into a simple and beautiful formula (Gleick, 2011). One of Feynman's worth mentioning achievements in this area is what is now known as Feynman diagrams by which he simplified some of the calculations used to observe and predict the behaviour of systems of interacting particles. These diagrams reflect his brilliant and creative effort of explaining physics in elegant and simple ways. Besides that, reading *The Feynman Lectures on Physics* collection (Feynman at al., 1977), one can clearly grasp Feynman's efforts to explain physical concepts in detail without losing the simplicity in ways of explaining those concepts.

In terms of Feynman's suggestion regarding how to effectively learn physics (actually this also applies to other field of studies), Feynman is famously known for so-called *Feynman Learning Method*. Generally, Feynman Learning Method comprises four important steps. *Firstly*, choose a concept you want to learn about. Learn the topic independently; *secondly*, teach it to yourself or someone else as simple as possible as if you were explaining it to a child; *thirdly*, return to the source material if you get stucked; and *fourth*, simplify your explanations and create analogies (Carretero, 2020; Tariq, 2021; Worsley, 2020)

This Feynman Learning Method is abundantly available online and is assumed to have very positive impacts on learning faster and effectively. However, to the best of our literature review search, there was no research based publication regarding the implementation of this method in a physics classroom setting domestically and internationally. The scarcity of the publication regarding this topic inspired us to conduct this research. In the context of exploring physics learning method, this research was worth conducting for the fact that the learning method being explored is recommended by one of the most brilliant 20th century physicists.

This research was an exploratory research aiming at investigating the implementation of Feynman Method in a physics classroom setting. The research aimed at answering the following questions: firstly, can Feynman method improve students' physics concepts understanding? Secondly, what are students' spontaneous responses to the implementation of this learning method? To answer the first research question, the pre and post test experimental design was used. The second research question was analyzed using data obtained from unstructured interview with participating students.

METHOD

This research was an exploratory research conducted at a grade X science class of St. Gabriel Catholic Senior High School. The school is located in Maumere city, Flores Island, East Nusa Tenggara province. The research was treated as an exploratory research due to the fact that there was a scarcity of published articles regarding the implementation of this learning model in the classroom settings domestically and internationally. This scarcity is leading to lack of referencing resources and materials about the implementation of the method in the classroom settings. Therefore, the researchers decided to design this research as an exploratory research in which a total of 22 students (labeled as *S1* to *S22*) were purposively chosen as the participants.

In terms of data collection, this research adopted quantitative one group pretest post test design to answer the first research question. The second research question was answered through more qualitative method using unstructured interview. Regarding the procedure, the research was carried out in five meetings. The first and fifth meetings were for the 60 minute pretest and post test while the second, third and fourth meetings were for 90 minute intervention programs. The pretest was administered one day before the intervention programs, the post test and unstructured interviews were conducted three weeks after the last day of the intervention program.

In the intervention programs, participating students were instructed to apply Feynman Learning Method to learn physics concepts related to the topic of *Motion in One Dimension*. Due to lack of previous references about the Syntax of Feynman Learning Method, the authors initiated to create the learning syntax which was validated by two experienced colleagues before being used in this research (the syntax of Feynman Learning Method is provided in table 1).

Table 1. Syntax of Feynman Learning Model

Steps	**Classroom Activities**
1st Step Choose a concept you want to learn about. Learn the topic independently	Participating students were asked to learn topics related to One Dimensional Motion from several sources, both printed and online sources. The main source was their physics textbook.
2nd Step Teach it to yourself or someone else as simple as possible as if you were explaining it to a child	Firstly, all participating students were instructed to do a monolog, teaching themselves. Next, students were divided into two groups: explainers and listeners. Explainer students found a friend and explained materials they just independently learn. After that, they did a role change; listener students became explainer students. Students were highly encouraged to explain things in very simple ways.
3rd Step Return to the source material if you get stucked	Students were reminded to return to their source materials when they encounter difficulties. Practically, students did the 2nd and 3rd steps together.
4th Step Simplify your explanations and create analogies	Students were instructed to summarize what they just learnt in their own notes using their own words and symbols, and using models and analogies

On pretest and post test, identical questionnaires consisting of five essay questions were administered to measure students' understanding of concepts related to Motion in One Dimension. These questionnaires were developed by the authors and were validated by two experienced colleagues before being used. Questions 1 and 2 were designed to test students' ability to apply concept of distance and displacement to solve the problems given; Question 3 was designed to measure students' ability to solve problems using concepts of one dimensional motion with constant acceleration; and students' understanding about free falling motion was measured through questions 4 and 5.

Data obtained from pretest and post test were analyzed statistically. The authors calculated the pretest and post test N-gain score and interpret the result referring to their achieved N-gain score, categorizing as "High" for (<g>) > 0.7; "Medium" for 0.7 > (<g>) > 0.3 and "Low" for (<g>) < 0.3 (Hake, 1999). Data regarding students' responses obtained through unstructured interview were analyzed using steps proposed by Miles, Huberman, & Saldaäna (2014). These quantitative and qualitative data were then analyzed to answer the research questions (Creswell, 2012).

RESULT AND DISCUSSION

The Impact of the Implementation of Feynman Method on Students' Understanding

The impact of the implementation of Feynman Method on students' understanding of physics concepts was analyzed by interpreting the results of their pretest and post test.

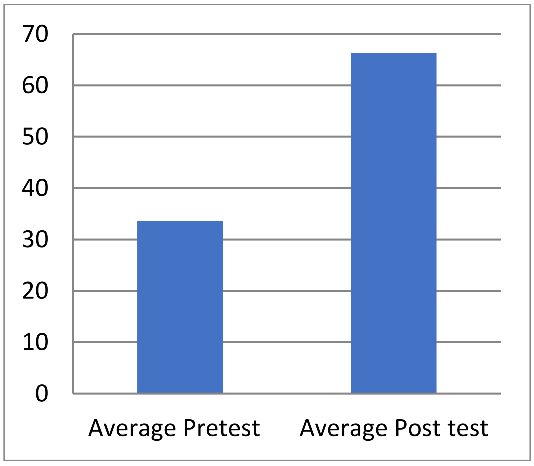

Figure 1. Students' Pretes and Post test Average Score

Figure 1 above depicts the results of students' average pretest and post test. Before the implementation of Feynman Method, none of the students could achieve score above 70 (the maximum score for pre and post test was 100). Students' pretest average score was 33.64 with the lowest score was 20 and the highest one was 60. After the intervention programs, students' average score improved. The average of their post test score was 66.27 with the lowest and highest score was 56 and 80 respectively. Based on these results, there was an improvement in students' understanding with *a medium* (0.49) N-gain score.

The N-gain score for each question in pretest and post test is presented in figure 2 below.

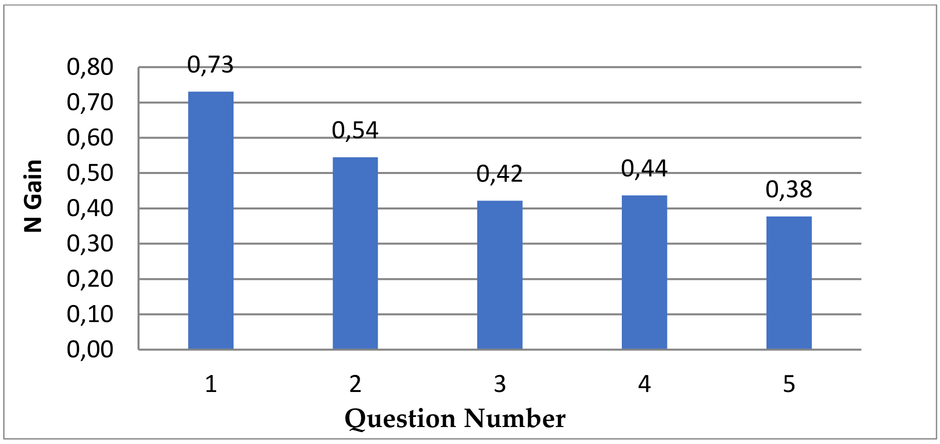

Figure 2. The N-gain Score for Each Question

From the figure 2 above, it can be seen that the highest N-gain score was achieved in Question 1 ("High" N-gain). The N-gain scores for other four questions were "medium". The fact that no "low" N-gain score achieved in each question reveals that the Feynman Learning Method has very positive impact on students' conceptual understanding. The results were in line with claims made by Carretero (2020) and Tariq (2021) which believed that the Feynman Learning Method could improve students' achievement as this learning method can even be used to master and convey complicated topics in a very short time. On the other hand, the fact that students only achieved "high" N-gain score in question 1 also raised interesting discussion. The authors believed that students' unfamiliarity with this new learning model could be the main factor. As emphasized by Worsley (2020), the unique feature of Feynman Learning Model is that the learning model promotes "learning by teaching others" and hence, when applying this learning model in the classroom, the ability of peer teaching plays a very crucial role. Arguably, the participating students are not accustomed to "teaching" their peer friends during the learning process which is confirmed by students' responses in the interview. It is believed that students could have achieved better N-gain score provided they keep practicing this learning model.

Students' Spontaneous Responses about the Implementation of Feynman Method

Students' spontaneous responses about the implementation of Feynman method were obtained through randomly unstructured interview to eleven participating students. These students were mainly asked about their previous experiences with the learning method, what positive things they could obtain after getting exposed to each step of this learning method, what difficulties they have encountered in each step, and their suggestions for the better implementation of the learning method.

Several points of participating students' spontaneous responses to each step of the implementation of Feynman Learning Model are summarized in the table 2.

Table 2. Students' Responses Regarding Each Step of Feynman Learning Model

Steps	Positive Responses	Non-positive Responses
1st Step Choose a concept you want to learn about.Learn the topic independently	" I like physics so I am enthusiastic to learn the topic asked by the teacher (read: researcher) independently" (S3, S5, S7, S13). "Usually, we just listened to our teachers. I tried to learn independently to challenge my ability [to learn physics]" (S18) "It is a bit hard but it is challenging. It tested our adrenalin" (S3)	" I tried but I didn't have self confidence to learn independently" (S2, S8, S10, S14, S17) "It is not easy. We are not accustomed to learning independently. Our teachers usually explained the concepts and then we solve the exercises and problems given" (S8, S17) " When dealing with physics and mathematics, I can't learn new materials [read: concepts] independently" (S8)
2nd Step Teach it to yourself or someone else as simple as possible as if you were explaining it to a child	Teaching it to yourself " It's fun" (S1, S7, S19, S14, S17) " It was like I was standing in front of the mirror; it helped me to understand the topic" (S5) " I could reflect and it helped me to understand well. Maybe, because I often speak to myself" (S7) "It is very helpful as you tried to explain it to yourself until you can understand the concept" (S13) Teaching Someone Else "By explaining the concepts I just learnt to other friends, I felt that I am also learning" (S3, S7) " I learnt how to communicate my thoughts to others" (all interviewed students said this)	Teaching it to yourself "I couldn't hold to laugh when seeing my other friends speak to themselves. [I] did not concentrate" [S10] Teaching Someone Else " I could not explain concepts I just learnt without looking at the textbook" (S14) "To me, it was still difficult as I was afraid of saying something [physics concepts] incorrect " (S2, S19) " I was laughing when explaining the concepts and so was my partner so we didn't learn well" (S10)
3rd Step Return to the source material if you get stucked	"It was helpful" (all interviewed students agreed)	-
4th Step Simplify your explanations and create analogies	"we made notes by using our own words and symbols which are helpful for us to learn" [all students made their own notes as observed]	"Finding examples were easier but very hard to find good analogies" (almost all students agreed)

	"We tried to explain concepts as simple as possible. we tried very hard" (all students admitted this)	"It is a bit annoying when our partner did not get what we mean" (S2)

Asked about the impact of this learning method on their activeness, majority of students revealed that this learning method did significantly influence their activeness. "*We could freely express our ideas and could pretend to act like a teacher*" (S7); "*We did not just sit and listen. We were active*" (S13). Regarding their previous experiences with Feynman Learning Method, these students admitted that none of them have been exposed to the Feynman method in their previous physics learning process. The method is new to them. So far, learning has been dominated by teachers explaining and students listening to teachers' explanations, so students are not used to learning independently in class (Parjiyo at al., 2022). Asked about their suggestions for the better implementation of the Feynman Learning Method, several students pointed out that while this method is very powerful in encouraging their participation and learning independence, it would be challenging to make sure that they have understood the concepts and whether the concepts being delivered were correct. This learning method is better delivered in a class where students are highly motivated to learn independently and are perseverant when encountering difficulties. Besides that, the number of students in that class should also be taken into account.

Reflecting on students' responses tabulated above, it is clearly seen that students always consider physics as a difficult subject which is in line with ideas stated by Angell, Guttersrud, & Henriksen (2004). A salient consequence of this view is that students are not confident to learn physics independently. They will always believe that physics concepts must first be taught by their teachers. This is a significant challenge for the implementation of Feynman Learning Method. Yet at the same time, this reveals the strength of the Feynman Learning Method as a learning method which can be used to promote independent learning. It is suggested that to effectively apply Feynmen Learning Method to learn physics, students' attitudes and mental state towards physics must be well prepared.

Feynman Learning Model heavily promotes "learning by teaching" which implies that in applying this learning model, students' communication skills are very important. The learning model requires students to explain things in simple ways, use their own words, and better to use analogies they create themselves. This is very challenging as communicating physics ideas is very different from communicating ideas in Biology, History or Civic classes. Physics contains concepts and formulas and hence explaining ideas related to physics is much more challenging. For instance, the explainers need to put in words the meaning of a formula or relationship among physics quantities in that formula. This explains why participating students encountered difficulties when explaining their ideas. It seems that to successfully implement Feynman Learning Model, students' communication skills must be well prepared. At the same time, this reveals the significant role of Feynman Learning Model to enhance students' communication skills which is considered as one of a very important 21st Century skills (Trilling & Fadel, 2009). The Feynman Learning Model is therefore an important learning model which can be used to enhance students' 21st century skills (communication skills). The communication skills are one of the important skills in the science learning process, especially in physics learning (Pratama at al., 2019). Physics consists of mathematical equations, so it requires the ability to communicate these equations using words.

CONCLUSION

Feynman Method applied in this classroom could improve students' understanding about the concepts related to Motion in One Dimension topic with a medium N-gain score (0.49). It is evident that this method could encourage students to actively participate in their learning process, improve their communication skills, and more importantly, train their abilities to explain things in simple ways. However, there are several variables which must be taken into account in order to better implement this method. This method is better implemented in the classroom where students are highly motivated to learn and are perseverant when encountering difficulties. It is very crucial for a teacher to prepare students' mental state before implementing this method.

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