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The teaching of physics at upper secondary school level: A comparative study between Indonesia and Ireland

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This study aims to investigate the teaching approaches taken by physics teachers in Indonesia and Ireland when teaching a module on Medical Physics in the classroom. Additionally, students' attitudes to the module on Medical Physics were also explored. In particular, the views of these teachers toward inquiry based science education (IBSE) and direct instruction (DI) when implementing this module with students in the 14–16 age group were examined. Data were collected to investigate how teachers in the two countries used combinations of the IBSE and DI teaching approaches when teaching the module to their students. Arising out of the implementation of the module, it was hoped that the module would serve as a "hook" to interest students in physics by teaching topics in physics *via* real-life applications of physics. Thus, the attitudes of the students toward science on completion of the module were assessed. A total of 15 schools in Indonesia (402 students) and 15 schools in Ireland (263 students) participated in the project. Data were collected from the teachers and students using questionnaires. Among the findings were that while teachers in Ireland were unanimous in their agreement with the inclusion of IBSE activities in the lesson plans supplied, only 67% of the teachers in Indonesia agreed with the inclusion of these activities in the module. There was a strong relationship between the type of school and the students' attitude toward the module. Students in the more academic type schools in both Ireland and Indonesia were less positive about the module. Among the problems highlighted by teachers in Indonesia was the lack of laboratory facilities. Also, students in both countries commented on the problems with terminology and literacy in general when studying physics. While the module brought out a positive response from students convincing them to continue with their study of physics at the upper secondary school level.

KEYWORDS
attitude toward science, direct instruction, inquiry based science education, medical physics, comparative study

1. Introduction

In the 2012 program for international student assessment (PISA) test results, it was found that of the 65 countries that participated in the test, Indonesia ranked 60th in literacy skills, and 64th in mathematics and science (OECD, 2014). A similar pattern was observed for Indonesia in the PISA 2009 results. On the contrary, Ireland has seen considerable improvement in recent years where it is now ranked ninth out of 65 OECD countries for science, fourth out of 65 countries for reading, and 13th of the 65 OECD countries for mathematics (OECD, 2014). Arising these results, it was felt appropriate to carry out a comparative study between the two countries in order to investigate the issues involved in teaching science in very different environments.

In comparing the teaching approaches adopted by teachers in the two countries, it was decided to investigate the different approaches to teaching physics using either an inquiry based inquiry based science education (IBSE) approach or a direct instruction (DI) approach. When discussing these contrasting teaching approaches, the inquiry-based approach is often described in terms of being student-centered [Sweitzer and Anderson, 1983; American Association for the Advancement of Science (AAAS), 1990; National Research Council (NRC), 1996, 2000; Alberts, 2008; Juntunen and Aksela, 2013; Jiang and McComas, 2015]. On the contrary, the direct instruction approach is often described in terms of a teacher-centered approach (McKeen, 1972; Peterson, 1979; Becher, 1980; Rosenshine, 1995; Cobern et al., 2010). However, as will be discussed in this paper, these two categories of IBSE and DI are part of a continuum or spectrum of teaching approaches. Some authors represent DI in terms of a traditional classroom setting where students are perceived as sitting in straight rows of desks and learning through rote memorization (Brown et al., 1982; Borko and Wildman, 1986; Brooks and Brooks, 1999). In this scenario, students are described as attentively listening to the teacher standing in front of the class to impart information and compliantly taking notes without necessarily interacting with the topic being taught. Direct instruction should not be confused with didactic teaching. Hattie (2009) discusses in detail the main characteristics of direct instruction and outlines them in terms of seven major steps as outlined in Table 1 (Hattie, 2009, pp.205–206).

It is the above description of direct instruction that was adopted in this study, and which may be summarized as follows:

> "In a nutshell: The teacher decides the learning intentions and success criteria, makes them transparent to the students, demonstrates them by modeling, evaluates if they understand what they have been told by checking for understanding, and re-telling them what they have been told by tying it all together with closure" (Hattie, 2009, p. 206).

The inquiry based science education approach is described as "*the art of developing challenging situations in which students are asked to observe and question phenomena; pose explanations of what they observe; devise and conduct experiments in which data are collected to support or contradict their theories; analyze data; draw conclusions from experimental data; design and build models; or any combination of these*" (Hattie, 2009).

In the IBSE approach, students are described as being actively involved in their own learning with the teacher using student investigations and discussions to challenge the students to think about the work being undertaken.

Many teachers will recognize the above descriptions as being at the extreme ends of the spectrum of teaching approaches and may see themselves as using various aspects of the two approaches in their everyday teaching to achieve the learning outcomes of the lesson. In this paper, we will investigate and discuss how teachers in Indonesia and Ireland used combinations of the IBSE and DI teaching approaches when teaching a module on Medical Physics to their students. Arising the implementation of the Medical Physics module, it is hoped that more students will be encouraged to undertake the study of physics at the senior high school level.

TABLE 1 The seven major steps involved in direct instruction (DI; Hattie, 2009).

Direct instruction involves seven major steps:
1. Before the lesson is prepared, the teacher should have a clear idea of what the *learning intentions* are. What, specifically, should the student be able to do, understand, care about as a result of the teaching?
2. The teacher needs to know what *success criteria* of performance are to be expected and when and what students will be held accountable for from the lesson/activity. The students need to be informed about the standard of performance.
3. There is need to *build commitment and engagement* in the learning task. In the terminology of direct instruction, this is sometimes called a "hook" to grab a student's attention. The aim is to put students into a receptive frame of mind; to focus student attention on the lesson; to share the learning intentions.
4. There are guides to *how the teacher should present the lesson*—including notions such as input, modeling, and checking for understanding. Input refers to providing information needed for students to gain the knowledge or skill through lecture, film, tape, video, pictures, and so on. Modeling is where the teacher shows students examples of what is expected as an end product of their work. The critical aspects are explained through labeling, categorizing, and comparing to exemplars of what is desired. Checking for understanding involves monitoring whether students have "got it" before proceeding, it is essential that students practice *doing it right,* so the teacher must know that students understand before they start to practice. If there is any doubt that the class has not understood, the concept or skill should be re-taught before the practice begins.
5. There is the notion of *guided practice*. This involves an opportunity for each student to demonstrate his or her grasp of new learning by working through an activity to exercise under the teacher's direct supervision. The teacher moves around the room to determine the level of mastery and to provide feedback and individual remediation as needed.
6. There is the *closure* part of the lesson. Closure involves those actions or statements by a teacher that are designed to bring a lesson presentation to an appropriate conclusion; the part wherein students are helped to bring things together in their own minds, to make sense out of what has just been taught. "Any questions? No. OK let us move on" is not closure. Closure is used to cue students to the fact that they have arrived at an important point in the lesson or the end of a lesson, to help organize student learning, to help form a coherent picture, to consolidate, eliminate confusion and frustration, and so on, and to reinforce the major points to be learned. Thus, closure involves reviewing and clarifying the key points of a lesson, tying them together into a coherent whole, ensuring they will be applied by the student by ensuring they have become part of the student's conceptual network.
7. There is *independent practice*. Once students have mastered the content or skill, it is time to provide for reinforcement practice. It is provided on a repeating schedule so that the learning is not forgotten. It may be homework or group or individual work in class. It is important to note that this practice can provide for decontextualisation: enough different contexts so that the skill or concept in which it was originally learned. For example, if the lesson is about inference from reading a passage about dinosaurs, the practice should be about inference from reading about another topic such as whales. The advocates of direct instruction argue that the failure to do this seventh step is responsible for most student failure to be able to apply something learned.

Thus, we first consider some aspects of students' attitude toward physics as a subject and then investigate the effect that the intervention package had on the attitude toward physics of the participating students.

1.1. Students' attitude toward physics in school science

The study of students' attitudes toward science is not a new topic in science education. For almost 50 years, hundreds of journal papers as well as reviews (Gardner, 1975; Schibeci, 1984; Simpson and Oliver, 1990; Crawley and Koballa, 1994; Osborne et al., 2003; Koballa and Glynn, 2007; Hofstein and Mamlok-Naaman, 2011; Bennett et al., 2013; Ültay et al., 2017, 2021; Ültay and Alev, 2017a,b) and dissertations have been published at international level in the area of students' attitudes toward science.

The concept of an attitude toward science is somewhat nebulous, often poorly articulated and not well understood (Osborne and Dillon, 2008). Considerable clarity was brought to the topic in the PISA 2012 project since when discussing the results of this project (PISA 2013) the area of students' attitudes toward science was discussed under four main headings:

a. Support for scientific inquiry, i.e., do students value scientific ways of gathering evidence, thinking logically, and communicating conclusions?
b. Self-belief as science students, i.e., what are students' appraisals of their own abilities in science?
c. Interest in science, i.e., are students interested in science-related social issues, are they willing to acquire scientific knowledge and skills, and do they consider science-related careers?
d. Responsibility toward resources and environments. Are students concerned about environmental issues?

It is in part (c) above that the focus of this research took place, i.e., looking at the challenges involved in trying to improve students' attitudes toward science and increasing their interest in science. At the international level, the falling numbers choosing to pursue the study of physics at senior high school level (OECD, 2014) are mirrored in Indonesia and Ireland (Kompas, 2013; Hyland, 2014).

Enhancing a positive attitude toward science lessons is essential for two reasons: (a) students' attitudes and their academic performance are closely related and (b) attitudes may be used to forecast students' behavior in encouraging them to choose to continue with their study of physics (Glasman and Albarracín, 2006; Cheung, 2009). The subject of Physics presents particular difficulties for students as they encounter problems related to the use of mathematical equations and the manipulation of mathematical data (Angell et al., 2004; Ornek et al., 2007; Collins, 2011). This results in many concepts and principles of physics being difficult to understand. Hence, the interest of students in studying physics is adversely affected.

Of the several factors that can affect students' interest in science, especially in the area of Physics, the approach to teaching that is adopted by the teacher is one of fundamental importance (Wellington and Ireson, 2008). We now focus this approach in terms of the two main sub-divisions, i.e., inquiry-based science education and direct instruction.

1.2. The balance of inquiry-based science education and direct instruction

As previously mentioned, some authors have put forward the idea that direct instruction represents an undesirable form of teaching and interpret the term "direct instruction" as didactic teaching. Direct instruction has been described as "authoritarian" (McKeen, 1972), "regimented" (Borko and Wildman, 1986), "fact accumulation at the expense of thinking skill development" (Edwards, 1981), and "focusing upon tests" (Nicholls, 1989). Direct instruction has also been portrayed as a "passive" mode of teaching (Becher, 1980). Direct instruction has been described as the "pouring of information from one container, the teacher's head, to another container, the student's head" (Brown and Campione, 1990). All of these critics of direct instruction are proposing that teachers use forms of "student-centered" or activity-based instruction in place of direct instruction.

Many educators feel that inquiry instruction rather than direct instruction is mostly in keeping with the widely accepted constructivist theory of how people learn, i.e., that meaningful knowledge cannot simply be transmitted and absorbed but learners have to construct their own understanding (Anderson 2002; Cobern et al., 2010). Some studies have found a positive effect of IBSE [e.g., Bredderman, 1985; National Research Council (NRC), 1996, 2000, 2005; Donnelly et al., 2014; Ireland et al., 2014]. Other researchers have found a negative effect of IBSE, e.g., Buntern et al. (2014) argued that IBSE leads to high cognitive load and is thus not effective in the classroom. On another side, Arnold et al. (2014) argue that direct instruction cannot embrace the complex nature of scientific reasoning in an authentic fashion (Chinn and Malhotra, 2002) nor is it consistent with the constructivist views of learning (Hmelo-Silver et al., 2007). One of the big challenges facing teachers is in deciding when to use IBSE, when to give support and when to hold back information in order to maintain authentic inquiry settings, especially in upper secondary school (Crawford, 2000; Furtak, 2007). Wiggin and McTighe call it the dilemma of "direct instruction versus constructivist approach" (Wiggins and McTighe, 2005).

Educators have been indoctrinated with the mantra "constructivism good, direct instruction bad" (Hattie, 2009). Colburn (2000) stated perhaps that one source of confusion about inquiry based science education is that it is only for "advanced" students. This is a misconception as all students can achieve success if teachers guide them toward understanding by implementing different activities in the classrooms. However, there are many times when inquiry-based science education may be less advantageous than other methods. It depends on our experiences as teachers to find the right balance between inquiry and non-inquiry methods that engages our students in their study of science (Gagne, 1963). In addition, Kennedy (2013) argues that "one of the clear outcomes from the research literature is that IBSE approaches to science teaching do result in an increase in the interest levels of students in sciences. Based on the research evidence outlined in this paper, it does not seem wise to "put all our eggs in one basket" and promote IBSE as the only approach to effective science teaching. We need to get the right balance between the direct instruction and approach and the IBSE approach" (Kennedy, 2013).

In most cases, it may be best for teachers to use a combination of approaches to ensure that the needs of all students in terms of knowledge, understanding, skills, attitudes, values, scientific literacy, and overall interest in science and science-related topics are met. The

TABLE 2 Advantages and disadvantages of inquiry based science education (IBSE).

Advantages of IBSE	Disadvantages of IBSE
Students learn best when they take an active role and practice what they have learned (Smart and Csapo, 2007). It is very important that in order to facilitate inquiry-based learning, the teacher make simple changes and organize the classroom in a way so he/she could manage transition and gain attention as the children use hands-on investigative activities, use of science journals, use of group-based activities, and guided studies students to reflect on their learning process.	Many teachers experience interactional difficulty with their students. Teachers also face lots of difficulties in channeling and maintaining the interest of students as they engage themselves in inquiry activities and try to derive appropriate conclusions about nature (Bencze, 2009)
Theorists such as John Dewey believed that inquiry-based scientific approach could improve education. Children can also use their natural activity and curiosity when learning about a new concept (Vandervoort, 1983; Dewey, 2008).	Many science teachers are unprepared for the social demands of this of type of strategy (Oliveria, 2009).
Inquiry method of teaching requires taking into consideration the psychological needs of the child rather than introducing science as a logical coherent subject (Eshach, 1997; Henderson and David, 2007).	Careful planning and preparation is also required for adequate content information to be imparted to students, which makes it difficult for some science topic to be taught using the inquiry method (Robertson, 2007).
Piaget, believes that as the child grows and his/her brain experiences intellectual development and he/she starts to construct mental structures through his interaction with the environment (Lawson and Renner, 1975).	Science being a vast accumulation of discoveries must be transmitted through books, charts, tables etc. Therefore, a great deal of science content must be taught and education cannot possibly fulfill its obligation by simply arranging for rediscovery (Skinner, 1987).
	Inquiry teaching methods does not provide for much adult support. The child always needs the support of an adult (Beliavsky, 2006).

advantages and disadvantages of IBSE as outlined in the literature are summarized in Table 2.

The advantages and disadvantages of direct instruction as outlined in the literature are summarized in Table 3.

1.3. Overview of the medical physics intervention package

The Medical Physics module used in this research was designed to encourage an interest in physics among young students through a relevant hands-on interactive learning experience using many real life examples. The module offers an introduction to medical physics through investigative and cooperative learning experiences.

TABLE 3 Advantages and disadvantages of direct instruction (DI).

Advantages of DI	Disadvantages of DI
Many teachers prefer to use direct instruction methodology because it is structured and can be assessed with validity. Many researchers advocate direct instructions so children can have planned experience in science rather than incidental experiences as with inquiry method (Mason, 1963).	It is possible for students to forget facts if rote memorization is a method of imparting information. Dewey was disturbed to see rote memorization and mechanical routine practices in science classroom (Vandervoort, 1983).
Teachers prefer to use direct instructions because this is the most organized way of teaching (Qablan et al., 2009).	The danger with this practice is that there is no foundation of knowledge built which the students can draw from in the event that he/she forgets the memorized knowledge. Their process skills and abilities to make judgment would not have been significantly developed (Vandervoort, 1983; Wang and Staver, 1995).
Teachers find it hard to keep students motivating as they are left by themselves to acquire knowledge through inquiry-based learning (Bencze, 2009).	With direct instruction, the teacher poses the problem and may then solves it without giving the students an opportunity to discover. Therefore the child is not given an opportunity to use the necessary process skills (Ray, 1961).
Children receive more guidance as teachers make sure that students have understood the step before moving on to the next (Skinner, 1987).	Teachers who do not possess a major understanding of scientific principles can find it difficult to teach using the direct method of instruction. It is therefore advisable that the use of the inquiry method instead of the direct instruction method in the elementary school should be emphasized (Chiapetta and Collette, 1973). However, in using IBSE teachers need to have a good foundation in subject content in order to answer the many questions that arises.
It is also considered the best teaching method for learning content and new skills. Robertson made a very important point in his article that not every science topic can be taught using the inquiry method (Robertson, 2007).	
This method is accepted and promoted in many cultures and languages (Lee, 2002).	

The module is divided into five units (X-Rays, Ultrasound, Endoscopy, MRI & CT Scans, and Radioactivity) with the objectives of each units clearly stated at the beginning of each unit. Each unit focuses on basic physics concepts presented in a logical sequence with learning outcomes stated at the end of each unit. The Medical Physics module is designed to challenge and motivate students. Whereas each lesson can be taught in a single class

(40 min), it is recommended that, if possible a double lesson (80–90 min) be devoted to each lesson in order to allow time for discussion and other activities.

The module encourages a teaching approach involving a balance between inquiry based science education and direct instruction approaches. These approaches are encouraged by the inclusion of a detailed Teacher's Guide and a wide variety of student activities to encourage IBSE. Practical work activities are included throughout the module. These practical activities are used to model scientific principles as applied to medical physics. Expert Group Tasks are included in the module and are designed to encourage IBSE. The students work collaboratively and prepare presentations for the rest of the class. In addition this module is designed for teaching using an integrated IBSE-DI approach in each lesson.

2. Methods

This study involved a case study comparative research approach using qualitative method. Also, some aspects of action research were involved as feedback from the schools involved in the implementation of the module was used to incorporate modifications in the module for implementation with schools that will participate in future trials. Due the fact that the main language of the target sample is both native English speakers and native Indonesian speakers, the teaching package was translated from English into Indonesian by the researcher. A total of 34 teachers received in-service training on the module. Of these, 15 schools in Indonesia and 15 schools in Ireland were selected to participate in the project using random sampling. In Indonesia, the researcher took samples from three different school types, i.e., Madrasah secondary schools which are equivalent to the voluntary schools in Ireland, general secondary schools in Indonesia which are equivalent to community/comprehensive schools in Ireland, and vocational secondary schools in Indonesia which are equivalent to Education and Training Board (ETB) schools in Ireland. Circulars were distributed to schools and teachers were invited to attend training workshops to familiarize them with the teaching package. Trialing was carried out by seven schools in each country, and this helped to "fine-tune" the teaching package. No major modifications were necessary.

In general, there were over 5.1 million secondary school pupils enrolled in Indonesia. 26,000 secondary schools exist. The Ministry of Education and Culture oversees 84% of these schools, and the Ministry of Religious Affairs oversees the remaining 16%. In Indonesia, high school lasts 3 years to complete. Indonesians have access to pre-professional and vocational high schools in addition to traditional high schools. In Indonesia, attending elementary through high school is required (Pambudi and Harjanto, 2020; Setiawan, 2020). In comparison, there are roughly 395,611 secondary school students in 3,968 secondary schools in Ireland. Dublin is the largest province, accounting for 18% of the market (706 Secondary schools). With 428 secondary schools (11%), Cork comes in second. Galway also has 233 secondary schools, which is a lot. Together, these three provinces account for 34% of the market for Irish secondary schools (Coolahan, 1995).

For this study purposes, a total of 402 students in the 14–16 age group from Indonesia and 263 students from Ireland participated randomly. The smaller number of students in Ireland was due to the fact that many transition year students (age 15–16) were involved in work experiences programs and therefore were unable to participate in the project. Teachers were supplied with the module as a teaching package and were given complete freedom in how they wished to implement it in the classroom. Questionnaires were issued for completion by teachers and students. In this study, all questionnaires were distributed to the teachers in in-service training courses and returned to the researcher *via* the postal system. The response rate was 100%. The data were analyzed using quantitatively and qualitatively. Triangulation was carried out by comparing data obtained from the students about each lesson with descriptions from teachers on how they taught the lesson.

3. Result and discussion

3.1. Response of teachers to the medical physics intervention package

The questionnaire issued to teachers ranged over a number of areas, e.g., type of school, size of the school, subject specialism in degree, teaching experience, gender, time spent implementing the intervention package, the assistance obtained from level of detail in objectives, learning outcomes and lesson plans, and the Teacher's Guide. Teachers were asked about their use of IBSE and DI when implementing the intervention package in the classroom. In this paper, we concentrate on the teachers' responses to the questions relating to IBSE and DI.

When the Irish science teachers were asked their opinion about the inclusion of inquiry based science education activities in each of the lesson plans provided, all of the teachers (100%) agreed that it was a good idea to include these activities. Typical responses were:

- *Yes, IBSE results in greater student engagement.*
- *Allowed students the opportunity to think/reflect on their own knowledge.*
- *Inquiry based science education is an advanced approach. Students questioning, researching, thus enhancing their communication skills; solving problems or creating solutions. Also encourages student "thinking" visible to the center of the learning. So, it is a good idea to included IBSE activities.*

This result compares with Indonesian teachers' responses where only 67% of the science teachers had a positive response to the inclusion of IBSE activities in the lesson plans provided. Interestingly, 33% of science teachers argued that it wasn't a good idea to put IBSE activities in the learning process.

> *This approach is designed for students of high ability; most science teachers have difficulties implementing this method of teaching. This approach takes too much time.*
>
> *This method of teaching is difficult to implement and difficult to design assessment for it. There is a lack of laboratory equipment, administrative support and school facilities to help me to use this approach.*

Clearly, the majority of the sample of teachers in both countries expressed a positive attitude toward IBSE. However, it is clear that in the case of a significant number of science teachers in Indonesia, the perception that IBSE was only for higher ability students and the lack of laboratory facilities were clearly seen as an impediment to the teachers in implementing an IBSE approach due the fact that some of the practical activities could not be carried out.

Some interesting points of agreement were observed between the science teachers in Ireland and in Indonesia when asked about the balance between IBSE and DI in their teaching for the lessons in the intervention package. The results are summarized in Figure 1.

Clearly, the comparative analysis above showed that approximately 40% of teachers in both countries reported that the balance of IBSE and DI was in the ratio of 50:50 DI. It is also worth noting that a significant number of teachers in Ireland (41%) and in Indonesia (29%) felt that that that a balance between IBSE and DI was in the ratio of 1:3. Some typical comments obtained were:

> "In my classroom, I tried to teach with more emphasizes on inquiry based learning, but it needs more time allocated. Comparing IBSE with DI is a good idea."
>
> "I think there are many reasons why the balance should be 50% IBSE-50% DI": (1). The number of students in the classroom, (2). Laboratory equipment, (3). Students' abilities, (4). Allocation of learning time."

When teachers were asked to comment on the benefits that they saw of IBSE and DI approaches to teaching, a wide variety of comments were received. These comments are summarized in Tables 2, 4.

As seen from the above summary of the data obtained, the science teachers do not believe that there is any one perfect teaching approach to implementing the intervention package. There appears to be a continuum of a shifting balance (dynamic equilibrium) between student-centered learning (inquiry based science education) and teacher-centered learning (direct instruction) to ensure that these two approaches complement each other.

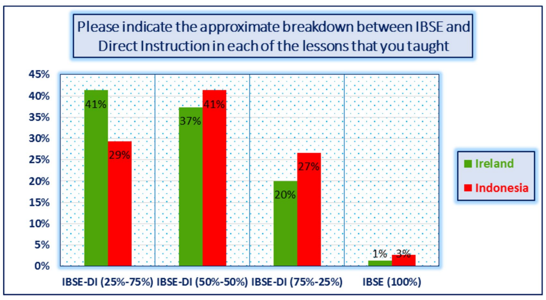

FIGURE 1
Comparative analysis regarding the reported balance between inquiry based science education (IBSE) and direct instruction (DI) during the teaching process.

3.2. Response of students to the medical physics module

The questionnaire issued to students asked their views on a number of areas, e.g., (1) gender, (2) age, (3) type of school, (4) level of interest in science, (5) performance in past science examinations, (6) level of difficulty in understanding topics, (7) participation in group activities, (8) level of interest in topics covered in module, and (9) willingness to continue with their study of physics. Due to restrictions on space, in this paper, we concentrate on the students' responses about their level of enjoyment of the module and their interest in the study of physics. A detailed analysis of all the data is given elsewhere (Sudirman, 2016).

Students were asked to indicate their level of enjoyment on a five-point Likert scale ranging from "extremely unenjoyable" to "extremely enjoyable." The results are summarized in Figure 2.

It is clear that the majority of the students in both countries reported that they found the module enjoyable. Typical comments received from those who found the module enjoyable were:

- *It was really enjoyable to learn about different topics in physics.*
- *It was interesting and helped further my studies.*
- *I really enjoyed it because it shows how medical analysis works.*
- *Not my favorite topic but it was a good lesson to know in general.*
- *I thought the lessons were enjoyable. I participated in the expert group task and my role was as a speaker when my group presented our research project.*

It is clear from Figure 2 that while Irish students showed a higher level of enjoyment of the module than Indonesian students, overall, the majority of students reported that they enjoyed the module. A statistical analysis of the data was carried out and some interesting points emerged:

- In Ireland male students were more interested in the module than female students but in Indonesia female students were more interested in it than male students.
- In both Ireland and Indonesia, students in vocational type schools expressed the most positive attitude toward the module. Students in the more academic type schools were less positive about the module.

When the Irish students were asked if the study of this module would encourage them to continue with their study of physics at senior level (Leaving Certificate), 45% indicated "yes" while more than half (55%) said "no." Interestingly, a significant number of Indonesian students (78%) said "yes" while only 22% said "no." Some typical comments from students were:

> *Science = awesome, Science makes me happy to further…it increased my curiosity and interest in physics.*
>
> *I actually like physics, but for the next year I will choose the Social Sciences Program which does not include physics (compulsory). Maybe if I were allowed to choose physics, I would also choose it.*

10.3389/feduc.2023.1118873

TABLE 4 Summary of the benefits of inquiry based science education (IBSE) and direct instruction (DI) in teaching physics as outlined by teachers who participated in the study.

IBSE	DI
Engages students and provides a greater cognitive challenge, i.e., scientific attitude and scientific process.	Teachers are able to guide students in face-to-face teaching and maximize students' understanding.
Students work independently.	Can be adapted for the complete range of students' abilities.
Can serve the needs of students who have above average ability. That is, students who have good ability and good study skills.	Can determine what the students need in facing difficulties in understanding.
IBSE is a teaching strategy that emphasizes the development of a balance between the cognitive, affective, and psychomotor domains.	Creates an interactive learning environment, particularly for students with lower abilities.
Allows students to understand the scientific process.	Listening activities play a key role for success in implementing the DI approach.
The teacher identifies the depth of students' knowledge and understanding of the concepts being discussed.	Can be used to determine the important points or difficulties that may be faced by students.
Pace and content can be adapted to suit individual learning needs of students and also helps develop critical thinking skills.	The most effective way to teach concepts and skills to students who are underachieving.
Allows students to think more critically about the topic being explored.	Teachers can demonstrate how a problem can be approached, how the information is analyzed, and how the knowledge is generated.
Provides a space for students to learn according to their learning styles.	It makes learning science interesting and relevant to students' everyday life by establishing a direct link between theories and its application.
	Focuses the students' attention on relevant content.

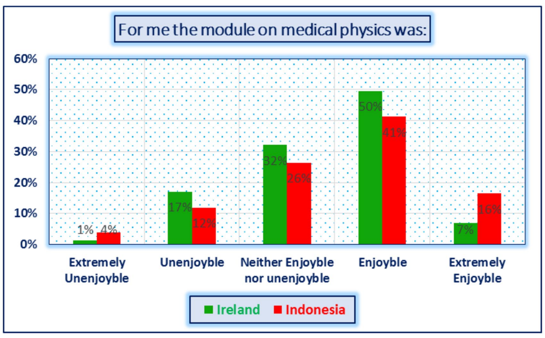

FIGURE 2
Responses of students indicating their level of enjoyment of the module.

The latter quotation above points to the fact that in Indonesia it is not possible to choose to study science subjects if one is specializing in subjects that are part of the Social Sciences program. This problem does not arise in Ireland where students study a total of seven subjects which include both social science subjects and science subjects.

Analysis of the comments from the students in both countries revealed that some terms used in this module affected their interest due to a lack of literacy skills. The study shows that students had difficulty not only with the technical words, but more commonly with everyday words used in the module. It would appear from the analysis of the student questionnaires that some of the teachers did not explain the meaning of many of the common terms encountered in the module as they may have assumed that they were understood by the student. This is in keeping with the findings of Cassells and Johnstone (1985) and Wellington and Osborne (2001). The use of the DI approach during the teaching process has clear significance for helping students to overcome literacy problems. Without an emphasis on supporting literacy, students may become frustrated with the problems being encountered and this may contribute to develop a negative attitude due to the difficulty of understanding the subject matter.

4. Conclusion and recommendation

Analysis of the data obtained from teachers and students clearly shows that the Medical Physics module has been successful in generating positive responses from both teachers and students. There is a statistically significant difference of responses regarding some variables in the module between Indonesian and Irish science teachers as well as in the responses from students. Analysis of the data from teachers and students shows that the teaching package was teacher-friendly, clear and concise, well laid out, and easy to follow. Teachers reported that the various methodologies and strategies used in the package were popular and could be easily adapted and modified for use in secondary school science lessons.

Based on the findings of the study that arise from the data analysis and bearing in mind its implications the following recommendations are confirmed. (1) There are some clear implications arising from this study for policymakers. Policymakers refer to those involved in curriculum design, members of the inspectorate, and other government agencies whose responsibility involves guiding the future of science education. Policymakers must ensure that continuing professional development programs for science teachers are provided to help them to develop a balance in their teaching between inquiry based science education and direct instruction. Also, teachers were clearly happy with the clearly defined learning outcomes for each lesson in the module. Hence, it is important to provide training to science teachers in the writing of learning outcomes and the methodology involved in teaching within a learning outcomes framework. While the concept of learning outcomes is well known in Ireland, the concept of a learning outcomes framework is quite new to teachers in Indonesia. (2) The availability of suitable laboratory facilities is very important in supporting an effective science teaching and learning environment. Policymakers at national and local level could better address the needs of science teachers in schools in terms of providing better quality laboratory facilities—this problem was particularly acute in Indonesia in promoting IBSE. (3) The Medical Physics module has received strong positive response from both teachers and students. Similar modules could be devised such as in astronomy, biotechnology, electronics, and other areas. Learning physics in the context of applications of science and technology allied with good pedagogy can create a good learning atmosphere.

While the students enjoyed studying the module, it had limited success in convincing them to continue with their study of physics at a higher level. The response of the teachers showed that there was a good balance between IBSE and DI in the teaching approach used by teachers when implementing this module. It is hoped that the study presented here will contribute to the development of new and innovative ways of teaching physics at the secondary school level.

Data availability statement

The data that support the findings of this study are available from the corresponding author.

Ethics statement

Ethical approval was not required for the study involving human participants in accordance with the local legislation and institutional requirements. Written informed consent to participate in this study was not required from the participants in accordance with the national legislation and the institutional requirements.

Author contributions

SuS conceived of the presented idea, developed the theory, verified the analytical methods, and performed the writing–original draft and conceptualization. DK supervised the findings of this work. SoS performed writing–review and editing. All authors contributed to the article and approved the submitted version.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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