UNIVERSITI PUTRA MALAYSIA

DEVELOPMENT OF AN INTERACTIVE MULTIMEDIA NOTE ON PARTICLE PROPERTIES OF WAVES (A SUBTOPIC IN MODERN PHYSICS COURSE)

NURHANIS SYAHIRAH BINTI ADNAN

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By

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Thesis Submitted to the Department of Physics, Universiti Putra Malaysia, in partial Fulfilment of the Requirements for the Degree of Bachelor of Science in Physics with Honours

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ABSTRACT

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February 2022

Supervisor: Assoc. Prof Dr. Raba'ah Syahidah Azis

Faculty: Faculty of Science

In this study, an interactive multimedia note is developed to observe its effectiveness in aiding online classes. The interactive multimedia note which combines five different media (graphics, audio, video, animation, and text) is introduced to a group of students from the Department of Physics, UPM. A survey consisting of Likert's scale was conducted beforehand to identify the students' opinions for Modern Physics and interactive multimedia note. To observe the effectiveness of the interactive multimedia note, two similar set of questions regarding Particle Properties of Waves were distributed to students before and after the implementation of the interactive multimedia note, namely pre-test and post-test. This study observed that there was a significant increase in correct answers for every student in the post-test after being exposed to the interactive multimedia note compared to students' correct answers in pre-test. Besides, data that is obtained from survey and feedback form concluded that the implementation of interactive multimedia note is considered an effective method to be used during the online lecture on Modern Physics. Improvements for the interactive multimedia note in the future were also suggested by students in the provided feedback form.

Keywords: *interactive multimedia material*, *modern physics*, *survey*, *pre-test*, *post-test*, *feedback*

ABSTRAK

PEMBINAAN NOTA MULTIMEDIA INTERAKTIF UNTUK SIFAT-SIFAT ZARAH GELOMBANG (SEBUAH SUBTOPIK DI DALAM KURSUS FIZIK MODEN)

oleh

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Februari 2022

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Dalam kajian ini, bahan multimedia interaktif telah dibina untuk melihat keberkesanannya dalam membantu kelas dalam talian. Bahan multimedia interaktif yang menggabungkan lima media berbeza (grafik, audio, video, animasi dan teks) diperkenalkan kepada sekumpulan pelajar Jabatan Fizik, UPM. Satu tinjauan yang merangkumi skala Likert telah dijalankan terlebih dahulu untuk mengenal pasti pendapat pelajar mengenai Fizik Moden dan nota multimedia interaktif. Bagi melihat keberkesanan nota multimedia interaktif ini, dua set soalan yang sama mengenai Sifat-sifat Zarah Gelombang telah diedarkan kepada pelajar sebelum dalan selepas pelaksanaan nota multimedia interaktif. Dua set soalan ini dipanggil ujian pra dan ujian pasca. Kajian ini mendapati bahawa terdapat peningkatan yang ketara dalam jawapan betul untuk setiap pelajar bagi ujian pasca selepas mereka didedahkan dengan nota multimedia interaktif berbanding dengan jawapan betul untuk ujian pra mereka. Selain itu, data yang diperoleh daripada borang tinjuan dan maklum balas merumuskan bahawa pelaksanaan nota multimedia interaktif ini dianggap sebagai kaedah yang berkesan untuk digunakan di dalam kuliah Fizik Moden secara dalam talian. Penambahbaikan untuk bahan multimedia interaktif

pada masa hadapan turut dicadangkan oleh pelajar dalam borang maklum balas yang disediakan.

Kata kunci: *bahan interaktif multimedia*, *fizik moden*, *tinjauan*, *ujian pra, ujian pasca, maklum balas*

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APPROVAL

This thesis entitled “Development Of Interactive Multimedia Material On Particle Properties Of Waves (A Subtopic In Modern Physics Course)” by Nurhanis Syahirah binti Adnan (Matric No.: 196633), was submitted to the Department of Physics, Faculty of Science, Universiti Putra Malaysia and has been accepted as partial fulfilment of the requirement for the degree of Bachelor of Science in Instrumentation Science with Honors

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CHAPTER 1
INTRODUCTION

1.0 Background of Study

In 2020, many countries around the world were affected by the coronavirus disease 2019, commonly known as COVID-19. The disease has forced most countries to impose a lockdown on their citizens which resulted from the governments halting most economic and social activities until the outbreak is no longer considered a threat.

In Malaysia, the movement control order (MCO) that was announced in March 2020 included an order to shut down all educational institutions which are schools, kindergartens, universities and skills development centers (Menhat et al., 2021). A few days later, all higher education institution were given permission by the Ministry of Higher Education (MOHE) to perform online teaching, commonly known as Open and Distance Learning (ODL). As a response to the new normal from the COVID-19 pandemic, Malaysian higher education institutions have accelerated their effort to implement online learning approaches. The director of the Centre for Development of Academic Excellence (CDAE), Universiti Sains Malaysia (USM) has stated that online learning is no longer an option, instead it is a must considering the pandemic is nowhere reaching an end (Malaysian Investment Development Authority, 2021).

Online learning is a technology trend that allows for lifetime learning and demands a level of digital proficiency. According to the Malaysian Education Blueprint 2015-2025 for Higher Education, digital proficiency, critical thinking, and problem-solving are among the 21st century learning abilities that will help students excel in Industrial Revolution 4.0 (Malaysian Investment Development Authority, 2021).

1.1 Online Learning

The term online learning refers to learning experiences in synchronous or asynchronous situations through a variety of devices with internet access (Dhawan, 2020). Through a synchronous learning environment, students attend live lectures and have actual conversation with lecturers. On the other hand, asynchronous learning environment does not require students to attend live lectures as the learning content is available at different learning system (Dhawan, 2020 as cited in Littlefield, 2018). Online learning is an effective way to reach out to learners as the learning process will be more student-centered, innovative, and flexible.

According to Dzakiria (2005), open distance learning which is the opposite of conventional learning in Malaysia was first introduced in 1969. Malaysian distance learning began with correspondence schools to serve students who were unable to enroll in government-funded schools. In the present day, it is reintroduced again to university students to promote social distancing hence curbing the spreading of COVID-19 in academic institutions.

Ali et al. (2006) reported that online learning system has an advantage over traditional learning system as it meets the needs of students who are not able to attend physical classes, allows self-paced learning, provides innovative yet flexible cost-efficient education besides providing self-explanatory and appropriate learning materials for students.

Even though online learning is a better choice compared to the traditional learning system especially in the pandemic time, it still has loopholes such as maintaining students' motivation through online learning (Rawashdeh et al., 2021). Students with lack of self-motivation have the tendency to not complete assignments on time therefore, submitting poor quality work to their lecturers.

1.2 Interactive Multimedia Notes

In the present day of multimedia technology, there is a harmonious existence of five arts which are text, video, sound, graphics, and animation as shown in Figure 1.1. Multimedia is the use of technology to combine multiple media types such as text, symbols, graphics, images, audio, animations, and video to improve knowledge or memorization (Abdulrahaman et al., 2020, as cited in Guan et al., 2018). It is known that multimedia is a cost-effective method and becoming a practical learning medium for students of this generation.

Figure 1.1 Multimedia Components (Savov et al., 2019)

With the help of multimedia elements in students' learning process, students will get to boost their learning experience as it can be used to demonstrate complicated process or topics that they have to understand. In a study conducted by researchers at University of Maryland, it was revealed that 55 to 121% of problems were solved more accurately for students who learned from resources that included both text and visuals in their learning tools (Malhotra & Verma, 2020). This proves that multimedia learning experience is effective for students to learn and understand the subjects better.

Multimedia hoards more advantages compared to a traditional learning style that is physical classes or lectures. In a multimedia learning environment, students can polish up the required soft skills such as mutual learning, critical thinking and constructive discussion when solving problems (Malhotra & Verma, 2019). This will become beneficial for students once they set foot into the working phase.

In this study, interactive multimedia elements that are incorporated into lecture notes for a Modern Physics (PHY3105) topic will be developed. The chosen topic for this study is Particle Properties of Waves that consists of a few subtopics such as Photoelectric Effect, Compton Scattering, and Pair Production. The interactive multimedia note is developed using several applications such as Microsoft PowerPoint, Canva, and Powtoon. The interactive multimedia note can make students' learning experience more attractive and fun but at the same time it also helps to enhance students' critical thinking skills (Djamas et al., 2018).

1.3 Modern Physics through Interactive Multimedia Notes

Modern physics is a physics subfield that was established in the early twentieth century onwards. Quantum physics, special relativity and general relativity are among the many branches of modern physics.

This subfield is concerned with high velocities that are compatible with the speed of light (special relativity), small distances equivalent to the atomic radius (quantum mechanics), and extremely high energies (relativity).

In this work, the topic that will be focused on is Particle Properties of Waves. It is a topic that requires students to understand and imagine the concept instead of the usual read-through or memorizing.

1.4 Problem Statement

Conventional lectures are no longer an effective method to teach students in the 21st century. The teaching method results in students being passive receivers of information and influence as it focuses more on teacher centricity and rote memorization (Malhotra & Verma, 2020). The conventional teaching method is lacking in applying logic skills or problem solving as students are mostly aimed to only understand theories instead of being given a chance to relate the topic to real-life situations.

Teaching modules, skills and knowledge are frequently conveyed to learners in a framework that does not consider the learners' needs. Therefore, using the multimedia approach as a teaching aid may help to tackle the problem (Malhotra & Verma, 2020). Multimedia material is a non-linear approach that allows learners to use their skills and navigate the learning path independently. The soft skills that are required in real life such as mutual learning, critical thinking, constructive discussion, and problem-solving approach are practiced in a multimedia learning environment.

Several studies (Ramlatchan & Watson, 2020; Zainuddin et al., 2019) prove that the interactive multimedia approach has more benefits than the conventional teaching method. However, there is an inadequate amount of research on the interactive multimedia being used in courses or subjects in university as a learning tool for students. Thus, the idea of using interactive multimedia note in Modern Physics is proposed through this study.

1.5 Objectives

The objectives of this research are as follows:

1. To develop an interactive multimedia note for a Modern Physics subtopic, Particle Properties of Waves.
2. To construct assessment questions and questionnaires for the implementation of interactive multimedia note for students of Department of Physics, UPM.
3. To evaluate the effectiveness of the interactive multimedia note by analyzing the data obtained from assessment and questionnaires.

1.6 Hypothesis

1. There is a significant increase of correct answers in post-test scores compared to pre-test scores after exposing students to the interactive multimedia note for topic Particle Properties of Waves.

1.7 Learning Outcomes of Particle Properties of Waves (Modern Physics course)

1. Describe the photoelectric effect and the Compton scattering

2. Differentiate the photoelectric effect, Compton scattering, and pair production

3. Solve problems related to Particle Properties of Waves.

CHAPTER 2

LITERATURE REVIEW

2.1 Multimedia in Education

Multimedia applications play an important role in education. It is used in education such as in preschool, school, and tertiary education. Back in the day, newspapers, which consisted of text, infographics, and pictures may have been the first mass communication medium to use multimedia to transmit ideas (Li et al., 2014). These graphics and pictures were often hand-drawn before the invention of the still-image camera. According to Webster's research, the word "multimedia," which can be defined as "using, involving, or including various media," was first used in English in 1962 (Mediaeng, n.d.).

Multimedia provides various learning resources for students in an integrated way for the purpose of instruction. As a result, students can learn in ways that suit their learning requirements and interests through the resources that are provided by instructors or lecturers (Smyth, K., Manika, 2010).

Undeniably, multimedia inclusion into learning materials requires additional time and effort. However, the use of multimedia as a learning aid can offer an enhanced learner experience. Through the correct ways of implementation, students will be able to experience an enhanced learning experience besides developing deeper comprehension of the subjects.

In the late 1960s, educational multimedia was not able to sustain itself (Fletcher, 2017; Smyth, K., Manika, 2010) as a result of the emphasis on the technology rather than the learner. According to Smyth, K., Manika (2010), spectacular multimedia has rarely lived up to its creators' goals and has little impact on the learning process. Instead of including multimedia for teaching through a showcase of advanced technology, creators should aim to adapt the technology to enhance the student learning experience. For instance, a wide range of beautiful animations that deliver a lot of information can become disturbing, but one semi-interactive tutorial is possibly able to maintain students' attention.

2.2 Interactive Multimedia

Interactive multimedia has been coined as "hybrid technology." It combines computer database technology's storage and retrieval capabilities with enhanced tools for viewing and altering these resources. Multimedia has a wide range of meanings, and definitions fluctuate based on the situation (Bass, 1997)

Bass (1997) explained that the materials of interactive multimedia are packed, integrated, and connected in a way that allows users to browse, explore, and analyze them using various searching functions, as well as the ability to annotate or personalize the materials.

2.2.1 Elements in Interactive Multimedia

Interactive multimedia consists of several elements which are words, graphics, audio, animation, and video. Each element has different benefits that could be used for students (Smyth, K., Manika, 2010).

2.2.1.1 Text

Text is often overlooked as one of the multimedia elements. It is a crucial element that is effective in delivering information or act as a reinforcement to other multimedia elements. It is often used as headlines, slogans and subtitles.

2.2.1.2 Graphic

It is a visual element as shown in Figure 2.1 that includes stationary images, icons, graphs, diagrams and illustrations. Information that is presented in graphics helps with visualization and thinking skills.

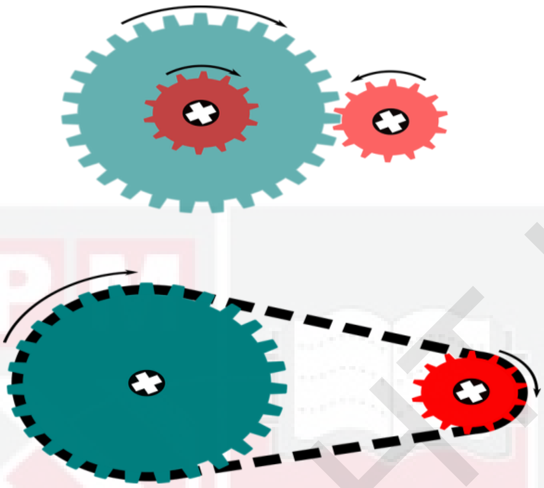

Figure 2.1 Example of a graphic (Pixabay, 2020).

2.2.1.3 Video

Video is a recording of moving images and sound. For example, Figure 2.2 is a screenshot of a video that shows the motion of a bouncing ball. Videos can portray authentic learning circumstances thus presenting scenarios that are unavailable in conventional classrooms.

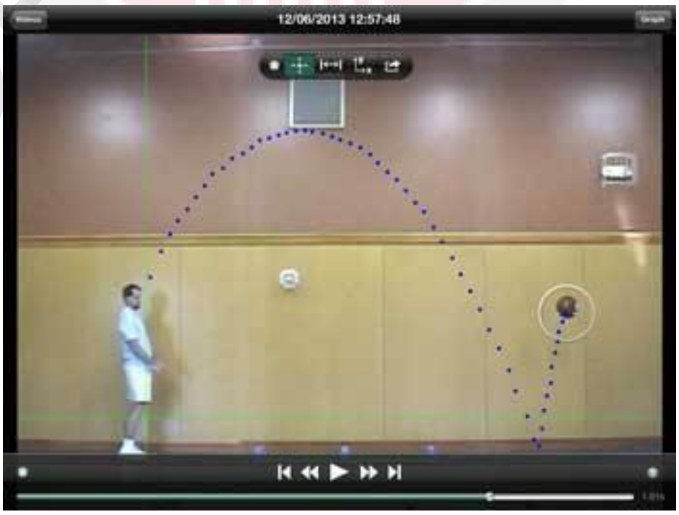

Figure 2.2 Example of a physics video (Ritter, 2014).

2.2.1.4 Audio

It is a sound recording that can either mean voice, music or sound effects. Adding audio elements to learning conditions aid students to recognize sounds, improve listening skills and pronunciation skills for foreign language courses. Figure 2.3 shows examples of audio devices that are available in the market such as earphones, headphones and speakers.

Figure 2.3 Example of audio devices (PCQ Bureau, 2016).

2.2.1.5 Animation

Animation is a set of simulations of moving graphic images. Animations are excellent at adding impacts to presentations and illustrating complex steps to appear easy. Figure 2.4 shows the process before a set of pictures are animated.

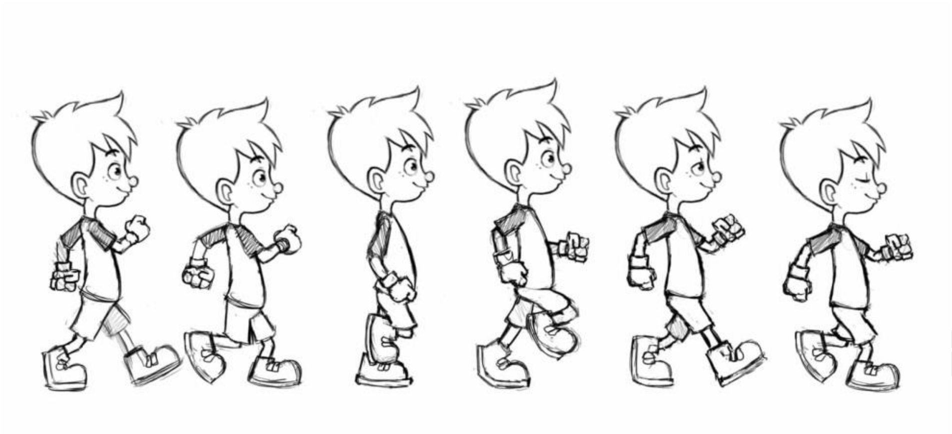

Figure 2.4 Animation (Ivanov, n.d.).

2.2.2 Effectiveness of interactive multimedia approach

Through interactive multimedia, students have complete control over the reading experience by selecting from a variety of options and creating unique courses and sequences through the materials. The flexibility that students have to explore through information in a meaningful way for them is the reason why interactive multimedia is known as "reader-centered" instead of "teacher-centered" as in conventional classes.

Table 2.1 shows the effectiveness of using the interactive multimedia approach in education.

Table 2.1: Target group, interactive multimedia materials used and the outcomes.

Target groups	Interactive multimedia materials	Outcomes	References
Financial accounting students	• PowerPoint presentation • iSpring Suite	• Practical and feasible for students	Aryanti & Marwan (2021)
Physics students	• Lectora	• Feasible for high school physics learning	Zainuddin et al. (2019)

High school students	Games developed through • Macromedia Flash 8 • Adobe Photoshop CS3	• Materials were valid, practical, and effective • Enhanced students' critical thinking skills	Djamas et al. (2018)
Undergraduate students	• Comic strip	• Students find the approach enjoyable	Ozdemir (2017)
Dental and nursing students	• Gamification	• Improved students' writing skills • Improved empathy in nursing students	El Tantawi et al. (2018); De Wit-Zuurendonk & Oei (2011)

YouTube is also gaining interest from students these days. It is a video-sharing platform that is increasingly being used by students to watch short educational videos according to students' respective courses. For instance, Khan Academy started sharing recorded voice-over lectures on YouTube since 2006. The main learning aid that Khan Academy used in their videos was a digital blackboard to write down equations and illustrations.

The studies mentioned in Table 2.1 suggest that the adaptation of multimedia in education could cater to different learning styles and deliver better results as compared to conventional lectures. Universities can take advantage of using interactive multimedia notes as an online learning aid during the COVID-19 pandemic. The approach is proven to be beneficial for students as stated in Table 2.1.

2.3 Online Learning

Online learning can be referred to as "e-learning" or "distance learning". Fundamentally, it is a type of learning that occurs across distance and does not happen in conventional lecture halls. There is a long history of distance learning that birthed several types of it today such as correspondence courses, telecourses, CD-ROM courses, online learning and mobile learning (Stern, 2004).

2.3.1 Online learning during the pandemic COVID-19

The pandemic had caused a significant impact not only on students, but also on lecturers and educational institutions across the world. It has snitched the opportunity for students to resume conventional lectures in university. Students were introduced to online learning that does not require students and lecturers to be in the same place at the same time.

2.3.2 Advantages of Online Learning

Online learning allows a lot of opportunities for social interaction (Dhawan, 2020 as cited in McBrien et al., 2009). Amid the COVID-19 situation, classes can still go on as usual through video-conferencing platforms such as Zoom, Google Meet and Microsoft Teams. The platforms can accommodate more than 50 students from their respective homes at once. This helps lower physical interactions among students and lecturers. Besides, online learning is also cost-efficient (Rawashdeh et al., 2021) because students do not have to pay accommodation fees or facility fees. Indirectly, online learning eases students' financial burden thus helping students to focus on gaining better education.

2.3.3 Disadvantages of Online Learning

Even though online learning is beneficial for lecturers and students, there are also drawbacks to this learning mode. According to Dhawan (2020), students may find online classes to be dull and uninteresting at times. It is understandable since students attend an average of 6 hours of classes daily which means they have to sit in front of their computers for a long time. Besides, students are unable to perform in classes due to ambiguous course explanations (Rawashdeh et al., 2021). This leads to students being unable to answer tutorial questions or tests perfectly.

However, the disadvantages of online learning can be aided with other learning methods that can attract students to understand the subjects or courses they are taking better. Dhawan (2020) stated in a study that online classes are meant to be dynamic, interesting and interactive between lecturers and students. Thus, good effort should be taken to personalize the learning process to a greater extent.

2.4 Students' Preferred Learning Styles

Learning style is defined as a pattern of behavior and/or performance by which an individual absorbs new information and develops new abilities as well as the process through which the individual recalls new information or skills (Aldajah et al., 2014, as cited in Sarasin, 1999). It can also be defined as a learning process favored by individuals (Berková et al., 2020 as cited in Fenyvaisova, 2006).

Every student has different learning styles thus information is often perceived diversely. Research on learning styles commonly uses the sensory modalities which are Visual, Aural, Read or Write and Kinesthetic (VARK) learning styles questionnaire as shown in Figure 2.5. Vagg et al. (2020) reported that in a research conducted by Baykan & Naçar (2007) on 155 first-year medical students, it was observed that the majority of the students preferred multimodal learning style (99 students). In other words, the students are keen to learn through different learning styles instead of sticking to one modality. Even though a minority of the students do prefer unimodal learning, most of the students are kinesthetic learners who enjoy simulations and role-plays that help the students to understand advanced concepts. Lujan & Dicarlo (2006) reported in research that first-year medical students prefer multiple learning styles. Based on the VARK questionnaire, it was found that 63.8% of the participants preferred multiple modes of learning whereas the rest preferred single-mode learning. These studies show a tendency that medical students prefer multiple modes of presentation due to being kinesthetic learners.

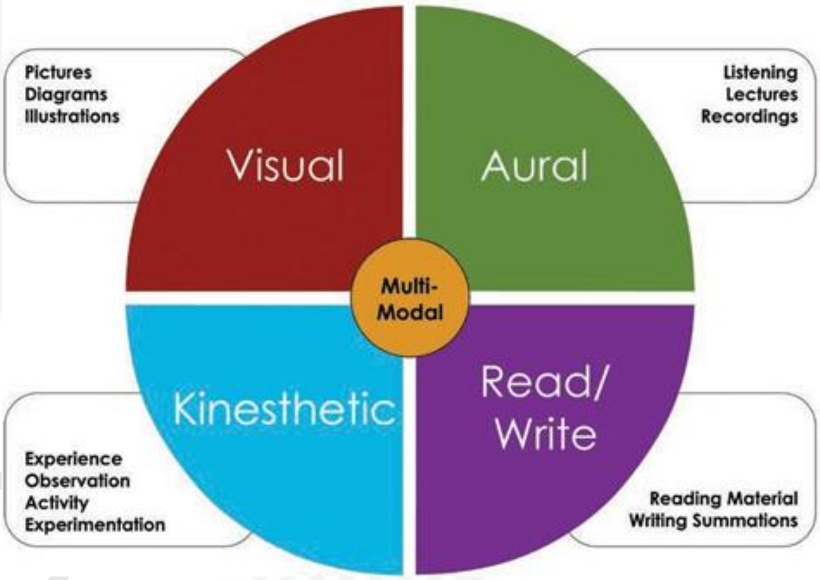

Figure 2.5 VARK learning styles

In another study conducted on engineering students, different learning instrument was used. Aldajah et al. (2014) used Solomon-Felder Index of Learning Styles (ILS) for 40 mechanical engineering students. The results are as shown in Figure 2.6.

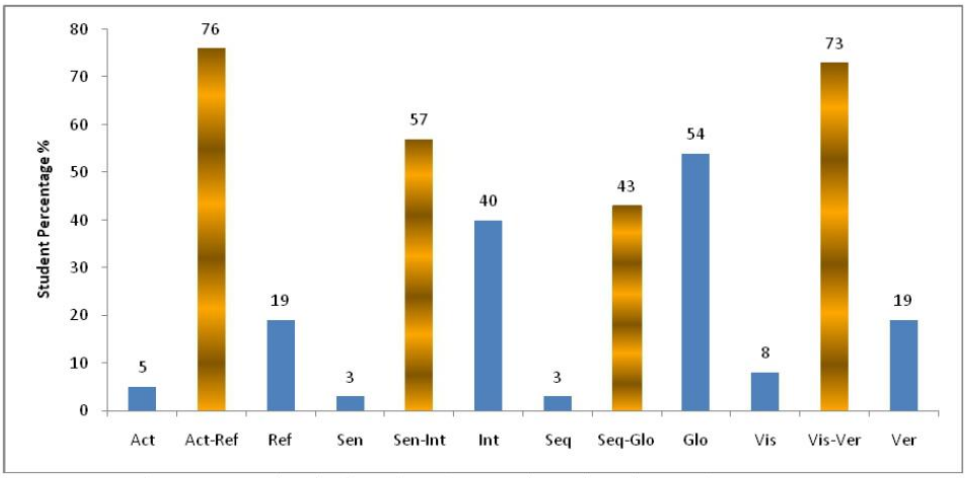

Figure 2.6 Students' preference over learning styles using ILS instrument

As seen from Figure 2.6, the dominant learning styles for the mechanical engineering students are active-reflective (76%) and visual-verbal (73%) compared to active, reflective, sensor, intuitive, sequential, global, visual and verbal learning styles.

Active-reflective is a learning dimension that is associated with the processing of the information that has been perceived. An active learner enjoys experimenting with, testing, discussing and explaining the information they gathered. A reflective learner, on the other hand, prefers to explore and alter information in a more introspective manner.

As for visual-verbal learners, they deal with the input of information. Visual learners prefer information to be taught in images, diagrams, videos, experiments and charts meanwhile verbal learners love information to be delivered verbally such as in discussions and presentations.

In the study, Aldajah et al. concluded that 73% of the students preferred to be taught verbally and visually. Therefore, it was recommended that lecturers or facilitators include meaningful images, diagrams and videos whenever possible during lectures.

Lectures or classes that are conducted during the pandemic will be more interesting if students' educational needs are satisfied. When instruction is synchronized to learning styles, students will become more motivated and perform better in classes (Baykan & Naçar, 2007).

2.5 Modern Physics

Modern Physics is a subfield of physics. It is a fundamental field for Solid-State Physics, Relativity, Photons, Quantum Mechanics and Nuclear Physics. Over the years, Modern Physics has contributed to a lot of scientific inventions and discoveries. For example, the in-depth study of quantum mechanics has resulted in the invention of semiconductors, lasers, magnetic resonance imaging (Strikman et al., 2014) whereas general relativity is critical in measuring accurate GPS coordinates.

The interactive multimedia note that is developed by researcher will focus on subtopic Particle Properties of Waves of Modern Physics. It will cover on Photoelectric Effect, Compton Effect, Pair Production and Photon Absorption.

2.5.1 Photoelectric Effect

A German physicist Henrich Rudolf Hertz first discovered the photoelectric effect in 1887. While working on radio waves, Hertz observed sparks in the air gap of the transmitter when ultraviolet light was illuminated at the metal balls. Thus, the photoelectric effect was studied further by other physicists. The physicists discovered that electrons are emitted from the metal surface if the frequency of light was high (Beiser & Page, 1965). Through the photoelectric effect experiment, three findings were observed:

1. No time interval between arrival of light at metal and the emission of electrons.
2. A brighter light emits more photoelectrons compared to a dimmer light of the same frequency.
3. Photoelectrons have more energy when the frequency of light is higher.

2.5.2 Compton Effect

Compton effect is the process when an x-ray photon strikes an electron which in turns scattered the photon away from its original motion whereas the electron receives impulse that allows it to move (Beiser & Page, 1965). The energy and momentum are conserved during the event. As a result to this event, scattered photon has lesser energy compared to the incident photon. Besides, the scattering of photon also causes deviation in angle between the incident photon and scattered photon. Bigger deviation angle means bigger wavelength difference for incident and scattered photons.

2.5.3 Pair Production

Pair production occurs when a gamma ray photon is replaced by two new particles, electron and positron. The replacement must be produced in pairs for the process to conserve its electrical charge. Each photon must have at least 1.022 MeV to produce a pair production. This is because the total rest energy of electron and positron are 1.022 MeV. Hence, to conserve the energy for the process, a photon is required to have a minimum energy of 1.022 MeV.

2.5.4 Photon Absorption

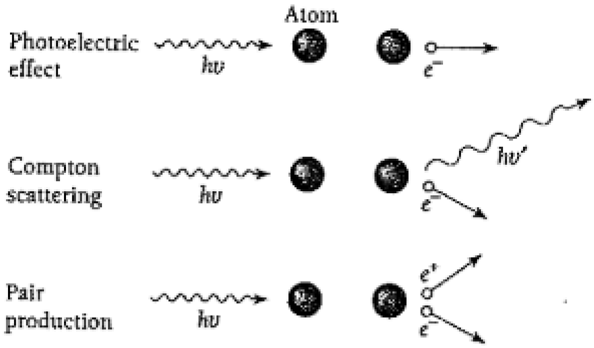

Figure 2.7 X-ray and gamma rays interact with matter (Beiser & Page, 1965)

Figure 2.7 shows three different ways of photons interacting with matter. All of these processes result into photon energy being transferred to electrons hence losing energy to atoms of absorbing metals.

2.5.5 Reasons for Negative Perception towards Modern Physics

Even though modern physics has contributed a lot to the development of science, a lot of students still find the subject intimidating. Students experienced a lot of problems when studying modern physics. According to Aksakalli et al. (2016), the common problems are listed as below:

1. Students struggle with arithmetic solutions because they are unable to relate the key concepts of modern physics.
2. Students deem modern physics as insignificant as they have poor perception of modern physics.
3. The traditional teaching technique makes it harder to comprehend the subject.
4. Students are unable to fathom the principles of modern physics due to their inability to connect modern physics and everyday life.

5. Students’ knowledge of classical physics become a barrier to understand modern physics concept since they do not understand the differences the two subjects have.
6. Students’ established views about modern physics ideas generate confusion and lead to failure in this course.
7. Lecturers use non-scientific methods of simplification when teaching the subject because they are unaware of students’ negative conceptual ideas of modern physics.

To summarize the above list, students have a hard time learning modern physics because of the conventional teaching technique, inability to connect modern physics with real-life, and usage of non-scientific methods of simplification by lecturers. This proves that students need to see visuals or real-life examples when learning the subject.

Aksakalli et al. (2016) interviewed three groups of students to identify the most common negative perception of the students and their frequencies towards modern physics. Table 2.2 summarizes the interview of 36 students.

Table 2.2 The most repeated negative perceptions of the students regarding modern physics (Aksakalli et al., 2016).

Key Constructs Used in the Interviews	No. of students	Most Repeated Constructs During the Interviews
Concerns	6	12
Abstract	5	9
Preconception	5	7
Alienation	8	13

Contains conceptual difficulty	3	6
Includes mathematical challenge	4	6
It is difficult to visualize	5	10

From Table 2.2, it is noted that students face difficulty in learning modern physics because it comprises conceptual, mathematical challenges and hard to visualize the contents of the subject.

The same researcher has conducted a study on 123 undergraduate students to further investigate which subtopic of modern physics the students have troubles with. The result is shown in Table 2.3.

Table 2.3: Students' perceptions towards subtopics in modern physics (Aksakalli et al., 2016)

	Interesting	Difficult concept	Mathematical difficulty	Difficult to visualize
Blackbody Radiation	76%	57%	47%	67%
Photoelectric Event	74%	44%	55%	56%
Compton Event	71%	48%	58%	66%
Electron Diffraction	56%	53%	57%	67%
Bohr Atom Model	62%	53%	57%	67%
Photon Concept	80%	50%	54%	69%

Out of all modern physics topics that are listed above, more than 50% of the participants agreed that all of the topics are interesting to learn with Photon Concept having the highest percentage.

However, it is also observed that more than half of the participants find almost all topics listed in Table 2.3 to be difficult to visualize. This is because the topics have difficult concepts for students to understand through traditional lectures. It is also shown that most students prefer to learn through visuals rather than sit in long hours of conventional lectures.

2.6 Interactive Multimedia Approach for Modern Physics

The widespread use of interactive multimedia applications in education is due to their numerous benefits (Abdulrahaman et al., 2020 as cited in Almara'beh et al., 2015). Some of the benefits include turning abstract concepts into concrete contents, presenting a lot of information in a limited time with lesser effort and stimulating students' interest into learning.

Ozdemir (2017) designed a short comic story that focused on the historical emergence of Planck's explanation of blackbody radiation in his research. The purposes of the research were to see what students learned from it and what they thought about using comic strips in modern physics.

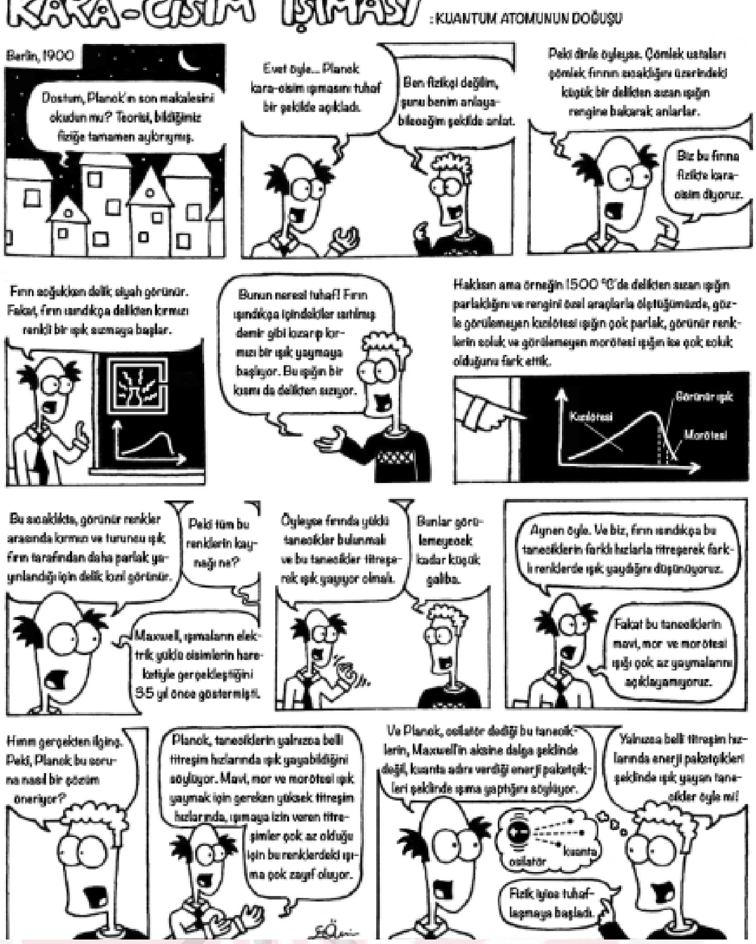

Figure 2.8 Final version of the short comic strip (Ozdemir, 2017)

The comic as in Figure 2.8 illustrates a short conservation between a physicist and a coworker about Planck's blackbody paper in 1900. The physicist thoroughly explained Planck's theory that demonstrates why a hot body does not radiate ultraviolet light through quantized energy emitted by oscillating particles.

The comic itself underwent many trials and revisions by science education specialists and undergraduate students before reaching the final version. A few open-ended questions regarding blackbody theory were asked to each student before reading the comic strip. Later, they were instructed to read the comic strip individually before answering the same open-ended questions again.

The research concluded with students who participated in the research describing modern physics as difficult and boring since the subject lacked lab activities and daily life examples. Besides, students' wrong answers regarding blackbody theory decreased after the comic strip implementation (Ozdemir, 2017). In the opinion forms that were distributed to the students, it was revealed that the students enjoyed the instructional comic strip due to its context-based nature, entertaining and the use of informal language. In addition, the students thought the comic strip simplified the complex modern physics concepts more sufficiently. Nonetheless, some design considerations were noted from the students' opinions and suggestions for the revisions and developments for the new comic strip. Such suggestions include visual and context design of the comic strip should be made suitable to the target age. For instance, more daily life examples and humorous scenarios should be included in the comic strip to appeal to students.

CHAPTER 3

METHODOLOGY

3.1 Introduction

This chapter elaborates on the experimental setup in a detailed manner. This project is intended to assess the understanding of students on the topic Particle Properties of Waves.

3.2 Process of Interactive Multimedia Note Implementation towards Participants

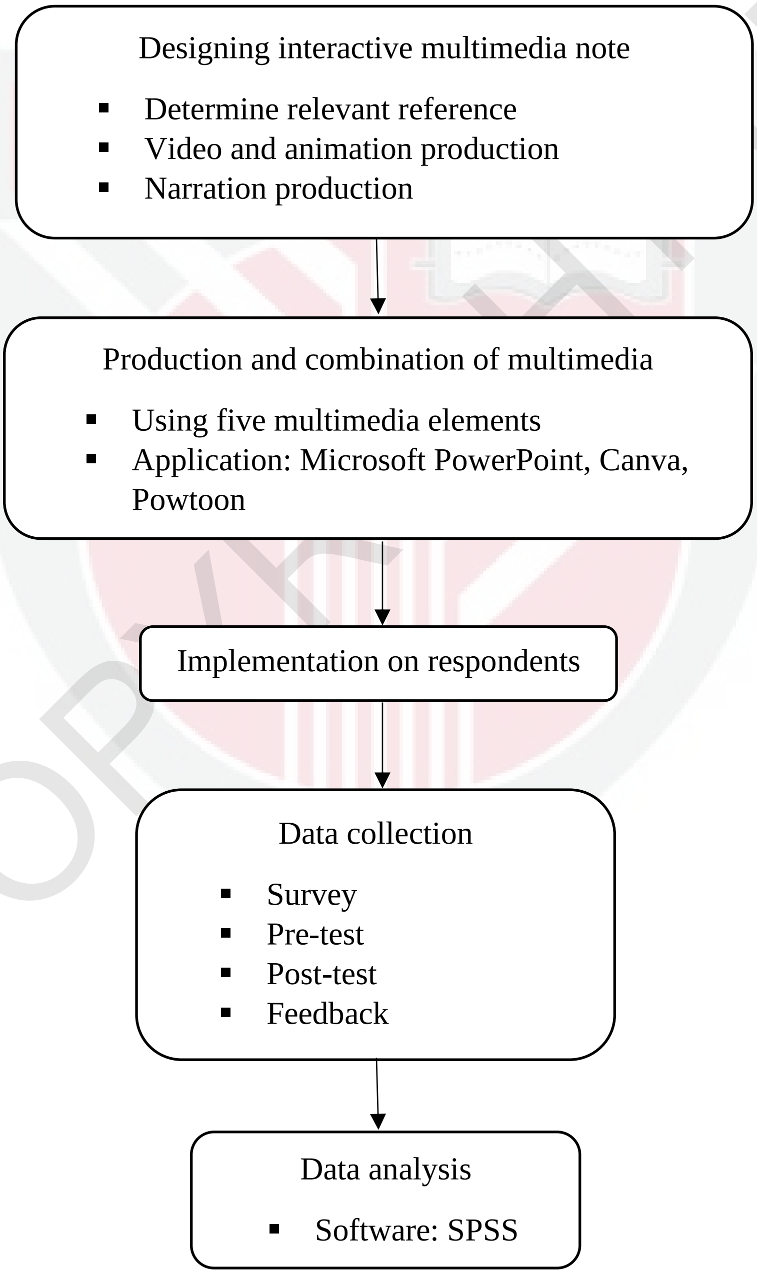

Figure 3.1 Flowchart for the implementation of interactive multimedia on respondents

3.3 Design of the study

Quantitative and qualitative approaches are used for this study. A part of the outcome of this study will be obtained through numerical data from surveys and feedback questions. Besides, another part of this study will collect data in written form for section (E) of the feedback form, hence data will be analyzed qualitatively which includes coding and categorizing similar answers from the respondents.

This study was conducted in three stages. In stage one, a set of the survey is distributed to a group of students to assess their understanding of modern physics. Next, respondents will move up to stage two where they are given access to the interactive multimedia notes of the chapter Particle Properties of Waves. Respondents are required to conduct self-learning with the material before proceeding to stage three. In stage three, respondents need to answer a feedback form to assess the effectiveness of the multimedia notes. The percentage of correct answers obtained by the students from pretest and posttest that came from the survey and feedback forms determine their understanding of Particle Properties of Waves.

3.4 Population and Sampling

The population of this study consists of undergraduate students from Department of Physics, Universiti Putra Malaysia. The study is conducted upon this population because this population is required to enroll in Modern Physics (PHY3105) course as an undergraduate requirement. From the population, a total of 31 respondents were selected to participate in the study. Samples consist of second year undergraduate students who are currently taking Modern Physics course this semester and final year undergraduate students who have taken the course.

3.5 Ethical Consideration

The study was conducted with the cooperation and participation of the researcher and respondents. Protecting the integrity of responders is a crucial ethical norm in research (Kaiser, 2019). Thus, respondents were not asked for their personal information such as name, identity card or personal email. This study however asked for respondents' matric numbers but with a good reason. The survey form, interactive multimedia notes and feedback form were distributed to respondents' institution email in the form of [matric number]@student.upm.edu.my. Apart from the matric number, no other personal information was asked.

3.6 Research Instruments

3.6.1 Phase One

The first instrument that was used in this study was an online survey form distributed through Google Forms. The online survey consists of five main sections:

(A) Demographic

(B) Students' Opinions on Modern Physics

(C) Students' Understanding of Particle Properties of Waves

(D) Students' Perception on Modern Physics Lecture Notes

(E) Students' Exposure to Interactive Multimedia Notes.

A variety of questions were asked in the survey form to learn their opinions and perceptions towards Modern Physics. Besides, a set of diagnostic questions, called pre-test, were asked in section (C) of the survey to assess their understanding of the topic Particle Properties of Waves that was taught during lectures. Since the purpose of this study is to introduce interactive multimedia notes to students, a few questions are asked in the survey form to observe the efficiency of the current lecture notes that students have now. Lastly, students' exposure to interactive multimedia notes was also asked in the survey form. When all of the students' opinions were gathered from the survey, an interactive multimedia note was developed using the data analyzed from the survey.

3.6.2 Phase Two

Microsoft PowerPoint is a common software used for presentations and notes-making. The templates that are available in the software are easy to use for a first-time user or an expert. It also allows users to build notes and presentations on their own using multimedia elements including text, graphics, videos, audios and animations.

Hence, Microsoft PowerPoint was chosen as a tool for this study because it is easily accessible software that is readily available on laptops.

3.6.2.1 Text

Text is a means of communication. The right selection of font and size play important roles when implementing text element into the interactive multimedia notes. Text that are effective will be able to deliver knowledge accordingly and set the overall theme of the presentation that will help to engage its users. In this study, several text fonts were used such as Abadi, Calibri (light) and Black Bubble. Figure 3.2 shows the main page of the interactive multimedia note that uses a cheerful colored font to attract readers.

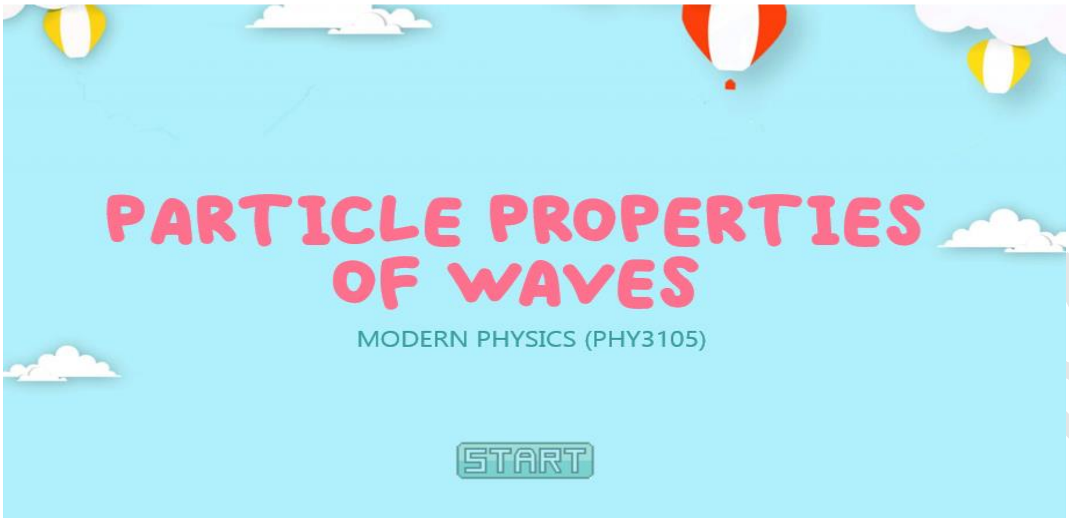

Figure 3.2 Text

3.6.2.2 Graphic

Graphic is a commonly used multimedia element in presentations. It aids users to grasp concepts better by stimulating imagination and improving their cognitive abilities. Besides, graphic is also used in this project to avoid the presentation from being loaded with texts only. Figure 3.3 shows that graphic is included in interactive multimedia note as an aid to the explanation.

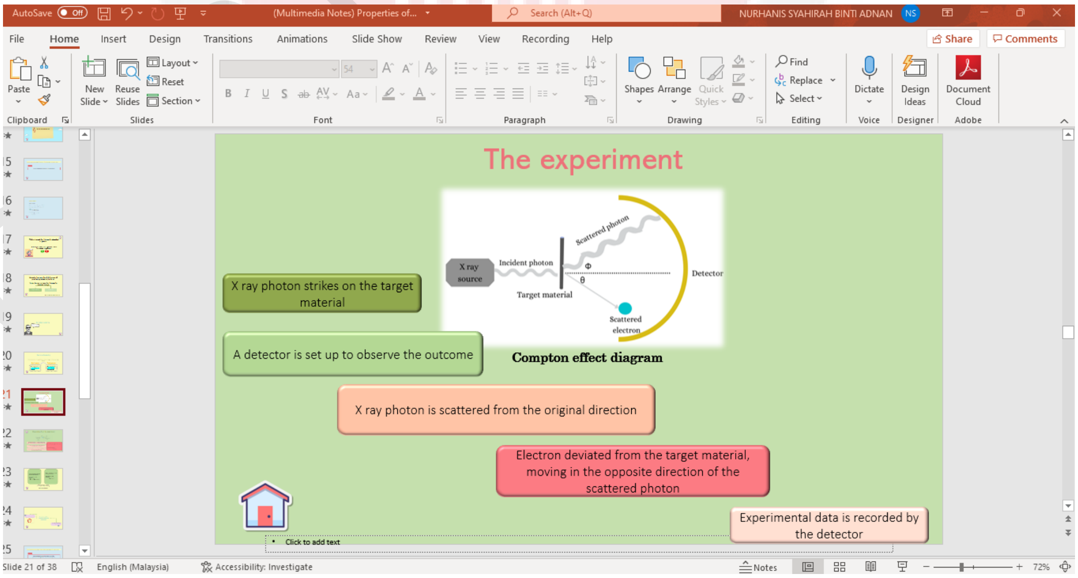

Figure 3.3 Graphic

3.6.2.3 Animation

Learning physics concepts merely through texts and graphics could be boring especially if the topic is difficult to understand. Therefore, animation element was also added into the project to enhance the learning experience. It was used in this project to ensure that the modern physics concepts are delivered attractively. Animations in this project were created from an online animation-making website, Powtoon. Powtoon can be used easily for a beginner or professional because of its simplified interface as shown in Figure 3.4. The website offers cool objects and characters in the libraries section to let its users create a unique and fun animation video.

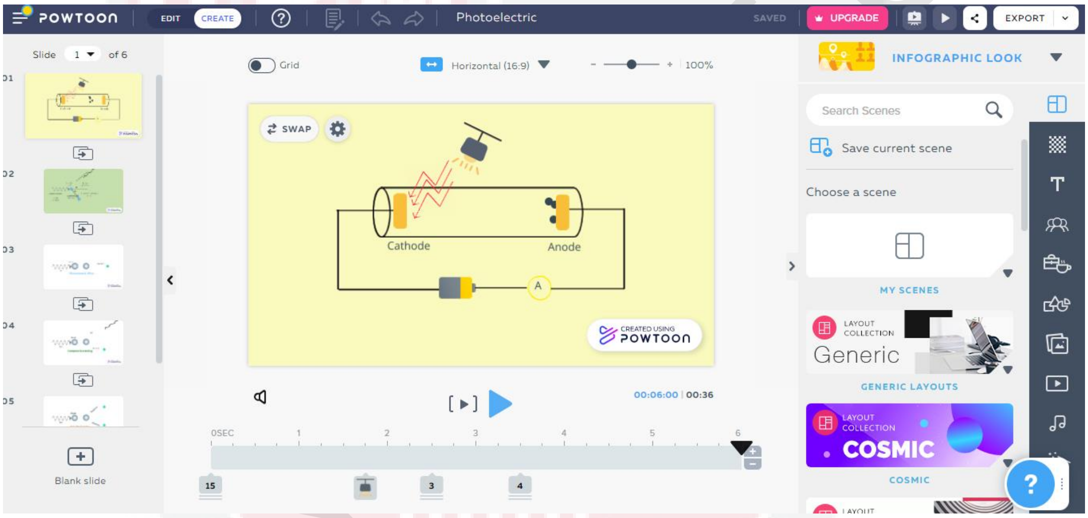

Figure 3.4 Animation on Powtoon

3.6.2.4 Audio

Audio element is also used to reduce the number of texts in this project. A highly effective audio will lessen the number of texts that users have to read and help them to stay focus on the lesson that users are learning. In this project, audios were recorded using the Audio feature that is available on PowerPoint as shown in Figure 3.5.

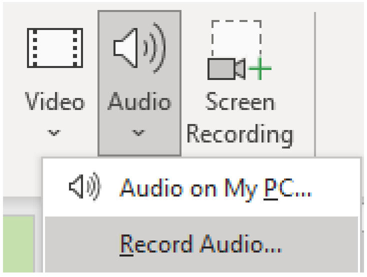

Figure 3.5 Audio Feature in PowerPoint

3.6.2.5 Video

Adding videos in this project makes it become more interactive and attractive to the users. A few explanation videos were edited using Powtoon software that houses a lot of interesting and comic templates that helps to create a story while explaining modern physics concepts such as Photons and Pair Production in an interesting manner. Animations, graphics and texts were added into the explanation videos thus creating a fun experience learning for the users.

3.6.3 Phase Three

Instrument that was used in this phase is a feedback survey after the implementation of the interactive multimedia note to the respondents. It was distributed after the respondents finished reviewing the notes. The sections of the feedback form are as follows:

(A) Students' Understanding of the chapter Particle Properties of Waves,

(B) Understanding of Modern Physics,

(C) Interactive Multimedia Elements,

(D) Interactive Multimedia Design,

(E) General.

The main purpose of this instrument is to observe the effectiveness of the notes for the students. Besides, it is also to observe the understanding of students towards topic Particle Properties of Waves. Thus, the same set of questions from Phase One, now called post-test was added into the feedback survey.

3.7 Likert's Scale

Likert's scale is a psychometric response scale that is typically used in questionnaires to determine a respondent's preferences or level of agreement with a statement (Bertram, 2007). Thus, Likert's scale is used in the questionnaires of this study specifically in sections (B), (D) and (E) of the survey form, and sections (B), (C), (D) of the feedback form.

A 5-point scale was used in this study where each level on the scale is assigned a numeric value as depicted in Table 3.1.

Table 3.1 5-point Likert's Scale

Item	Likert's scale
1	Strongly disagree
2	Disagree
3	Neutral
4	Agree
5	Strongly agree

3.8 Data Analysis

Qualitative data, specifically the data that was obtained from feedback form was analyzed based on the process of coding and grouping answers into different groups. On the other hand, quantitative data that is obtained through survey and feedback forms are analyzed using Statistical Package for the Social Sciences software (SPSS). It is commonly used by researchers to edit and analyzed different kinds of numerical data.

In this study, SPSS was used to calculate the mean and standard deviation of Likert's scale for each survey and feedback section. Besides, it was also used to compare data from pre-test and post-test answers through T-Test. T-Test is used in researchers to observe any significant difference between the means of two groups of data (Hayes, 2018). It is also used in this research to assess the creditability of a hypothesis through the pre-test and post-test data.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Introduction

This chapter discusses the results obtained from the survey, pre-test, implementation of the interactive multimedia note, post-test and feedback questions. The results obtained aligned with the objectives of this study.

4.2 Demographic information

This segment explains the general demographic features of the respondents such as year of study and courses. The demographic of the respondents is obtained from section A of the survey. A total of 31 students participated in this study. Figure 4.1 depicts that most of the respondents are from Year 4 which are 20 students, followed by 11 students from Year 2. This shows that more Year 4 students participated in the study compared to Year 2.

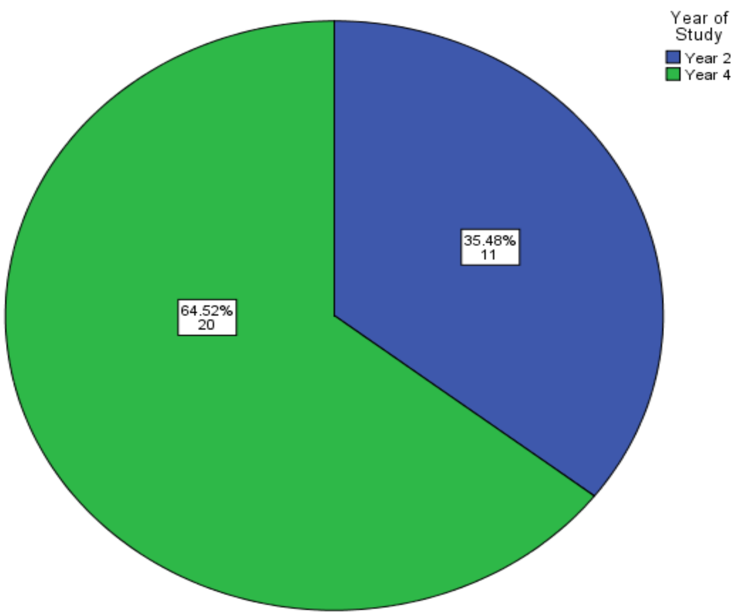

Figure 4.1 Distribution of respondents by year of study

Almost all the respondents are from Bachelor of Science in Physics with Honours (77.42%) as shown in Table 4.1. This is followed by Bachelor of Science in Instrumentation with Honours (12.90%) and the course that had the least respondents is from Bachelor of Science in Physics with Education (Honours) with only 9.68%.

Table 4.1 Distribution of respondents by courses

Courses	Frequency (N = 31)	Percentage (%)
Bachelor of Science in Physics with Honours	24	77.42
Bachelor of Science in Instrumentation Science with Honours	4	12.90
Bachelor of Science in Physics with Education (Honours)	3	9.68
Total	31	100

4.3 Respondents' Perception towards Modern Physics and Interactive Multimedia Note

This segment interprets the data obtained from a survey that was conducted before distributing the interactive multimedia note to respondents. Respondents' perceptions towards the Modern Physics course from section B of the survey were gathered.

Figure 4.2 concluded that the majority of the respondents are neutral when asked about their perceptions of the Modern Physics course in terms of the level of difficulty of the course and mathematical calculations for the course. Even though respondents were neutral of the difficulty of the Modern Physics course, they were divided when they reached Question 3 (Q3) of section B. Q3 questioned whether respondents were able to visualize the necessary concepts when learning Modern Physics course. The majority of the respondents, 9 (29%) picked disagree and agree respectively for Q3 as shown in Figure 4.3.

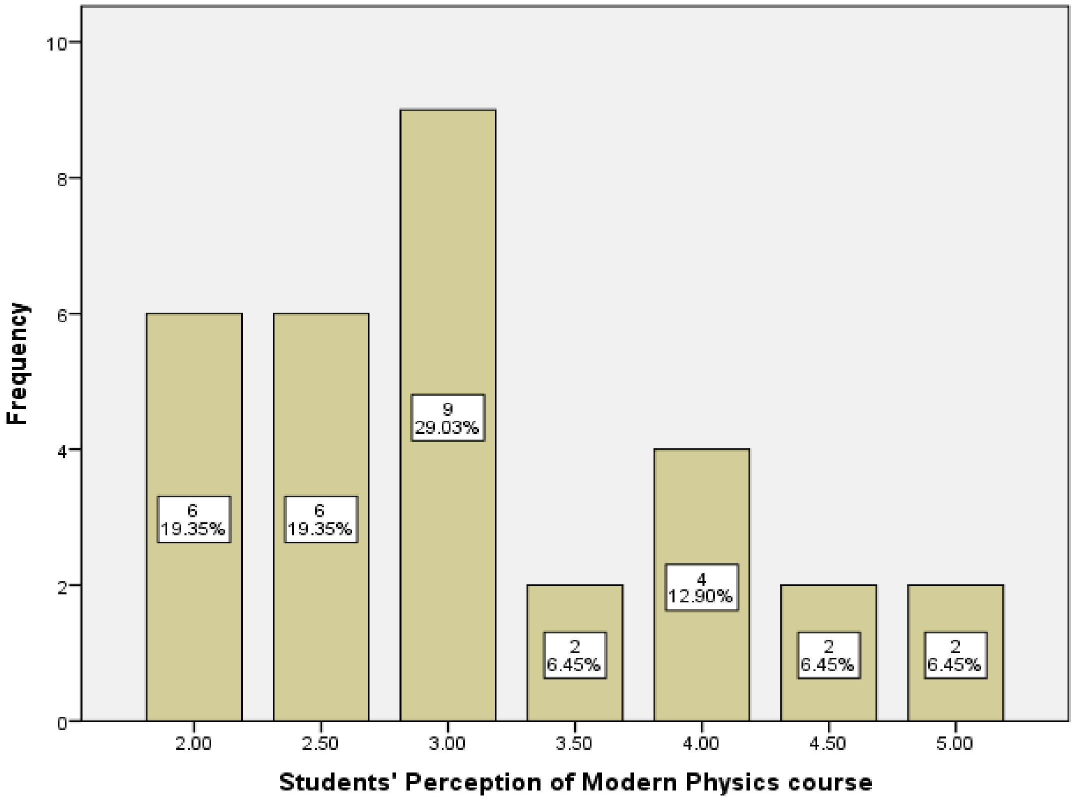

Figure 4.2 Respondents' perception of Modern Physics

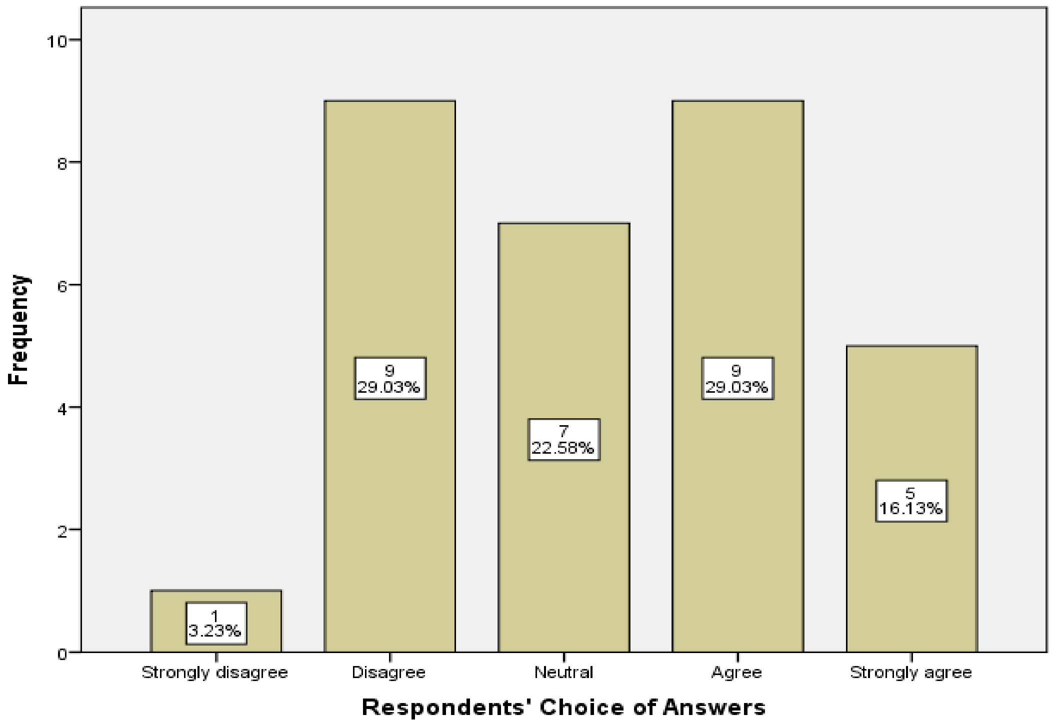

Figure 4.3 Respondents' answers to Question 3 of Section B in the survey

Table 4.2 lists down modern physics concepts that students find hard to visualize. Compton Scattering happens to be the hardest concept for the respondents to visualize its theory and findings. The result was followed by other concepts such as Pair Production (10), Photon Absorption (3), Photoelectric Effect (3). Two respondents also added other concepts that they find difficult to visualize which are Schrodinger's Equation and Blackbody Radiation.

Table 4.2 Modern Physics concepts that are difficult to visualize according to respondents

Physics concepts	**Frequency (N = 31)**	**Percentage (%)**
Compton Scattering	13	41.9
Pair Production	10	32.3
Photon Absorption	3	9.7
Photoelectric Effect	3	9.7
Schrodinger's Equation	1	3.2
Blackbody Radiation	1	3.2
Total	31	100

The interactive multimedia note that is prepared by the researcher carter to respondents' choices by giving more attention to concepts that are chosen to be difficult for visualizing.

Respondents' perception towards the available lecture notes were asked in Section D of the survey. 9 out of 31 respondents chose to be neutral when asked whether the current lecture notes are not detailed and difficult to understand as pictured in Figure 4.4.

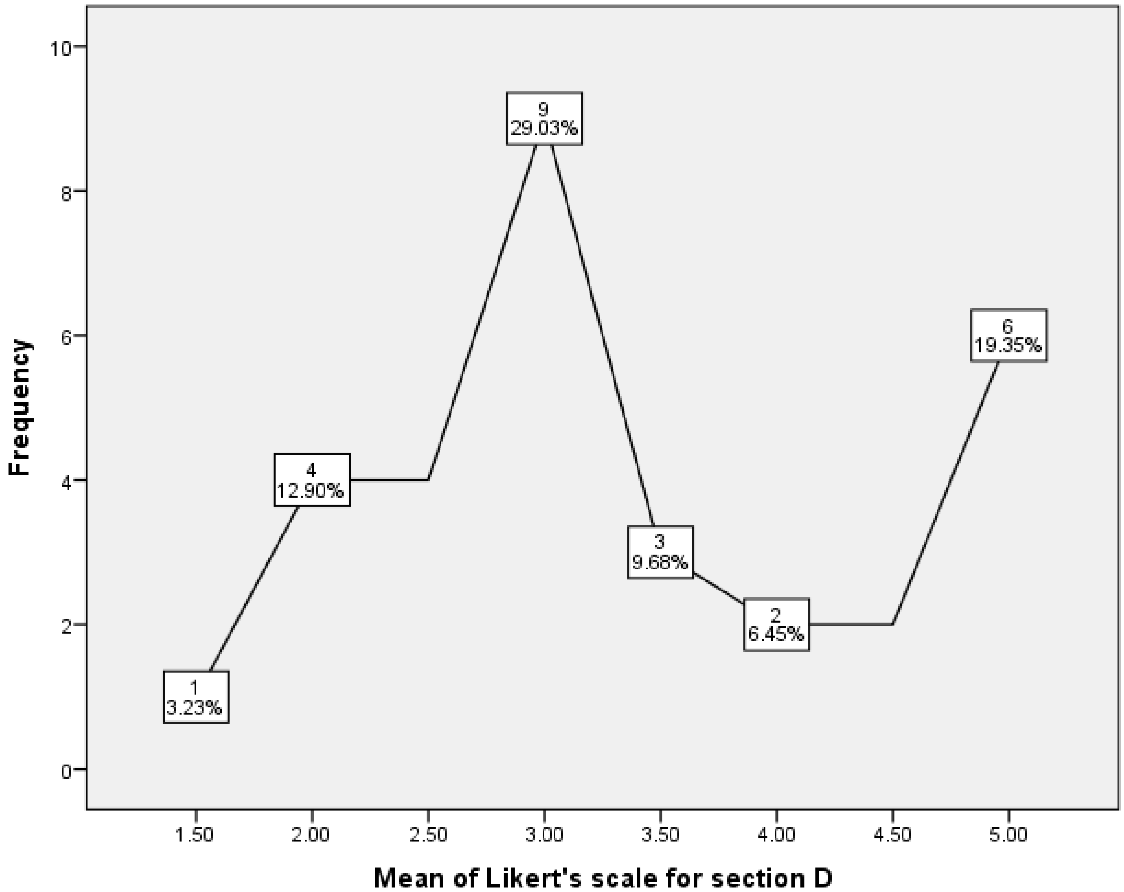

Figure 4.4 Respondents' perception of current Modern Physics lecture notes

Even though respondents were neutral about the current lecture notes, respondents admit to using other sources when studying the Modern Physics course. This does not necessarily prove that the current lecture notes are flawed, but it shows that respondents do find alternatives when learning Modern Physics to understand the subject to a better extent. Figure 4.5 shows other sources that respondents used when learning Modern Physics course.

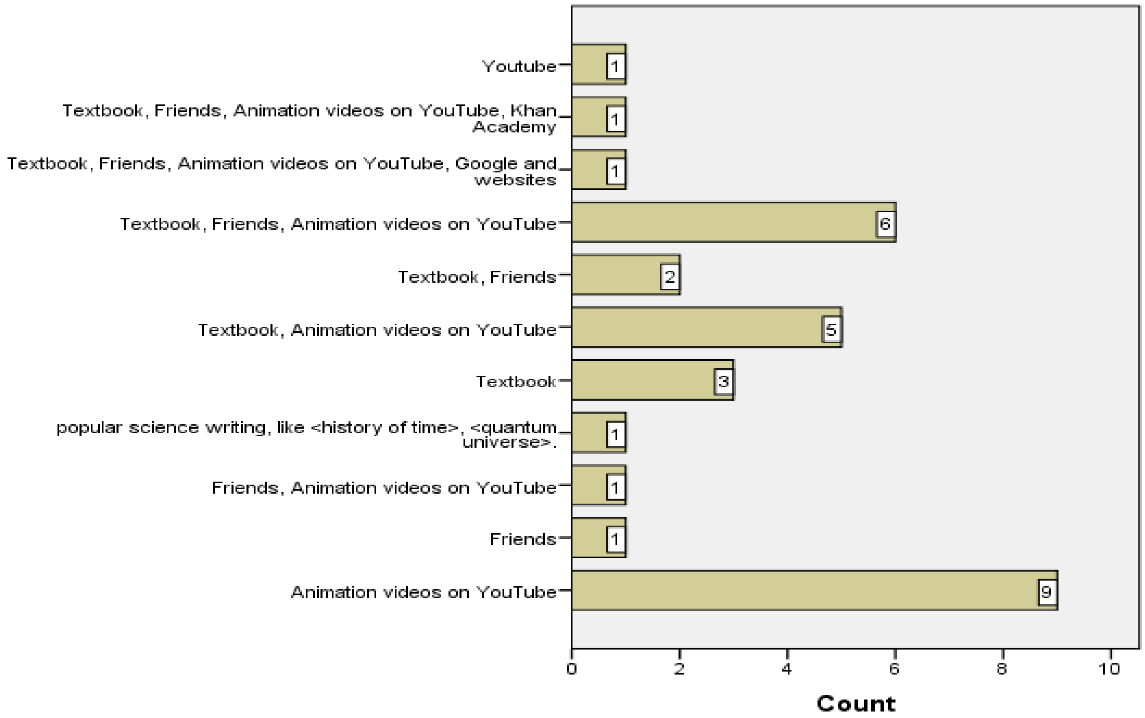

Figure 4.5 Respondents' respective alternatives to learning Modern Physics

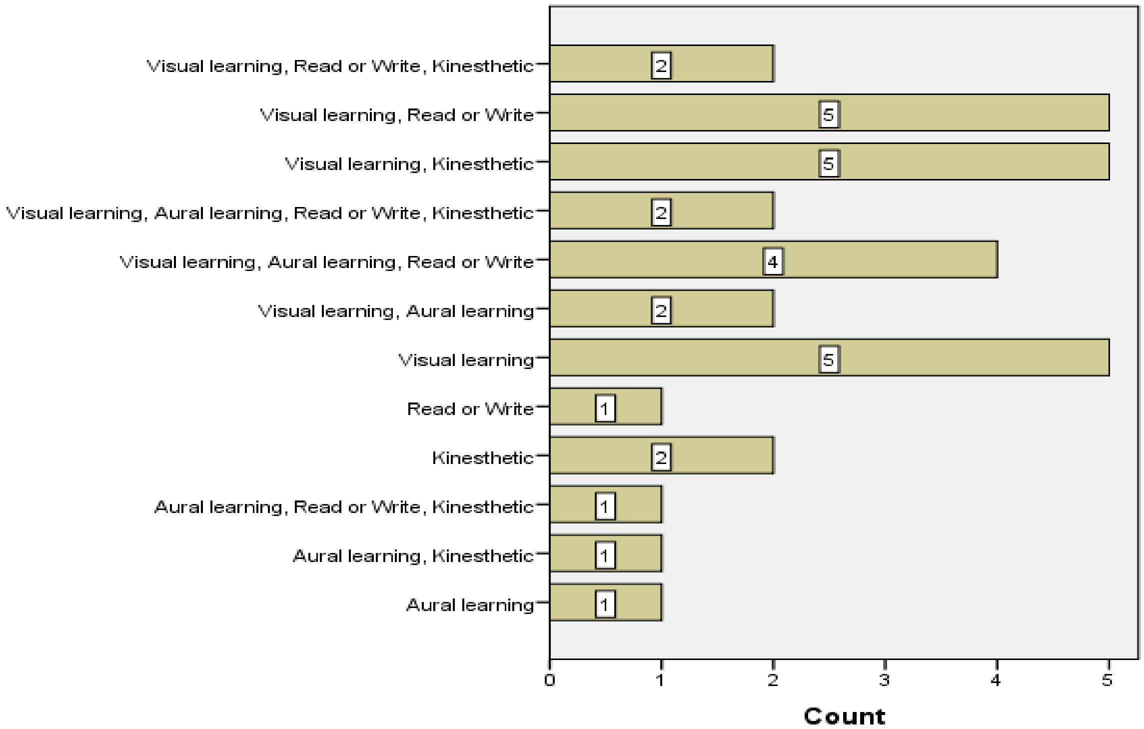

Figure 4.6 Respondents' Respective Learning Styles

Figure 4.5 shows the alternatives sources that are used by respondents are not limited to just one source. 9 out of 31 respondents chose watching animation videos that are related to the topic as their alternative to learning Modern Physics. This shows that the majority of them are visual learners that need moving objects to visualize certain concepts. Besides, the second majority of the respondents (6) chose textbook, learning from friends and animation videos on YouTube as alternative sources. This means that respondents are not tied to a specific learning style only. This is supported by answers in Figure 4.6 that shows several respondents choosing more than one VARK learning style. Most of the answers chose visual learning (5), visual learning and kinesthetics (5), and visual learning and reading (5) as their respective learning styles. Thus, the interactive multimedia note should consist of text, graphics, audio, video and animation elements to carter to students' needs.

Table 4.3 Questions from Section E of the survey

Questions	Responses	
	Yes	No
1. Have you been introduced to interactive multimedia notes in Modern Physics class before?	17 (54.8%)	14 (45.2%)
2. Do you think learning Modern Physics through interactive PowerPoint slides could help you understand the subject better?	24 (77.4%)	7 (22.6%)

Section E of the survey questions whether participants have had exposure to interactive multimedia note as depicted in Table 4.3 Majority of the respondents think that learning Modern Physics interactively could improve the understanding of the subject better. Thus, respondents have high expectations of the interactive multimedia note that the researcher is developing as seen in Table 4.4. The cumulative mean for items in Section E is 4.64 which is close to highest value of Likert's scale that is used in this study.

Table 4.4 Respondents' expectations of the interactive multimedia note

Item	N	Mean	Std. Deviation
1. The interactive multimedia note should be precise and clear.	31	4.68	.541
2. The interactive multimedia note should be engaging to students.	31	4.68	.599
3. The interactive multimedia note should be creative.	31	4.48	.926
4. The interactive multimedia note should include relevant examples of the topic	31	4.71	.643
CUMULATIVE		4.64	.584

4.4 Evaluating pre-test and post-test questions

Table 4.5 Score Indication of 31 students for Pre-test and Post-test

Score	Indication	N (%)	
		Pre-test scores	Post-test scores
< 5	Low	18 (58.1)	1 (3.2)
5 – 8	Moderate	13 (41.9)	9 (29.0)
> 8	High	-	21 (67.7)

Table 4.5 shows score indications for pre-test and post-test of 31 students who have taken part in the research. Students who achieve score below 5 is indicated as low achievers, whereas students who achieve a score between 5 to 8 are considered moderate achievers. Students who score higher than 8 are indicated as high achievers. For the pre-test, two observations are made. Firstly, 58.1% of the students achieved scores below 5. The rest of the students (41.9%)

achieved moderate scores. Another observation that was made here is no students achieved scores higher than 8. This is probably because students did not make preparation before answering the pre-test questions. Besides, students were not allowed to refer to any sources when answering the pre-test. This may have been a disadvantage to students because students are used to open-book examinations since the start of online learning during the pandemic. After the implementation of interactive multimedia approach, post-test results show a significant increase in scores. Only 3.2% of the students achieved scores below 5, whereas the percentage of moderate achievers decreased to 29%. Lastly, the majority of the students (67.7%) managed to achieve higher scores after the implementation of the interactive multimedia approach.

Table 4.6 Students' Correct Responses for Pre-test and Post-test (N = 31)

Question	Correct responses, N (%)		P value
	Pre-test	Post-test	
Q1	22 (70.97)	29 (93.55)	0.000
Q2	14 (45.16)	27 (87.10)	
Q3	6 (19.35)	21 (67.74)	
Q4	17 (54.83)	29 (93.55)	
Q5	17 (54.83)	25 (80.65)	
Q6	14 (45.61)	26 (83.87)	
Q7	5 (16.13)	22 (70.97)	
Q8	14 (45.16)	29 (93.55)	
Q9	15 (48.39)	29 (93.55)	
Q10	3 (9.68)	24 (77.42)	

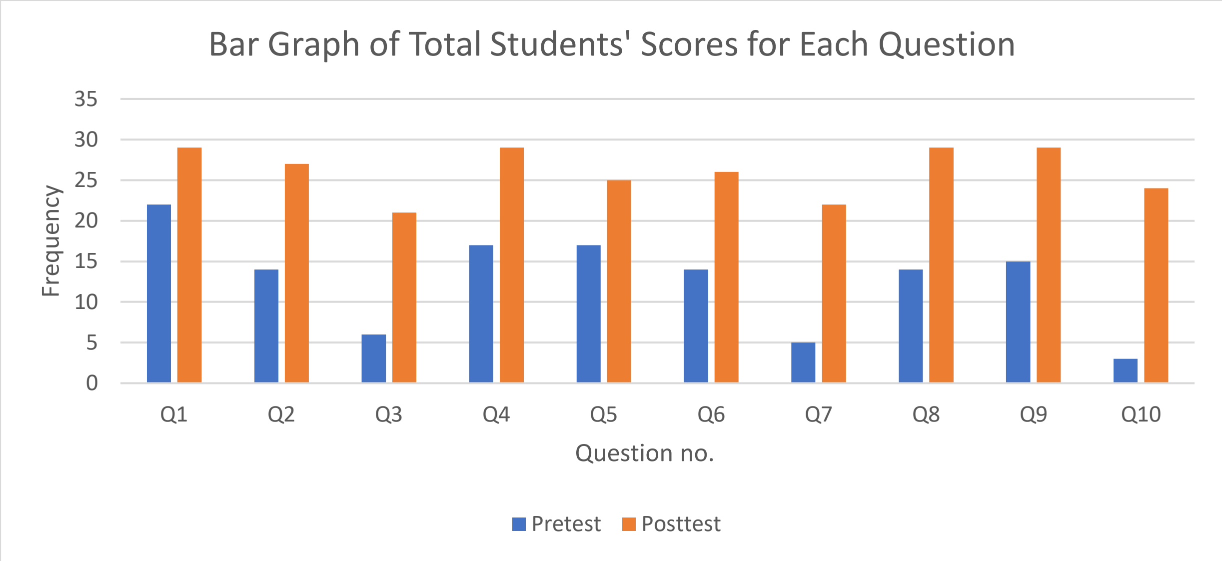

Figure 4.7 Total Students' Scores for Each Question

Table 4.6 and Figure 4.7 depict increment in correct responses for each question in pre-test and post-test by respondents. Through Paired T-Test, it is observed that correct answers for post-test responses are highly significant (P < 0.05) compared to correct answers for pre-test responses. The calculated P value, 0.000 is considered statistically significant because the value is smaller than 0.05. (Shivaraju et al., 2017). Thus, the hypothesis of this study is accepted because there is evidence to support that post-test scores significantly increased compared to pre-test scores after the implementation of interactive multimedia note to the students.

Figure 4.7 shows questions that were commonly wrong in pre-test among respondents (frequency < 15) include Question 2 (Q2), Question 3 (Q3), Question 7 (Q7), Question 8 (Q8), Question 10 (Q10).

Figure 4.8 Pie Chart for Respondents' Choice of Answer for Q2 in Pre-test

Q2 is a multiple-choice question that asks respondents to choose one true statement of observation from the photoelectric effect experiment. Figure 4.8 shows that in the pre-test, 14 (45.2%) of the respondents answered correctly. However, 9 (29%) of the respondents answered 'I am not sure' which indicated respondents are unsure of the answer. The rest of the respondents answered wrongly which make up to 25.6% of them. After the implementation of the interactive multimedia note, the number of respondents answering correct answer increased sharply to 27 (87.1%) respondents as seen in Figure 4.9. This means that the respondents understood the given material well. However, another 4 respondents did not manage to answer correctly in which 3 of them chose 'I am not sure'. This means that the note given is not enough for them to understand the concept.

Figure 4.9 Pie Chart for Respondents' Choice of Answer for Q2 in Post-test

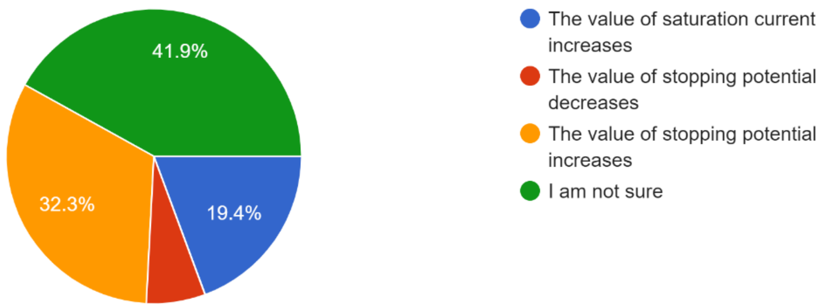

Figure 4.10 Pie Chart for Respondents' Choice of Answer for Q3 in Pre-test

Q3 asked what changes are observed when the frequency of the incident radiation is increased. As observed from Figure 4.10, the majority of the respondents (41.9%) chose to answer 'I am not sure'. This is probably because the choices given are close to each other hence it confuses them. However, in the post-test, most of the respondents (67.7%) managed to answer correctly and no one answered 'I am not sure', indicating they have understood the question and the concept as depicted by pie chart in Figure 4.11.

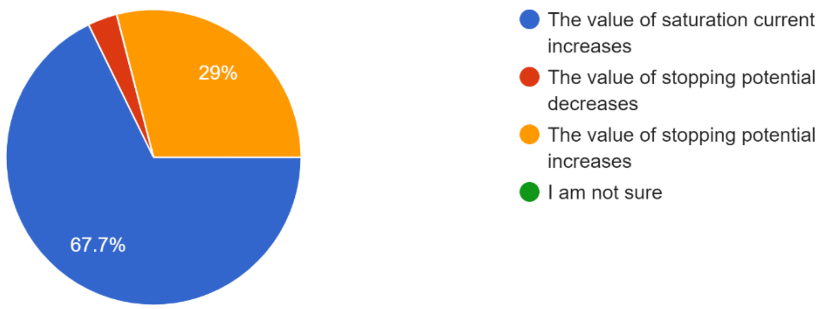

Figure 4.11 Pie Chart for Respondents' Choice of Answer for Q3 in Post-test

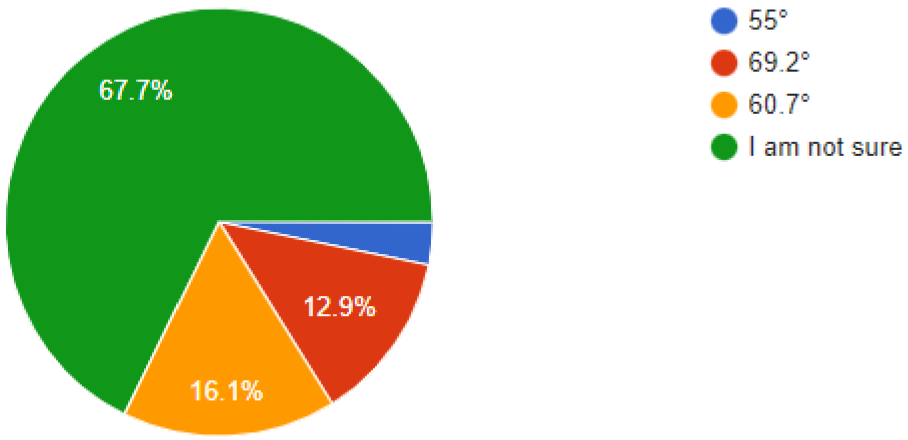

Figure 4.12 Pie Chart for Respondents' Choice of Answer for Q7 in Pre-test

Q7 involves a calculation that is related to Compton Scattering. From the pie chart in Figure 4.12, it is deducted that the majority of the respondents (67.7%) do not have the basic knowledge to calculate the angle of scattered X-rays. However, after the implementation of the interactive notes to respondents, the percentage of respondents answering 'I am not sure' significantly reduced to 29% as shown in Figure 4.13. This shows that the interactive multimedia note could help students to understand calculations as well.

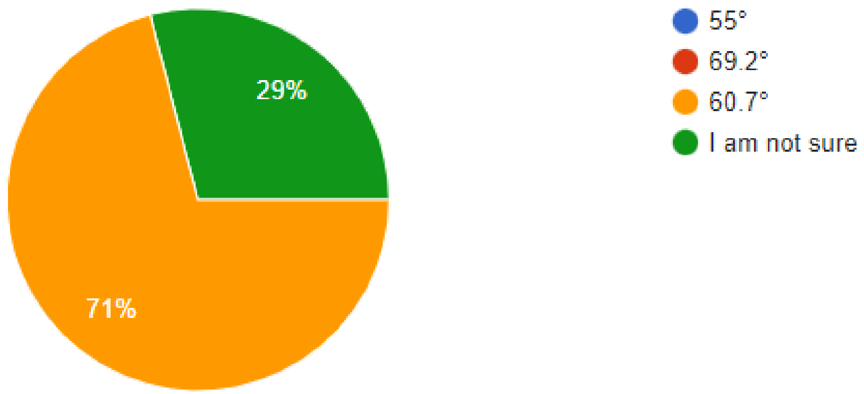

Figure 4.13 Pie Chart for Respondents' Choice of Answer for Q7 in Post-test

Q8 asks respondents to pick a pair of particles that replaces a photon when Pair Production occurs. The question is a direct question with simple answer choices. Figure 4.14 shows that only 14 that is 45.2% of the total respondents managed to choose the right answer. The second most chosen answer by respondents is a pair of electrons. This shows that respondents are not able to understand easy concepts such as conservation of electrical charge for pair production. However, post-test results in Figure 4.15 show improvement in their understanding of the concept because only 3 respondents answered wrongly for Q8.

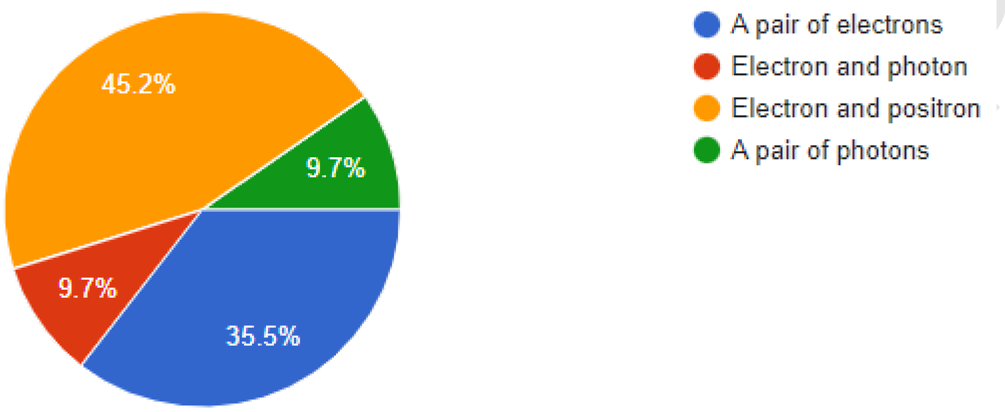

Figure 4.14 Pie Chart for Respondents' Choice of Answer for Q8 in Pre-test

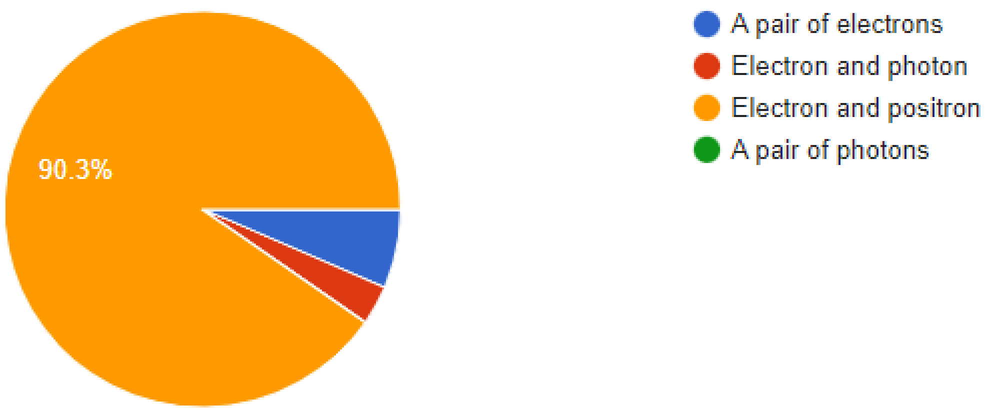

Figure 4.15 Pie Chart for Respondents' Choice of Answer for Q8 in Pre-test

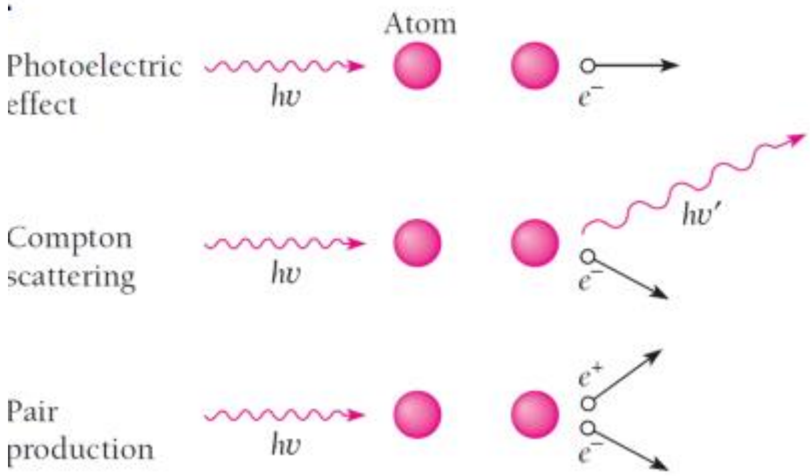

Figure 4.16 Photon Absorption Processes

Q10 asks students to point out the similarity from the diagram in Figure 4.16 Examples of respondents' answers to the open-ended question of Photon Absorption during pre-test and post-test are listed in Table 4.7.

Table 4.7 Examples of respondents' answers before and after implementation

No.	Answers before implementation	Answers after implementation
1	A photon always changes into electron.	All of them transfer photon energy into an electron and lose energy to atoms of absorbing material.
2	All processes are initiated by a photon.	All processes were initiated by photon and changed the direction of the target electron.
3	All of them produce or emit electrons when an incident photon hits the atom.	All of them transfers photon into electrons and lose energy to atoms of the absorbing material.
4	Electron scattering.	The velocity of atom increases.

In Table 4.7, respondents have correct, partially correct, and false answers for pre-test and post-test. As seen from the table and Figure 4.7, it was observed that there was a significant increment in correct answers after implementing the interactive multimedia note. However, answers of some respondents evolved from false to another kind of false. This can be seen from no. 4 of Table 4.7. Two possibilities for the wrong answers here are the respondent did not study the note properly or the note itself did not give enough explanation of how the absorption process occurs hence respondent got it wrong for the second time in the post-test.

4.5 Respondents' Evaluation on the Implementation of Interactive Multimedia Notes for Modern Physics Course

Table 4.8 Respondents' Understanding of Modern Physics Post-Implementation

Item	N	Mean	Std. Deviation
1. I can understand topic Particle Properties of Waves better.	31	4.39	.715
2. The interactive multimedia note helps me to understand the subject better.	31	4.61	.667
3. The interactive multimedia note explained the concepts in a detailed manner.	31	4.58	.672
4. Presentation of the interactive multimedia note lessen the misconception of the subject compared to reading.	31	4.61	.495
CUMULATIVE		4.55	.549

Table 4.8 summarizes the respondents' understanding of Modern Physics after the implementation of the interactive multimedia note. The mean for section B of the feedback form is 4.55. When rounded off to the nearest whole number, the mean of the Likert's scale is

5, which is the highest number of the scale and represents 'Strongly agree' to statements that were made by the researcher. This means that most of the respondents strongly agree that after conducting self-learning with the given note, they could understand the topic Particle Properties of Waves better. Besides, most of the respondents also agree that the given note explained modern physics concepts in a detailed manner thus lessening their misconception of the subject.

Table 4.9 Respondents' Feedback for Interactive Multimedia Elements

Item	N	Mean	Std. Deviation
1. The content of the notes is precise and clear.	31	4.65	.661
2. The interactive multimedia notes provided is easy to use.	31	4.61	.615
3. Videos are engaging and impactful for students.	31	4.61	.615
4. Animations in the notes are appropriate and able to explain the concepts clearly.	31	4.74	.514
5. The diagrams that are provided help to understand the topic.	31	4.74	.514
6. The audio used is suitable and entertaining.	31	4.61	.615
CUMULATIVE		4.66	.528

Respondents' feedback towards the interactive multimedia elements were gathered from Section C of the feedback form. Table 4.9 shows the cumulative mean of Likert's scale for Section C is 4.66. This depicts that most of the respondents strongly agree that the contents of the interactive multimedia are precise and clear, easy to use, and the elements that were used in the interactive multimedia (video, animation, graphic, text, and audio) are engaging and impactful for students.

Table 4.10 Respondents' Evaluation for the Design of Interactive Multimedia Note

Item	N	Mean	Std. Deviation
1. The background of the notes is attractive.	31	4.74	.514
2. The content arrangement of the notes is appropriate.	31	4.81	.477
3. Graphics used in the notes are suitable with the content.	31	4.81	.402
4. The colour scheme used in the notes is entertaining.	31	4.74	.575
CUMULATIVE		4.77	.420

Respondents' evaluation for the interactive multimedia design in Section D of the feedback form was analysed. As observed in Table 4.10, the mean of Likert's scale for Section D is 4.77. This shows that most respondents agreed with the statements made by the researcher which are related to the background design of the interactive multimedia, content arrangements, and colour scheme.

Respondents answered a few open-ended questions in the feedback form. Their answers were analysed qualitatively by coding and categorizing similar answers. Table 4.11 summarized the qualitative answers by respondents.

Table 4.11 Summary of the answers from Section E

Category	Explanation
QS01	**What do you like the most from the notes? State your positive opinion on the approach**
DIFFELEM	Different elements combined into one note makes it easy to develop an understanding of the topic
COLCOM	The colour combination help students to keep focused
EASY	Easy to read and understand
QS02	**What do you dislike the most from the notes? State your negative opinion on the approach**
LACKCALC	Lack of calculation for the tutorial part
IMPROVA	Improvise the voice for the audio element
LACKEXA	Lack of examples, videos, and graphics
LENGTHY	Lengthy words
QS04	**What other subject should be taught using the same approach? List one subject.**
QUANTUM	Quantum mechanics
ELECTRO	Electronics
EM	Electromagnetism
SOLIDSTATE	Solid state physics
QS05	**In your opinion, how can this approach be improved in the future?**
MOREAVE	More audio, video and examples
SIMPLER	Simpler notes
BETTERAPP	Use better software or application
3DIMAGE	Use 3D images for explanation
QUIZSECT	Add quiz section

In section E, QS01 asked what respondents liked the most from the notes that was distributed to them. Most respondents stated they liked how different elements which are audio, graphics, video, animation, and text are combined into one material (DIFFELEM). They explained that DIFFELEM makes it easy for them to develop more understanding of the topic they were learning. One respondent stated that they liked how the animation is coupled with a detailed explanation of the animation, especially where the movements of the electrons were shown. Moreover, respondents also stated that the colour combination of the material helps students to keep focused (COLCOM) thus avoiding them from napping when they are studying. Besides, the multimedia note was said to be easy to read and understand (EASY) by most of the respondents. They added that even though the note given is simple in terms of design, it is still full of related information to the topic hence easier for them to understand what they are learning.

QS02 asked what respondents disliked the most from the distributed material. A few respondents answered that they disliked how calculations were not included for the tutorial sections (LACKCALC). Thus, they have suggested to include calculations in the tutorial sections so students will be able to re-check their answers. This was a mistake on the researcher's part as the researcher thought that it was enough to only provide answers for each tutorial question. Besides, a few respondents also complained that the audios that were provided in the notes were quite slow hence they suggested researcher to improvise when recording the audio (IMPROVA). A better option to improvise on the audio is to use audio software such as TextAloud which uses a native English speaker's voice on behalf of its users. By using such software, it will help to eliminate problems such as voice tone, pronunciation and others.

QS03 asked respondents if the interactive multimedia approach contribute to learning undergraduate physics concepts. Respondents wholeheartedly agreed and listed various undergraduate physics subject in QS04 where they were asked to list one subject that should be taught using the same approach. Most of the respondents answered Quantum Mechanics, which is then followed by Electronics, Electromagnetism, and lastly Solid State Physics.

QS05 asked how this approach can be improved in the future. The most common response was to add more example audio and video elements, along with examples or expected questions for each topic (MOREAVE) into the interactive notes. Respondents requesting to add more audio and video elements is understandable because most of them preferred to learn visually, hence they prefer to watch or listen to videos instead of reading more texts. In addition, they also suggested making simpler notes (SIMPLER) which probably means to lessen the number of texts and add more other multimedia elements into the notes such as animation or videos. Besides, they also suggested using better software or application (BETTERAPP) in the future. When designing these multimedia materials, what the researcher had in mind was to make use of any software that is commonly used by students. In this case, it was Microsoft PowerPoint. Students are familiar with this software when making presentation slides or notes hence in the researcher's mind, it will be less hassle for them since they do not need to learn how to use it from the beginning. However, the suggestion will be kept in mind and better software such as Lectora, iSpringSuite will be considered in the future. Other suggestions to QS05 include using 3D images to replace the diagrams (3DIMAGE) and adding a quiz section (QUIZSECT) into the notes.

CHAPTER 5

CONCLUSION

5.1 Conclusion

Interactive multimedia note was developed as an initiative to a conventional learning method that could become boring for students especially during the pandemic where classes are conducted online. The combination of five multimedia element which are text, audio, video, animation, and graphic create an interactive and fun learning experience for students to gain knowledge in respective subjects. Besides, students seem to agree that the interactive multimedia approach could contribute to learning undergraduate physics concepts.

Through this research, students' understanding of the chapter Particle Properties of Waves increased due to the effectiveness of the interactive multimedia notes that was developed by the researcher. This is shown when students' correct answers increased after the implementation of the interactive multimedia notes. In addition, in the feedback form, the majority of the students agreed that the material helped them to understand the subject better and the interactive notes explained the topic in a detailed manner.

5.2 Recommendation and suggestion

Even though the interactive multimedia note was effective for the students, improvements must be made to the notes because it was still lacking from the researcher's point of view. For further research, students have suggested in the feedback form to include more audio, video and examples in the interactive multimedia note. This is because most students understand better when they are listening and watching audio and video. For audio, it is best to use a voice that has clear pronunciation, tone, and rhythm. Thus, the researcher suggests using the software TextAloud that can convert texts into natural-sounding speech. In the case of examples, more examples should be added for each subtopic to increase the understanding of the students.

Besides, calculations for the tutorial section must be included in case students need to quickly re-check their answers before asking their lecturer. Lastly, future research is suggested to utilize other education software such as Lectora and iSpring Suite that can create interactive learning materials with better options or effects.

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APPENDICES

APPENDIX A: INTERACTIVE MULTIMEDIA NOTE

INTERACTIVE MULTIMEDIA NOTE FOR PARTICLE PROPERTIES OF WAVES: https://docs.google.com/presentation/d/1ATPFUJWthDqpwDQkqT8YSCW4Eq-fShkS/edit?usp=sharing&ouid=116866225273342437868&rtpof=true&sd=true

#Download the file and view in SlideShow mode for better experience.

APPENDIX B: INSTRUMENTS

A SURVEY ON THE UNDERSTANDING OF MODERN PHYSICS COURSE (PHY3105) AMONG STUDENTS FROM THE DEPARTMENT OF PHYSICS, UNIVERSITI PUTRA MALAYSIA.

Greetings, students.

PHY3105 (Modern Physics) is a core undergraduate course offered for all students from the Department of Physics, Universiti Putra Malaysia. This questionnaire is conducted to collect data on the perceptions of undergraduate students for the development of Interactive Multimedia Notes for PHY3105 Modern Physics (Particle Duality Properties).

The questionnaire consists of 5 sections which are:

(A) Demographic,

(B) Students' Opinions on Modern Physics,

(C) Students' Understanding on the chapter Particle Duality Properties,

(D) Students' Perception on Modern Physics Lecture Notes and

(E) Students' Exposure on Interactive Multimedia Notes.

An approximation of 20 minutes is needed to complete this questionnaire and your allocation of time is well appreciated. Your e-mail address is required to prevent the redundancy of data. All data obtained from this questionnaire are considered confidential and are subjected to research purposes only.

Your participation is highly appreciated. Thank you.

PART A: DEMOGRAPHIC PROFILE

Students' personal information will be asked in this section as a part of our data collection.

Item	Choices
1. Matric number	○ ______
2. Course	○ Bachelor of Science in Physics with Honours

		○ Bachelor of Science in Instrumentation Science with Honours ○ Bachelor of Science in Material Science with Honours ○ Bachelor of Science in Physics with Education (Honours)
3.	Year of Study	○ Year 1 ○ Year 2 ○ Year 3 ○ Year 4
4.	Have you taken the Modern Physics (PHY3105) course?	○ Yes, I have taken the course ○ I am currently taking the course ○ No, I have not taken the course
5.	When did you take the course?	○ 2018/2019 ○ 2019/2020 ○ 2020/2021 ○ 2021/2022

PART B: OPINIONS ON THE MODERN PHYSICS COURSE

In this section, students will be asked for their perceptions on the Modern Physics (PHY3105) Course. Using the Likert scale, students may choose based on the scale of:

1: Strongly Disagree

2: Disagree

3: Undecided

4: Agree

5: Strongly Agree

Item	Choices
1. Modern Physics is a difficult subject for me	○ 1 ○ 2 ○ 3 ○ 4 ○ 5

2.	The mathematical calculations in the subject are hard to solve	○ 1 ○ 2 ○ 3 ○ 4 ○ 5
3.	I am unable to visualize the necessary concepts when learning Modern Physics	○ 1 ○ 2 ○ 3 ○ 4 ○ 5
4.	Among the concepts listed below, which one is the hardest to visualize?	○ Photoelectric effect ○ Compton Scattering ○ Pair Production ○ Photon Absorption ○ Other: ___
5.	I can relate Modern Physics with daily life applications	○ 1 ○ 2 ○ 3 ○ 4 ○ 5

PART D: STUDENT'S PERCEPTION ON MODERN PHYSICS LECTURE NOTES

In this section, students are required to value the current lecture notes that are distributed to them using the Likert's scale.

Each scale represents:

1: Strongly Disagree

2: Disagree

3: Undecided

4: Agree

5: Strongly Agree

Item	Choices

1. The provided lecture notes are not detailed	○ 1 ○ 2 ○ 3 ○ 4 ○ 5
2. The provided lecture notes are hard to understand	○ 1 ○ 2 ○ 3 ○ 4 ○ 5
3. Besides lecture notes, I use other sources to study Modern Physics	○ True ○ False
4. Choose other sources that you use to study Modern Physics	○ Textbook ○ Friends ○ Animation videos on Youtube ○ Other:

PART E: STUDENTS' EXPOSURE ON INTERACTIVE MULTIMEDIA NOTES

In this section, students are required to provide answer for the interactive multimedia notes design. The notes will be based on the chapter Particle Properties of Waves of Modern Physics (PHY3105).

Using the Likert scale, students may choose based on the scale of:

1: Strongly Disagree

2: Disagree

3: Undecided

4: Agree

5: Strongly Agree

Item	Choices
1. What is your preferred learning style? (Can choose more than one)	○ Visual learning (e.g understanding diagram/ chart) ○ Aural learning (e.g listening to lecture)

	○ Read or write (e.g writing notes) ○ Kinesthetic (e.g touch, feel and move when learning)
2. Interactive multimedia notes are a form of learning material that is used to convey lessons to students effectively and efficiently. Have you been introduced to interactive multimedia notes in Modern Physics class before?	○ Yes ○ No
3. Do you think learning Modern Physics through interactive PowerPoint slides could help you understand the subject better? *	○ Yes ○ No
4. The interactive multimedia notes should be precise and clear	○ 1 ○ 2 ○ 3 ○ 4 ○ 5
5. The interactive multimedia notes should be engaging to students	○ 1 ○ 2 ○ 3 ○ 4 ○ 5
6. The interactive multimedia notes should be creative	○ 1 ○ 2 ○ 3 ○ 4 ○ 5
7. The interactive multimedia notes should include relevant examples of the topic	○ 1 ○ 2 ○ 3 ○ 4

	○ 5

FEEDBACK FORM ON IMPLEMENTATION OF INTERACTIVE MULTIMEDIA NOTES ON STUDENTS

Greetings, students.

PHY3105 (Modern Physics) is a core undergraduate course offered for all students from the Department of Physics, Universiti Putra Malaysia. This questionnaire is conducted to collect data on the perceptions of undergraduate students for the development of Interactive Multimedia Notes for PHY3105 Modern Physics (Particle Duality Properties).

The questionnaire consists of 5 sections which are:

(A) Students' Understanding on the chapter Particle Duality Properties,

(B) Understanding of Modern Physics,

(C) Interactive Multimedia Elements,

(D) Interactive Multimedia Design and

(E) General.

An approximation of 20 minutes is needed to complete this questionnaire and your allocation of time is well appreciated. Your matric number is required to prevent the redundancy of data. All data obtained from this questionnaire are considered confidential and is subjected to research purposes only.

Your participation is highly appreciated. Thank you.

*Matric number :

PART B: UNDERSTANDING OF MODERN PHYSICS

Item	Choices
1. I can understand topic Particle Properties of Waves better	○ 1 ○ 2 ○ 3 ○ 4 ○ 5
2. The interactive multimedia notes help me to understand the subject better	○ 1 ○ 2 ○ 3 ○ 4 ○ 5

3. The interactive multimedia notes explained the concepts in a detailed manner	○ 1 ○ 2 ○ 3 ○ 4 ○ 5
4. Presentation of the interactive multimedia notes lessen the misconception of the subject compared to reading	○ 1 ○ 2 ○ 3 ○ 4 ○ 5

PART C: INTERACTIVE MULTIMEDIA ELEMENTS

Item	Choices
1. The content of the notes are precise and clear	○ 1 ○ 2 ○ 3 ○ 4 ○ 5
2. The interactive multimedia provided is easy to use	○ 1 ○ 2 ○ 3 ○ 4 ○ 5
3. Videos are engaging and impactful for the students	○ 1 ○ 2 ○ 3 ○ 4 ○ 5
4. Animations in the notes are appropriate and able to explain the concepts clearly	○ 1 ○ 2 ○ 3 ○ 4

	○ 5
5. The diagrams that are provided help to understand the topics better	○ 1 ○ 2 ○ 3 ○ 4 ○ 5
6. The audio used is suitable and entertaining	○ 1 ○ 2 ○ 3 ○ 4 ○ 5

PART D: INTERACTIVE MULTIMEDIA DESIGN

Item	Choices
7. The background of the notes are attractive	○ 1 ○ 2 ○ 3 ○ 4 ○ 5
8. The content arrangement of the notes are appropriate	○ 1 ○ 2 ○ 3 ○ 4 ○ 5
9. Graphics used in the notes are suitable with the content	○ 1 ○ 2 ○ 3 ○ 4 ○ 5
10. The color scheme used in the notes are entertaining	○ 1 ○ 2

	○ 3 ○ 4 ○ 5

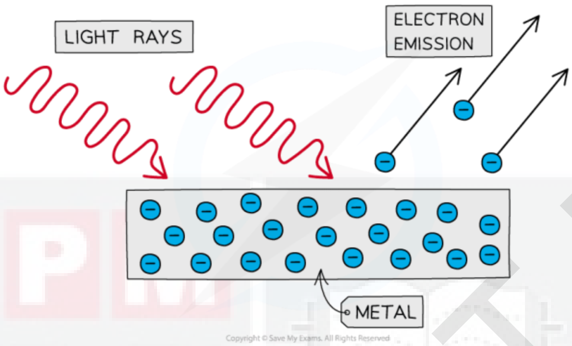
PART E: GENERAL

1. What do you like the most from the notes? Express your positive opinion on the approach
2. What do you dislike from the notes? Express your negative opinion on the approach.
3. Do you think the interactive multimedia approach contribute to learning undergraduate physics concept?
   A. Yes
   B. No
4. In your opinion, what other subjects should be taught using the same approach? List two subjects.
5. In your opinion, how can this approach be improved in the future?

Pre-test and Post-test (Section C of Survey Form and Section A of Feedback Form)

In this section, a few questions from the chapter 'Particle Properties of Waves' are to be answered by students.
Students are not allowed to refer to any lecture notes and other sources while answering this section. Your cooperation and honesty are highly appreciated.

1. What is photoelectric effect? Explain the term based on your understanding.

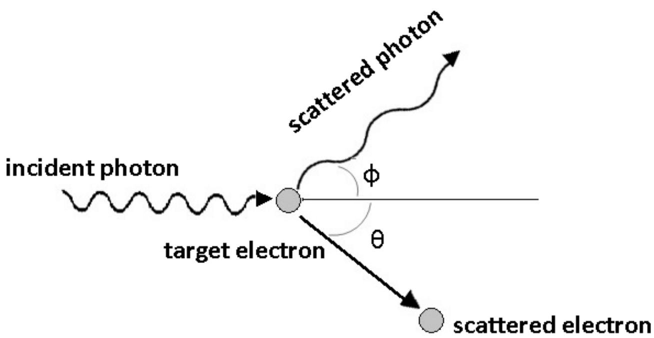


2. Which of the statement below is true regarding the observation of photoelectric effect experiment?
   A. The photocurrents does not depend on the frequency of light
   B. Stopping potential, Vo depends on intensity instead of frequency of light
   C. No time delay between the arrival of light at a metal surface and the emission of photoelectrons
   D. I am not sure

3. What changes are observed during Einstein's photoelectric effect when the frequency of the incident radiation is increased?
   A. The value of saturation current increases
   B. The value of stopping potential decreases
   C. The value of stopping potential increases
   D. I am not sure

4. Name one application of photoelectric effect that you can think of.

5. With the aid of the diagram, explain Compton Effect in your own words.



6. Which of the following is the correct equation of Compton effect?
   A. $\lambda' - \lambda = \lambda_c(1 - sin\, \emptyset)$

B. $\lambda' + \lambda = \lambda_c(1 - cos\,\emptyset)$
C.$\lambda - \lambda' = \lambda_c(1 - cos\,\emptyset)$
D. $\lambda' - \lambda = \lambda_c(1 - cos\,\emptyset)$

7. An amount of 0.124-nm x-ray photons is used in a Compton-scattering experiment. At what angle is the wavelength of the scattered x rays1.0% longer than that of the incident x rays?
   A. 55
   B. 69.2
   C. 60.7
   D. I am not sure

8. Which pair of particles replace a photon when Pair Production occurs?
   A. A pair of electrons
   B. Electron and photon
   C. Electron and positron
   D. A pair of photons

9. State the minimum energy required for a photon to produce a pair production.
   A. 1.5 MeV
   B. 1.02 MeV
   C. 1.22 MeV
   D. 1.05 MeV

10. What is the similarity observed from the diagram below?