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# STEM Education Implementation to Enhance Student Learning Outcomes in Optics Concept

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**Abstract:** This paper reports the implementation of the STEM learning strategy to the 20 physics students on optical physics concepts. Previously, student understanding on this subject was categorized as weak, this was caused by not only learning just carried out theoretically but also the student's limitation to figure out the optical phenomenon. This research is to identify the student learning outcomes before and after STEM implementation by using simple experimental work with a set of pre-test and post-test. The calculation results show that the student's outcome has a medium enhancement which is about 0.53. Certainly, a Stem learning strategy is a good choice as a teaching strategy in the Optical Physics subject.

**Keywords:** STEM; Project-based learning; Students learning outcomes.

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## Introduction

Optical physics is a subject matter contained physics curriculum in the university. This subject is categorized as a science subjects. Science is an activity carried out to understand the universe through observation and using certain procedures to get a conclusion. By studying science, one can get to know about living things and the natural surroundings) (Ardito, 2012; Bangao, 2020; Sudjito et al., 2018). Students who study science will be able to apply their knowledge in everyday life so that this learning is considered very important and must be understood by students. Various efforts have been made by the government to advance science education in schools. To maximize learning in the classroom, a strategy, supporting facilities, and innovative learning models are needed that facilitate the learning process in the classroom. one way to improve science learning outcomes is to use creative and innovative learning models (Julianti et al., 2020), (Azhar, 2008)

Optics is one of the topics in physics related to light. Application The science of optics is most visible in various optical instruments. Optical science continues developed along with the discovery of the concept of the speed of light which constant and quantum physics (Saktioto et al., 2021). Initially learning optical physics was limited in concepts mirrors, lenses, optical instruments, but then developed since the birth of modern physics until the invention of the optical laser, called modern optics (Agrawal, 2002; D. Irawan, 2017; D. Irawan et al., 2010; Dedi Irawan, Saktioto, Ali, Fadhali, et al., 2012). Currently, not all colleges higher education provides modern optics lectures, more physics courses are found laser, even though there are still developments that should be given to students in lectures. This is closely related to the development of science and technology.

The problem that often occurs today is that lecturers have not used innovative learning models that can increase student motivation in learning. Students are more dominant in using conventional learning models

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so that students feel bored when studying in class. This will affect the achievement of less-than-optimal science knowledge competencies. This problem was also found in one of the physics subjects. Based on the results of observations physics department, it was found that the quality of science learning outcomes of students was still low. Grade VIII grades for science subjects are mostly still below the minimum completeness criteria which is 62. As evidence of the results on the object classification material in grade VIII D the average value obtained by students is 44.26, and more than 85% of the students have not achieved completeness. The low acquisition of learning outcomes is caused by the lack of motivation of students to learn. It can be seen from the low active participation of students in the learning process. So far, the science learning process still uses the old paradigm where the lecturer provides knowledge to passive students. Lecturers teach with conventional methods, namely the lecture method and expect students to sit, be quiet, listen, take notes and memorize (3DCH) so that Teaching and Learning Activities become monotonous and less attractive to students. Such conditions will not improve the ability of students to understand science subjects. As a result, the learning outcomes achieved by students are not as expected. This assessment model causes students to tend to study only at the time of the test and are not motivated to study science thoroughly, deeply, and sustainably (Sinurat et al., 2015).

The basic needs of the science lecture to impart meaningful science teaching to his/her students, are – ideal laboratory (well-equipped according to syllabus), lecturer student ratio, class room infrastructure and power supply. At the same time, the lecturers must be properly trained so that they are able to handle the infrastructure & provide quality education to the students. For this continuous training & periodic refresher courses can be organized (Lee, 2012).

There is an urgent need to look into the quality of text books. The ray diagrams, pictures should be colored so that it can attract the students. Therefore, in order to make teaching optics effective & yet interesting, several techniques may have to be adopted, which has been discussed earlier. The teaching mode plays a very important part in bringing up the abilities of students in engineering, cooperation, digesting the knowledge at a high level and problem analyzing and solving. We bring into the field optical devices and components that the students have seen or used them before but they do not realize the principles behind. For example, an optical fingerprint scanner is used for their exploration of law of refraction and total internal reflection phenomenon. A multicoated eyeglass is used to guide them to the optical interference. The use of a CD or a DVD helps us to easily demonstrate the diffraction of white light and to investigate the spectrum of laser and other light sources (Cen et al., 2007) (Dedi Irawan, Saktioto, Ali, Fadhali, et al., 2012)(D. Irawan et al., 2011)(Saktioto et al., 2015).

In the field of research on science education, few published papers are available, concerning this connection between models. Several studies have shown that when using the light ray model in teaching, in analyzing shadows or image formation, many difficulties are likely to crop up. Wave optics are not dealt with in these papers. Some authors stress the lack of connection between geometrical and wave optics but do not develop this point of view any further (Azhar et al., 2022).

Others aim at building coherent bridges between these two fields of optics. Proposals for interpreting situations of geometrical optics (reflection and refraction at an interface) using the Huygens principle and observing these phenomena on a ripple tank are often made. This linkage between ray path and wavefront propagation is also used for image formation with a lens stressing the idea that within the framework of geometrical optics, a lens bends rays according to Descartes laws whereas in the framework of wave optics, it can be seen as a phase adjuster.

At the end of university courses, seeing image formation as a process of diffraction in the framework of Fourier optics is sometimes proposed. In this research-study, we focused on an intermediary level of analysis which did not include Fourier optics. Concerning what students understand about diffraction, Maurines seems to denounce some of their responses which, as the analysis we present below shows, we find acceptable. Such variants show the complexity of this field, and the lack of consensus on the way simple models, such as ray model of geometrical optics and diffracted waves, can be integrated in a coherent frame (Zulkifli et al., 2022) (Inriani et al., 2021).

Other papers stress the deficiencies of students' understanding in the case of diffracting apertures, but do not particularly comment on the cases where a diffracting object and a lens are employed simultaneously. As a contrast, we chose to analyze situations where diffraction and interference are observed in the presence of lenses, and we pay special attention to the meaning that the students ascribe to the « rays » traced on their diagrams (D. Irawan et al., 2015; Dedi Irawan, Saktioto, Ali, Erwin, et al., 2012; Dedi Irawan, Saktioto, Ali, Fadhali, et al., 2012; Dedi Irawan, Saktioto, et al., 2015; Dedi Irawan, Yendra, et al., 2015; Dedi Irawan & Saktioto, 2019). In order to analyze students' difficulties in this complex case, we took into account the highly academic character of this topic, and we chose to work on very classic and relatively simple situations that are currently proposed in traditional teaching situations. In our investigation, conducted at 3rd year university level, the students are faced with the same elements in each situation: an illuminated object, a lens and a screen on which a pattern is observed Figure 1.

At this level, students can use and need two models in order to understand all the variants of the prototypical situation: the ray model of geometrical optics and the wave model (a simple scalar theory is sufficient). These two models suffice to interpret what can be seen on a screen located somewhere beyond the lens. In some cases, the model of geometrical optics is sufficient. In other cases, the two models must be used together (Dedi Irawan et al., 2020; Dedi Irawan, Saktioto, Ali, Fadhali, et al., 2012; Dedi Irawan, Saktioto, et al., 2015; Dedi Irawan & Saktioto, 2019), (Syahfira et al., 2021).

## Method

This research was conducted in class third-year physics education students, University of Riau in the even semester 2020/2021 for the reason that during the learning process various problems caused learning activities in the class: having low learning outcomes, low interest in science learning, and still not optimal in absorbing science learning, so it has an impact on the low value of students' science learning outcomes. The material chosen is a Total Internal Reflection (TIR) on Single Mode Fiber (SMFs) with basic competence chosen is the students can explain the principle of light propagating inside the circular SMF shapes. The students are also expected able to present the results of investigations or problem solving about the Total Internal Reflection with indicators are (1) Observing the workings principle of light propagation in SMFs; (2) The numbers of mode allowed propagation inside (3) experimenting the light propagation and total TIR in the SMFs; (4) Reporting/presenting the results of an investigation. This research was designed and implemented in two learning cycles. Each cycle consists of four stages, namely action planning, action implementation, observation and reflection. Broadly speaking, this research can be like Figure 1.

The research subjects were all students of class VIII D, totaling 34 students and consisting of 15 males and 19 females at SMP Negeri 2 Gianyar in the odd semester of the 2018/2019 academic year on simple aircraft material. The data collected in this study is data on learning outcomes The evaluation test was carried out at the end of each cycle among STEM-based learning. The quantitative data of student learning outcomes is taken directly by the researcher which is in the form of numbers. To obtain that data, a test technique was used to obtain data on student learning outcomes in the form of a test with an objective form which was carried out at the end of each cycle which was an individual task at the end of each cycle. The data collection instrument can be shown in Table 1.

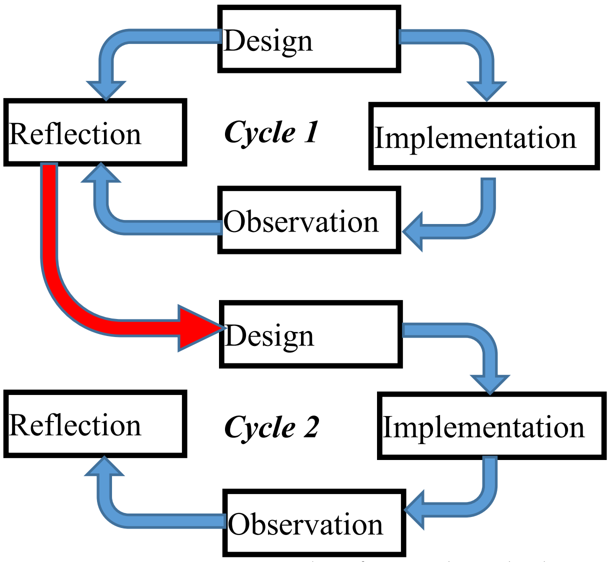


**Figure 1**. Two cycles of research method

The data collection technique used to assess the success rate of students is a test instrument. The test instrument is a tool to obtain data on learning outcomes that have been given to students. As for the test used is a written test in the form of multiple-choice questions as many as 20 items where each correct item gets a value of 1 and the wrong one is given a value of 0. The data collected in this study is data on learning outcomes on Simple Aircraft material using STEM-based learning. The instruments and data collection methods used in this study are presented in Table 1.

**Table 1.** Data Collection Instrument

| Conten | Methods | Data Collection | Test Scedule |
|---|---|---|---|
| Light propagation | Test | Learning outcome | At the end of cycle 1 |
| Total Internal Reflection | Test | Learning outcome | At the end of cycle 2 |

The data analysis technique used in this data processing is descriptive analysis method, namely the way of processing data by using simple formulas in order to obtain general conclusions. The general conclusion in question is a comprehensive conclusion regarding the problems discussed.

## Result and Discussion

The data obtained is related to the implementation of the class action plan which includes data on student learning outcomes. This data is then used to answer the problems formulated in the research entitled Application of STEM-based learning to improve students' science learning outcomes on Simple Optics material in Optical physics subject of Physics education program during period of 2020/2021 academic year. The details of the implementation of each cycle are as follows: 1) Actions in cycle 1 are carried out according to a plan designed with peer lecturers. Cycle I was held for 3 meetings (2 meetings for the process and 1 meeting for the learning outcomes test of cycle I). The material discussed includes KD 3.3, namely Explaining business concepts, simple machines, and their application in everyday life including muscle work on the human skeletal structure and KD 4.3, namely Presenting the results of investigations or problem solving about the benefits of using simple machines in everyday life. 2) The action in cycle II was carried out in 3 meetings (2 meetings for the process and 1 meeting for the learning outcomes test in cycle II). Based on the data generated, it can be stated that the learning outcomes of observation, in the first cycle, and in the second cycle, show an increasing class average value. This can be seen in Table 2.

**Table 2.** Data Collection Instrument

| Interval | Pre-test | Post-test 1 | Post test 2 |
|---|---|---|---|
| 88 – 100 | 0 | 1 | 3 |
| 76 – 87 | 4 | 11 | 15 |
| 62 – 75 | 12 | 7 | 2 |
| < 66 | 4 | 1 | 0 |

Figure 2 and Figure 3 show that more number of students has lower grade of students learning outcomes (pre-test). Their outcomes gradually increase after implemanting STEM. It can be seen clearly that their grade increase at the end of cycle 1 and cycle 2. Data at the time of pretest or before the action shows the average learning outcomes that exist in the low category, namely 48.2 with absorption and completeness respectively 41.2% and 9.18%.

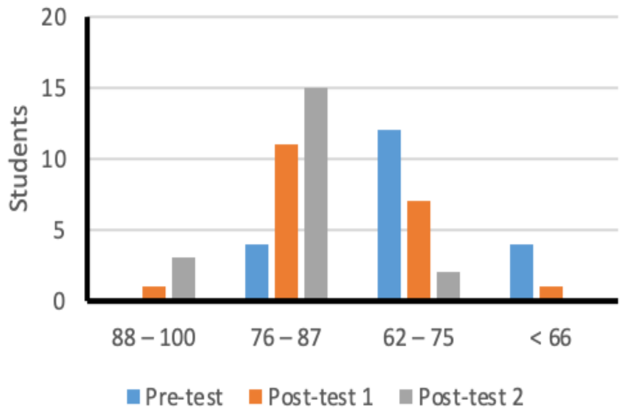


**Figure 2.** Data collection results of obercation, cycle 1 and cycle 2

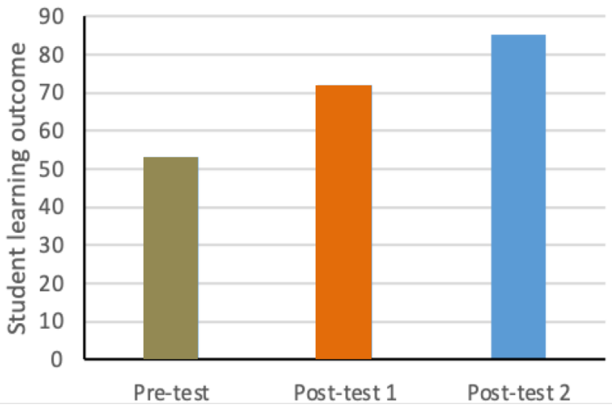


**Figure 3**. Avarage test score of student learning outcomes

In the first cycle the average obtained was 75.44 with a very high category. Pre-test 83.4% are in the very high category on a scale of 4. with completeness student learning reached 72. 7%. The results of the student learning outcomes test which is a test Objectives force students to really understand what they have learned. Average value students in the first cycle which amounted to 72.7 showed that students after mastering most of the material taught although not so perfect. This result shows increasing the ability of students to master science subjects when compared to observation.

The results of the student learning outcomes test in cycle I have shown an effect of using STEM-based learning as indicated by an increase in the average grade score quite significant. As we all know that science subjects focus on learning on cognitive, affective, and psychomotor aspects as behavioral guidelines for daily life learners. To solve the existing difficulties, the application of -based learning STEM can be used as an innovation method to be creative, act actively, exchange ideas express opinions, ask questions, discuss, argue, exchange information, and solve problems with the discussion group. This is what makes students think more critically, more creative and innovative so as to be able to solve problems that complex and the next effect is that students will be able to understand and absorb the eyes science lessons further. The remaining obstacle that needs to be discussed is the learning outcomes that achieved in the first cycle has not fully met the expectations in accordance with the KKM subjects. Therefore, more mature improvement efforts must be made for the next cycle.

Based on the results of the reflection in the first cycle, improvements were made in the second cycle which will Prizes are given to groups that come forward and present the results of their discussions very well and brave. From the beginning, they were still embarrassed because they were afraid of being wrong, in the second cycle the students became more dare, besides the lure of prizes, students have also begun to get used to the treatment of learning STEM-based in its class and will be given a surprise gift if it manages to get the highest score when assessment of learning outcomes takes place. Do not deny that this method is very active in improving acquisition of student learning outcomes. It is proven that the results obtained from the learning outcomes test in cycle II shows that the ability of students to take lessons has increased significantly significant where the average value of students reached 88.52. These results indicate that the application of STEM-based learning that has been updated has succeeded in increasing the ability of students according to expectations. This is due to several factors, namely as follows.

Application of STEM-Based Learning to Improve Science Learning Outcomes learning experiences oriented to the development of critical thinking (Dotson et al., 2020; Teevasuthonsakul et al., 2017). STEM-based learning can build critical thinking skills because it refers to an integrated approach in the educational process that focuses on problem solving in real everyday life as well as in professional life. The application of STEM-based learning is a strategy that is suitable for students if lecturers want them to have 21st century skills considering its important role in creating a civilization of a country which is marked by advances in technology and information where in general there are 4 skills (4C) needed in a country. 21st century as stated in the background above, among others: (1) Critical Thinking and Problem Solving; (2) Creativity and Innovation; (3) Communications; and (4) Collaboration.

The use of STEM-based learning is able to encourage students to think critically and find solutions to a problem in addition to seeking that student not only learn to memorize and imagine but can make it real with creativity, innovation, and collaboration. Second, STEM-based learning has an impact on science knowledge competence because it can improve student learning outcomes. The application of STEM which initially only aimed to increase student interest in the STEM field became wider. This situation arises because after being applied in learning, in fact STEM is able to increase mastery of knowledge, apply knowledge to solve problems, and encourage students to create something new. The application of STEM can be supported by various learning methods. Integrative STEM allows various learning methods to be used to support its application. This learning approach emphasizes more on a student-centered learning system so that it involves student activity in learning. In addition, this approach also trains students' skills so that students find more, understand learning concepts so that students have more experience, construct knowledge so that students' self-development can be explored to improve student learning outcomes (Dotson et al., 2020; Rusydiyah et al., 2021; Tati et al., 2017; Ziaeefard et al., 2017).

The results of this study turned out to provide the main effect for students in the learning process which can be seen from the very significant effect of learning outcomes. This finding proves that the lecturer has chosen the right ingredients for the diseases that exist in students where students want an innovative, effective, meaningful, and fun learning process. The implication of this research is to increase students' critical thinking skills and create a more active learning atmosphere so as to improve student learning outcomes. Regarding the results obtained through actions in the form of implementing STEM-based learning, it is hoped that every lecturer, especially science lecturer, will not stop to innovate and determine the appropriate treatment given to students because basically students have heterogeneous properties where we as lecturers must be able to think creatively and innovatively so that students do not get bored receiving the learning provided. Figure 4 shows the STEM based learning activity in Physics LAB, University of Riau.

**Figure 4**. STEM Based learning activity in Physics LAB

## Conclusion

The ability of students in participating in STEM-based learning increased significantly. It can be concluded that the application of STEM-based learning can increase student interest in learning so that it has an impact on increasing student learning outcomes in science

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