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Implementing Discovery Learning Model using Virtual Laboratory: An Insight to Differentiation Learning Strategies

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Abstract: Students have unique and diverse characteristics. One of the strategies used to facilitate student diversity is through differentiation learning. The research aims to explain the findings or problems of case studies in learning Physics at SMAN 8 Yogyakarta and explain the differentiated learning to solve these problems. The research approach used is qualitative with the case study method. Data collection techniques use non-test techniques using documentation and observation. Based on the results, differentiated learning can facilitate the needs of students who have diverse learning modalities, including students with visual and kinesthetic learning modalities. The implementation of discovery learning using virtual laboratories assisted by PhET Colorado can be an alternative learning model in teaching Physics. Future research can measure students' knowledge, attitudes or skills in applying differentiated learning and combining it with other learning models.

Keywords: Differentiation Strategies; Discovery Learning Model; Virtual Laboratory

Introduction

Each student has uniqueness and different characteristics. Education must accommodate these differences and meet the needs of students. Existing differences must be facilitated to students can grow and develop in different environments and cultures (Marliana et al., 2022). One of the strategies used to accommodate student differences is through differentiation learning. Educators can recognize and teach according to the student's learning modalities and talents using differentiated learning (Morgan, 2014). Differentiated learning serves to adapt educational strategies to the needs of each student, encouraging growth and development in diverse environments and cultures.

The differentiated learning concept refers to Ki Hajar Dewantara's educational philosophy, namely student-centered learning. Differentiated learning is one of the efforts made by teacher to adjust the learning process in the classroom to meet the learning needs of students. Differentiated learning aims to accommodate, serve and acknowledge the diversity of students to learn with students' interests, readiness, and learning preferences (Morgan, 2014). This approach shifts the focus from universal model to a more personalized, adaptive learning environment. Understanding and implementing differentiation strategies is essensial for creating student-centered learning.

The implementation of differentiated learning is affected by various factors, including environmental factors where students live. Urie Bronfenbrenner, a psychologist from Cornell University, introduced the theory of ecological systems in 1979, which views an individual's development by the environment. The focus of this theory is that the reciprocal relationship between individuals and the environment can form a behavior.

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The ecological system theory of individual development consists of five environmental systems. They are microsystems, mesosystems, ecosystems, macrosystems, and microsystems (Mulisa, 2019; Uribe, 2022). The microsystem is the environment in which students live, including family, school, and friendship circles. The mesosystem is a reciprocal relationship between microsystems, for example, the interaction between educators and parents. An ecosystem is a system that includes conditions that influence the development of students in their home environment, but students are not directly involved in the role. For example, economic status does not allow them to continue their education. The macrosystem is the system that surrounds the ecosystem, the mesosystem, and also the microsystem. The chronosystem is a system that influences over time and influences the behavior and development of students. Because microsystems, mesosystems, ecosystems, macrosystems, and chronosystems all play a role in shaping behavior, understanding how these factors influence different learning applications is critical.

Differentiation learning applies Howard **Gardner's (1993)** theory of multiple intelligences. Nine kinds of multiple intelligences are verbal-linguistic, logical-mathematical, visual-spatial, physical-kinesthetic, rhythmic-music, intrapersonal, interpersonal naturalistic, and extra-spiritual (Kurniawati et al., 2021). Gardner describes multiple intelligences as abilities used to solve problems and produce products in various settings and real situations.

Lev Vygotsky's concept also underlies differentiated learning to develop and provide meaningful learning for students at all levels according to the development of students, which is called the Zone of Proximal Development (ZPD). In ZPD theory, there are two levels. There is a level of potential development and actual development. The level of potential development can be seen from the ability of students to develop their understanding which still requires help from other people, both educators and friends. The level of actual development is seen from the student's ability to complete their tasks without help from others. So, the difference between the two levels of development is included in the ZPD or lies between the various things that students can do independently and those that need help from others. Therefore, each student has a varying ZPD, so the guidance provided needs to be adjusted to the potential of students. Recognizing and accommodating diverse intelligences and adapting guidance based on an individual's ZPD is an important component of effective differentiated learning.

Teachers can guide students according to their potential and learning modalities. That are also known as the visual, auditory, and kinesthetic approaches (Dörnyei, 2005). Students with visual learning modality can more easily receive and remember information through pictures. Students with auditory learning modality find it easier to accept the explanation from listening to verbal, both recordings and other people. Students with kinesthetic learning modality find it easier to understand the material by learning while doing it because students gain experience from activities carried out directly. Students can also use more than one learning modality called multimodal learner, which is appropiated to the situations and conditions of the students and the material they are studying.

Differentiation learning consists of four aspects, namely content, process, product, and learning environment differentiation (Kristiani et al., 2021). The indicator from aspects of content differentiation is the diversity of information sources and the amount of content or learning materials provided according to the student's ability. The application of process differentiation is the use of various instructions, assignments, strategies, and learning activities. In addition, the grouping of students is a differentiation process. Aspects of product differentiation include the provision of final product choices and assessments used for each student. The differentiation of the learning environment includes arranging tables or chairs according to learning needs and setting the room temperature so that the class is conducive. Investigating these aspects allows for a comprehensive understanding of how educators can adapt their teaching methods to accommodate diverse student needs.

Based on a preliminary study conducted at SMA Negeri 8 Yogyakarta, the conditions for learning Physics used a direct learning strategy in which the teacher delivered material directly. Students listened to the explanations from teachers. Students received a learning module containing material and practice questions before learning. The learning module is a digital file accessed by a smartphone or laptop. However, the learning module does not yet contain a series of experimental activities. This preliminary study highlights a gap in the use of direct learning strategies in Physics learning. The absence of experimental activities and the potential benefits of discovery learning and virtual laboratories indicate an opportunity for improvement in the current educational approach.

One of the learning models in Physics lessons is discovery learning. This model requires students to find conceptual understanding independently through materials provided with minimal guidance, such as simulations, examples of problems, and feedback (Alfieri et al., 2011). Discovery learning is a learning model that focuses on the ability to solve things that are relevant to the current situation (Nurcahyo et al., 2018). The discovery learning model in Physics lessons to students can improve student learning outcomes (Hilmi et al., 2017).

Practicum activities have a vital role in learning science, including learning Physics. Along with technological developments, now there is a virtual laboratory as an alternative to carrying out practical activities directly. The application of learning using a virtual laboratory has an effect on student learning outcomes and supports the learning environment from a physical laboratory (Kharki et al., 2021). The research aims to explain the findings or problems of case studies in schools and explain differentiated learning to solve these problems.

Method

The research was conducted in February 2023. The research location was at SMA Negeri 8 Yogyakarta for the academic year 2022/2023. The research subjects used were all students of class X MIPA 6, totaling 36 students, consisting of 19 boys and 17 girls.

This study uses a qualitative research approach with case studies. Case studies explore processes involving detailed descriptions of individuals and backgrounds, followed by data analysis for an issue or theme. Data analysis includes describing cases, collecting categories, carrying out direct interpretations, forming patterns, and finding equivalence between categories to develop conclusions that are naturalistic generalizations (Creswell & Creswell, 2018; Stake, 1995).

The learning carried out is the discovery learning model with a virtual laboratory. The virtual laboratory used is PhET Colorado with the topic "Energy Skate Park" on the Law of Conservation of Energy material. Discovery learning in this research is more about model design that encourages students to play an active role in the process (Druckman & Ebner, 2018). The implementation of the differentiation learning strategy follows the steps as in Figure 1.

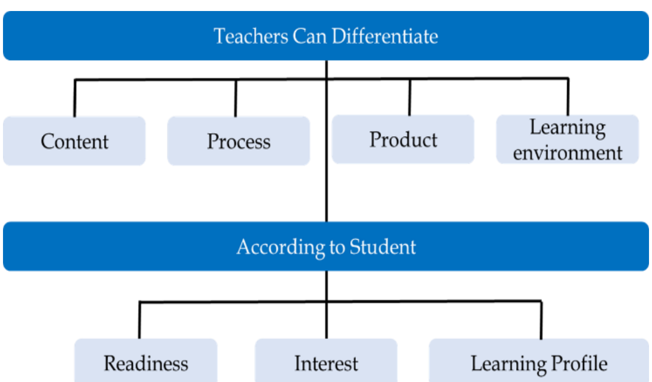


Figure 1. Differentiated learning strategies (Kristiani et al., 2021; Tomlinson & Imbeau, 2010).

Result and Discussion

Identify the Main Problem

Based on the results of the initial observations made, teachers are still dominant in using lecture, assignment, and question-and-answer methods. The reciprocal relationship between students and teachers is still one way. A teacher explains more about the material while the students receive the information from the teacher. In addition, learning Physics has not optimized the differentiating learning aspects. Even so, students tend to continue to follow the lesson because of the environment of the students, one of which is because some of them have attended tutoring outside of school. In order to respond to conditions and answer students' needs, the application of differentiated learning can be an alternative solution (Tomlinson, 2014). The implementation of differentiated learning can be combined with several learning models such as problem based learning (Dalila et al., 2022; Tomlinson, 2000), inquiry learning (Nur'aini et al., 2023; Rahmah et al., 2022), and discovery learning (Anđelković & Maričić, 2023).

In classroom learning, each student has a different intelligence with the advantages and uniqueness of each that underlies the implementation of differentiated learning. Class X MIPA 6 students tend to have logical-mathematical, visual-spatial, and verbal-linguistic intelligence because the student characteristics were quickly solving the given math problems, paying attention to the teacher when explaining material in front of the class, and recording material taught by the teacher. Students who have logical-mathematical intelligence abilities are influenced by the ability to understand and classify patterns and relationships (Arum et al., 2018), while students who have visual-spatial intelligence have better imagination and problem solving (Rimbatmojo et al., 2017). Students' verbal-linguistic intelligence can include sensitivity to sound, meaning, structure, function of words and language (Halil, 2017). Based on these findings, teachers need to design differentiated learning that utilizes methods that involve visual elements, discussion activities, and problem solving using logic or mathematics.

At the learning preparation stage, the teacher adds insight regarding differentiated learning by discussing with colleagues and also from the internet. Furthermore, the teacher conducts a non-cognitive diagnostic assessment to identify the profile of students learning modality and to determine the learning strategy. Based on the results of student profiling, students of class X MIPA 6 have learning modalities, as shown in Figure 2.

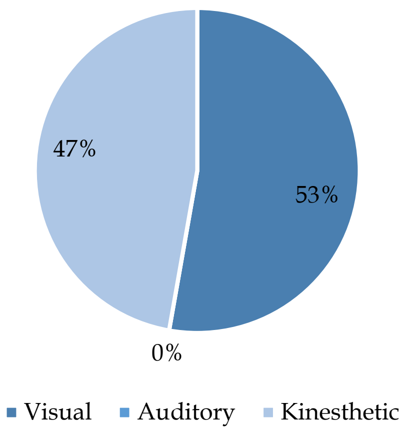


Figure 2. Profile of student learning modalities

The student profiling data became the basis for selecting the discovery learning model to be applied using a virtual laboratory assisted by PhET Colorado. It is from the percentage of students' learning modalities dominated by students with visual (53.00%) and kinesthetic (47.00%) learning modalities.

The learning outcomes of students in physics lessons in odd semester class X MIPA 6 SMA Negeri 8 Yogyakarta, as shown in Table 1.

Table 1. Student learning outcomes in odd semester

Learning outcomes	Grade
Maximum	88
Minimum	24
Average	62

Based on Table 1, the average student learning outcomes obtained a score of 73 from the Minimum Completeness Criteria (KKM) ≥ 75. The student's maximum Physics score was 88, and the minimum score was 24. Student learning outcomes in the previous material found that there were 36 participants students, consisting of 12 completed (33.33%) and 24 incomplete (66.67%). Based on these results, the learning outcomes of students in learning Physics need to be improved.

Differentiation Strategies

The problem identification was carried out from the basis for the preparation of the implementation of differentiated learning, the selection of learning models, the integration of Pancasila student profiles (cooperation and independence), and the assessment instruments preparation. The teacher chose the discovery learning model using a virtual laboratory with PhET Colorado material on the law of conservation of mechanical energy. The differentiation learning strategies through the following learning steps:

Preliminary Activities

Preliminary activities begin by praying, checking the presence of students, and identifying learning readiness. The teacher asks about the students readiness via Mentimeter, as shown in Figure 3.

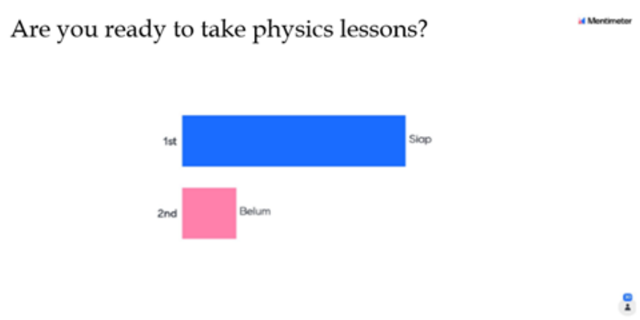


Figure 3. Students readiness to learn physics

Based on data on the readiness to learn Physics dominated by the answers "ready" from students. However, there are still students who are not ready to take part in physics learning. The teachers give motivational videos about the importance of learning from an early age. At this stage, the teacher can explore students' learning interests.

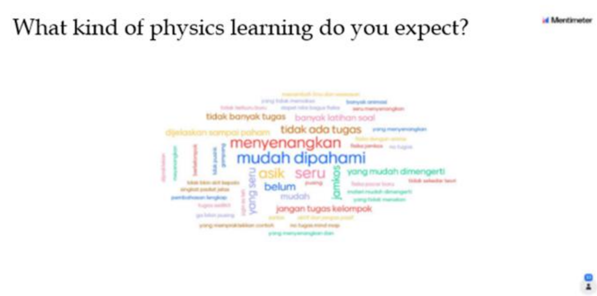


Figure 4. Student learning interest

In Figure 4, students have a learning interest in Physics dominated by fun learning, easy to understand, and exciting. In addition, at this stage, the teacher does an apperception using a Padlet so that students are involved in question and answer. The following Padlet display of student apperception activities, as shown in Figure 5.

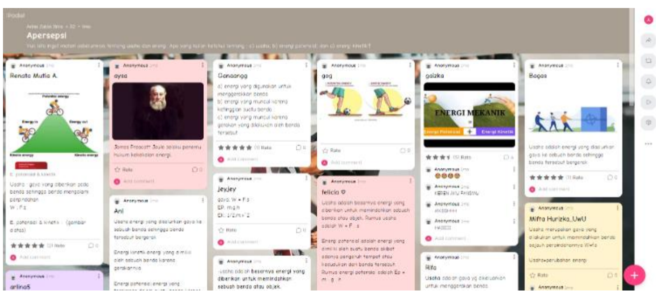


Figure 5. Padlet display on apperception activities: product differentiation

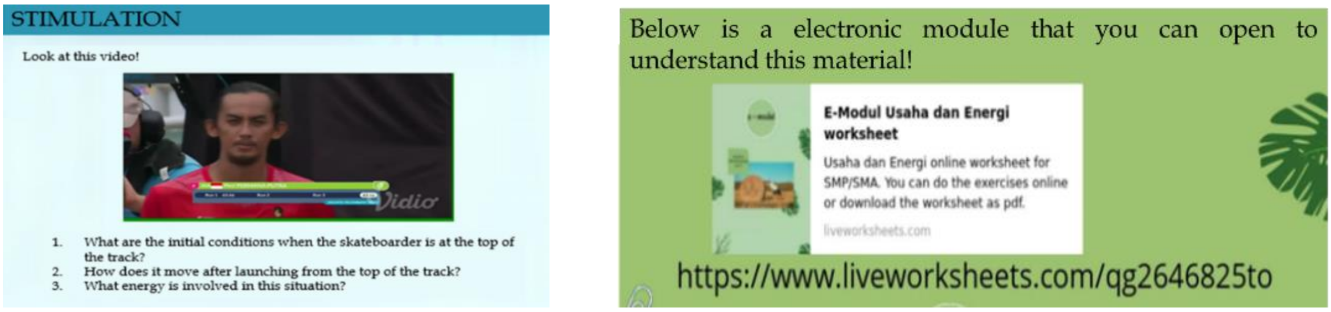
In apperception activities, product differentiation learning is applied. Students given freedom to express their answers with various products such as text, images, and others. This stage also conveys the flow and learning objectives. The teacher asks about the process of forming groups. These activities are included in process differentiation learning. Students want to form groups with the names of scientists such as Isaac Newton, Johannes Kepler, Albert Einstein, Nicolaus Copernicus, Thomas Alfa Edison, and James Prescott Joule.

Core Activities

In the core activities, the teacher applied discovery learning model using a virtual laboratory through the following stages:

Stimulation

Stimulation is according to the ability and readiness to learn. Students with low learning readiness are given video displays, while students with high learning readiness are given teaching materials using e-module. It is the application of content differentiation learning. In learning environment differentiation learning, students gather in their groups and choose their seats.



(a) (b)

Figure 6. Stimulation: differentiation of content (a) display of learning videos and (b) teaching materials using e-module

Problem Statement

Each group identifies and models a track loop for the gliding skates. Students work on their worksheets according to group creativity.

Figure 7. Design of a skate track loop with PhET colorado using a smartphone

Data Collection

At the data collection stage, students are free to look for reference sources from Power point, learning videos, reference books and so on. The activity of looking for references is the application of content differentiation learning. Furthermore, students collect practicum data such as the initial height of the track, the maximum height of the loop, and the final height of the track.

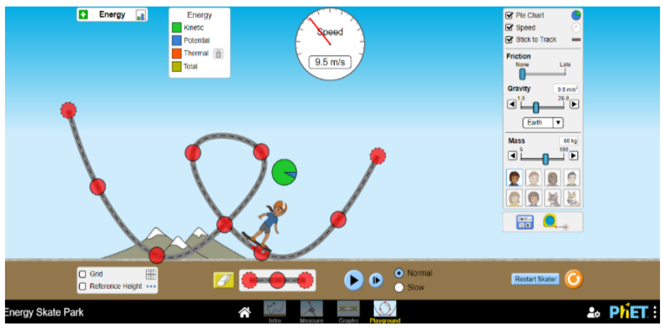


Figure 8. Display of the PhET colorado worksheet

Data Processing

After the data collection activities are carried out, students analyze the data to look for potential energy, kinetic energy, and mechanical energy. Each group given freedom to make a practicum report which is produced either in the form of data tables or text.

Massa Mike = 50 kg

No.	Height	Potential Energy (EP = m.g.h)	Velocity	Kinetic Energy (EK = ½ m.v²)	Mechanical Energy EM = EP + EK
1.	The initial height of the track h = …				
2.	Maximum height Loop 1 h = …				
3.	Maximum height Loop 2 h = …				
4.	The final height of the track h = …				

Figure 9. Display of Practicum Data Tables

Verification

At the verification stage, group representatives presented their practicum reports in front of the class, and other groups listened and checked the correctness of the data displayed. In addition, the peer assessment was applied during the presentation, that was an implementation of the cooperation and independence dimensions of the Pancasila student profile.

Generalization

The teacher and students draw a conclusion from the material studied, especially the material on the Law of Conservation of Mechanical Energy.

Closing Activites

Activities carried out in the closing stage include the teacher evaluating learning activities, providing feedback on the process and learning outcomes, giving assignments of resumes, submitting lesson plans at the next meeting, and closing with a prayer.

The discovery learning model influences students' cognitive abilities (Ilma et al., 2021) and science process skills (Haryadi & Pujiastuti, 2019; Samputri, 2020). Students can visualize practicum activities and apply more interactive concepts that have an impact learning outcomes (Akina et al., 2023; Minarni et al., 2022; Sari et al., 2016). Practical activities make new knowledge more meaningful and relevant in life (Masril et al., 2018).

The discovery learning model using a virtual laboratory can also improve the ability of science process, student learning outcomes (Aguanda et al., 2023; Dewi et al., 2020; Jannah et al., 2021; Rosnidar et al., 2021), problem solving (Sanggara et al., 2018), and understanding of physics concepts (Ilyas et al., 2022). Through experimentation and observation, students can investigate, analyze and find concepts through their own experiences so that students will continue to remember them for a long time (Jannah et al., 2021; Mukherjee, 2015).

The use of virtual laboratories can be used in face-to-face and online learning. It can be applied to online learning to increase motivate students, independence (Utami et al., 2022) and environmental literacy (Angreani et al., 2022). However, in using it, it is necessary to consider the instructions in the activity design and the choice of technology used (Chan et al., 2021).

Utilizing virtual laboratory like PhET Colorado also provides significant opportunities to improve students' creative thinking skills. In this context, virtual laboratories are not only a visual and practical tool, but also a forum for developing student creativity (Sari et al., 2021). The use of virtual laboratories can also improve students' critical thinking skills (Sujono et al., 2023), and understanding of physics concepts (Prayogi, 2022).

Differentiated learning through discovery learning using virtual laboratory provides a holistic and personalized approach. Students can access content according to their needs, participate in learning processes that suit their individual learning styles, interact in an environment that supports diversity, and produce learning products that fulfill various individual potentials. By considering teaching in the design of learning activities and the choice of technology used, teachers can implement effective differentiated learning through virtual laboratories.

Conclusion

Differentiated learning can facilitate the needs of students who have diverse learning modalities, including students with visual and kinesthetic learning modalities. The implementation of discovery learning using virtual laboratories assisted by PhET Colorado can be an alternative learning model in teaching Physics.

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Author Contributions

Conceptualization, A.Z.I, A.I and N.S.R; methodology, A.Z.I. and A.I.; validation, A.I. and N.S.R.; formal analysis, A.Z.I.; investigation, N.S.R.; resources, A.Z.I.; data curation, A.I.: writing—original draft preparation, A.Z.I.; writing—review and editing, A.I.: visualization, N.S.R.

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Conflicts of interest

There is no conflict of interest.

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