

Creativity in Deriving The Fermi-Dirac Equation Through STEAM Approaches

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Abstract

This research is motivated by statistical physics learning in deriving the Fermi-Dirac equation conceptually from lecturers to students or by rote and low creativity of students. This study aims to explore student learning creativity in deriving the Fermi-Dirac equation through the STEAM approach. This study uses a didactic design that includes the stages of prospective analysis, didactic metapedia analysis, and prospective re-analysis, which is applied to the sixth-semester physics tadaris student of UIN Sulthan Thaha Saifuddin Jambi. The research instrument used is a description test and a non-test through observation sheets and interviews. The results showed that the implementation of STEAM could increase the creativity of statistical physics with an achievement level of 87% asking questions, 78% learning outcomes, 75% reflection, and 75% analysis on the material of the Fermi-Dirac equation by adhering to student activities starting with phenomena that are easy to digest with the realistic situation during online lectures, which shows that the STEAM approach is quite well used in deriving the Fermi-Dirac equation in the online statistical physics course.

Keywords: Creativity; Fermi-Dirac Equation; STEAM Approach

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INTRODUCTION

Physics is the primary discipline that examines and supports technological change directed by teaching staff (Scott & Schumayer, 2017; Sulman, Sutopo, & Kusairi, 2021) and is an essential foundation in the world of life and acts as a catalyst or liaison with other knowledge abilities both in terms of

practice and analytically. Theoretical the study of physics, which is closely related to understanding concepts as the main study that causes many obstacles (Sutopo, 2016; Wells, Henderson, Traxler, Miller, & Stewart, 2020) and mathematics acts as a catalyst in the formulation of the study or formula derivatives that require students to be

able to build a flow and understanding by using good basic mathematical skills so that they can be more prepared and independent before receiving lecture material (Muwonge, Ssenyonga, Kibedi, & Schiefele, 2020; Sulman, Taqwa, Aminah Zb, Rafzan, & Fikri, 2020; Sumirattana, Mekanong, & Thipkong, 2017). The importance of the role of mathematics in physics education courses requires study programs to provide special techniques that are mandatory as an increase in students' basic abilities so that they can help students to think more mathematically and systematically and can bring up high creativity both individually and in groups in analyzing the problem (Hernández-Torrano & Ibrayeva, 2020; Ryckman, 2015).

Students' ability to basic mathematical concepts has not been able to play an optimal role in each individual (Legesse, Luneta, & Ejigu, 2020; Sarsengeldin, Satabaldiyev, Meirambek, & Guvercin, 2013); there are still many who think that mathematical studies are only for mathematics students; this paradigm is not entirely correct. Instead, it leads to errors in thinking (Baki, Çatlıoğlu, Coştu, & Birgin, 2009; Pampaka, Pepin, & Sikko, 2015). Basic abilities such as mathematics can support solving some problems in life, especially in the realm of students' logical thinking ability needs (Baki et al., 2009; Weaver, Chastain, DeCaro, & DeCaro, 2018). The basic ability of students in mathematics is classified as low (Legesse et al., 2020; Sarsengeldin et al., 2013; Sulman et al., 2020). This can result in students not being able to deeply analyze some of the equations in statistical physics that require a good understanding of mathematics. Problems that occur in the derivation of statistical physics equations, such as the Fermi-Dirac equation where the problems arise can be broken down into several factors,

namely conceptual factors and supporting concepts such as mathematical ability and literature (Baki et al., 2009; Sulman, 2019). Factors that hinder students' understanding can occur due to the separation between mathematics and physics. The mathematical material obtained is more likely to be considered information or prior knowledge that is not too important in deriving the Fermi-Dirac formula, which causes difficulties in constructing deeper Fermi-Dirac equations. Accurately one of them is proving the mathematical equation.

In providing solutions to several statistical physics problems in solving Fermi-Dirac equations, lecturers have a vital and strategic role in students' skills in solving fermi-dirac equations, which can be overcome by using an approach and assisted by appropriate learning media (Sulman, 2019; Zb, Novalian, Rozal, Sulman, & Habibi, 2021; Zb, Setiawan, Rozal, & Sulman, 2021). In deciding the use of learning media, one must be careful (Lehavi & Eylon, 2018; Rozal, Ananda, Zb, Fauziddin, & Sulman, 2021; Sulman, Tanti, Habibi, & Zb, 2021) which is not only based on the material of the Fermi-Dirac equation but also given based on the criteria or characteristics of students so that it can eliminate students' feelings that the Fermi-Dirac equation is a formulation that it is complicated to (Sergis, Sampson, & Pelliccione, 2018; Zb, Setiawan, & Sulman, 2020) in deriving the Fermi-Dirac equation. It can improve students' creative learning ability in deciphering the fermi-dirac mathematical equation. Creativity is the wisest solution for students to describe fermi-dirac, where creativity can encourage students' enthusiasm and motivation in solving these equations.

As for the solutions to phenomena that occur in statistical physics courses, especially in the mathematical derivation of the Fermi-Dirac equation

with the Science, Technology, Engineering, Arts, and Mathematics (STEAM) approach, in the STEAM approach, students can think critically and logically (Audunson & Shuva, 2016; Mullet, Kettler, & Sabatini, 2018) in describing mathematical formulas in the Fermi-Dirac equation. The STEM approach added with Art in the form of animated media in lectures will start from a realistic situation where the description of the Fermi-Dirac equation will begin with a real condition that can be described and can be described online so that it is more real and realistic (Honey, Pearson, & Schweingruber, 2014; Margot & Kettler, 2019; Zb et al., 2020). There are several STEAM studies that the researchers found only discussed creativity in general, and the researchers have yet to find using a qualitative approach with didactic procedures so that they can report the impact of the STEAM approach on creativity in detail and more comprehensively. Researchers aim to apply STEAM to student creativity in deriving the Fermi-Dirac equation in statistical physics courses.

METHOD

This study utilizes a qualitative approach with Didactical procedures. With the first stage is the prospective analysis stage, where the form of the analysis procedure is based on the Didactic and Pedagogic Situation (DPS) before the lecture, the synthesis of lecturers' thoughts as outcomes based on various possibilities that are predicted to take place in the learning activities; the second stage of metapedadidactic analysis, namely the analysis process was throughout the learning stages which include a component of unity, flexibility, and coherence; and universal; and the third stage of future re-analysis, namely the process of analyzing the results of the DPS analysis that has been carried out compared to the effects of

metapedadidactic research. The didactic design was conducted on 46 UIN Sulthan Thaha Saifuddin Jambi students in Semester VI of the 2020/2021 academic year.

The process at the interview stage is carried out by the lecturer using an interview sheet to obtain facts or data sources about barriers to the learning process before treatment is given. The implementation of observation activities is tried to get information about what points are suitable while implementing the didactic design. Essay checking is used as a measuring tool to identify student descriptions and creativity regarding the derivation of the Fermi-Dirac equation. The instrument's validity was based on expert analysis of the material provided. The flow of the lecture activity process consists of 3 phases can be seen in Figure 1.

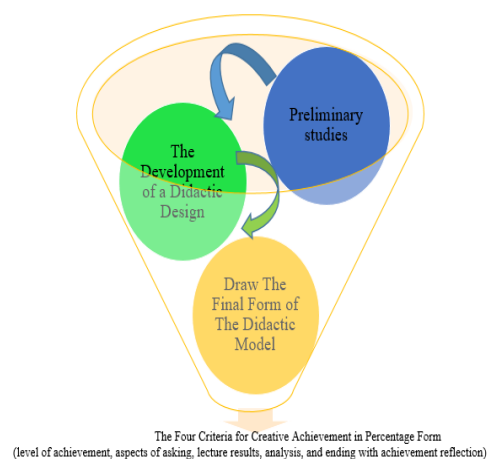


Figure 1 The flow of the lecture activity process consists of 3 phases (Cropley & Patston, 2019 modified by researcher)

The flow of the lecture activity process consists of 3 phases as shown in Figure 1, which can be explained as follows: (1) Preliminary studies in the form of analysis of diagnostic test barriers, identifying and analyzing lecture barriers, which then determine the STEAM approach with a didactical design model that will be used as a

lecture obstacle analysis tool; (2) The development of a didactic design is carried out in three forms: (a) a prospective analysis by making a didactic design which includes a prediction of student responses to be applied and looking for anticipators; (b) Metapedadidactic analysis, namely by implementing a design and learning process that includes components of unity, flexibility, and a prospective analysis process again by looking at the accessibility of the design didactically with the assumption that all students who have received the implementation of the process as a reference for the

revision of the didactical design. (3) draw the final form of the didactic model as the conclusion stage of the measurement phenomenon carried out, and this is the third stage of the Didactic design model. The results of the study will describe four criteria for creative achievement in the form of percentages in the Fermi-Dirac equation, namely the level of achievement of the questioning aspect, lecture results, analysis, and ending with the accomplishment of reflection (Cropley & Patston, 2019), so the researcher draws an understanding and modifies it into a table form as shown in Table 1.

Table 1 Achievement of Material Creativity Fermi-Dirac Equation

Indicator Criteria for Creative	Achievement Rate (%)
Understand the concept of permutations, integrals, and differentials	
Convert Equations with Stirling's approximation	
Formulate the maximum configuration	
Implementing the Fermi-Dirac equation	

Modified from Cropley & Patson (2019)

The categorization used as a reference in this research in the form of percentages uses the principle that the research has developed, namely dividing it into proportional parts from those referred to from several studies (Putra, Junaid, & Sulman, 2021; Sulman et al., 2020), which researchers have modified as shown in Table 2.

Table 2 Description of Categories in Percentage Earnings

Category	Achievement Rate (%)
Very good	81 - $\leq$ 100
Good	61 - $\leq$ 80
Pretty good	41 - $\leq$ 60
Not good	21 - $\leq$ 40
Very Not Good	0 - $\leq$ 20

RESULT AND DISCUSSION

Diagnostic Test and Student Activity Achievement

The results of the study began with several stages, namely through

interviews with statistical physics lecturers at UIN STS Jambi, obtained facts where important information was obtained where students had very basic obstacles in decreasing statistical formulations on the Fermi-Dirac concept, namely on students' basic mathematical abilities. Then the following process is carried out, namely observing the lecture aids by the lecturer when deriving the Fermi Dirac equation. As for the learning process used, among others: Journals and Books. At the analysis stage of the learning process of deriving mathematical equations from the Fermi-Dirac equation.

The data obtained from observations in terms of semester lecture plans are: (1) The treatment process carried out tends to be monotonous, which is more conventional, namely directly lowering the formula because students should have had good initial abilities because they were in the final semester of

lectures, namely semester VI, questions and answers, and exercises (expository model) (2) Exploration, Elaboration and Confirmation carried out during the lecture process with learning steps do not describe active learning; (3) There are no learning media other than textbooks, and Animations containing Basic mathematical formulas; (4) the statistical physics material provided is only information delivery, and memorization is not oriented to the reality that is known by students and (5) The derivation of the Fermi-Dirac equation tends to be carried out

regardless of students' initial mathematical understanding.

The research process was then continued by giving students a Fermi-Dirac formula derivation test to see what happened, which became a significant obstacle in the lecture process faced by students in statistical physics lectures in performing mathematical derivation to get the Fermi-Dirac equation. The diagnostic test results show that students have learning difficulties in conceptualizing the material of the Fermi-Dirac equation shown in Table 3.

Table 3 Percentage of Material Achievement of the Fermi-Dirac Equation

Indicator Criteria for Creative	Achievement Rate (%)
Understand the concept of permutations, integrals, and differentials	63
Convert Equations with Stirling's approximation	20
Formulate the maximum configuration	10
Implementing the Fermi-Dirac equation	5

The data that can be concluded from Table 3 is regarding the percentage of achievement of the Fermi-Dirac equation material wherein indicator 1 achievement 63% is categorized as good, indicator 2 is 20% very poor, and 3 achievement is only 10% very poor and indicator 4 achievement 5 % with very poor category. The results of the diagnostic tests that have been carried

out prove that most of the students are still unable to present the concept of the Fermi Dirac equation and do not understand how to formulate well enough in terms of basic mathematical abilities (Sulman et al., 2020). The results of the creativity of statistical physics learning in the derivation of the Fermi-Dirac equation can be seen in Table 4.

Table 4 Results of the Achievement of The Fermi-Dirac Equation Creativity

Indicator Criteria for Creative	Achievement Rate (%)
Understand the concept of permutations, integrals, and differentials	35
Convert Equations with Stirling's approximation	53
Formulate the maximum configuration	54
Implementing the Fermi-Dirac equation	35

Based on the facts listed in Table 4. regarding the percentage of achievement of creativity in the material of the Fermi-Dirac equation wherein indicator 1 achievement 35% is in the poor category, indicator 2 is 53% in the relatively good category, and indicator 3 the achievement is 54% in the good enough category 4 with an achievement

of 35% in the poor category. The observations show that most of the students are still not optimal in showing creativity in learning the derivation of the Fermi-Dirac equation, including asking questions, results, reflection, and implementation. Analysis of the results of the diagnostic tests that have been carried out and observations from the

point of view of creativity in statistical physics learning in the Fermi-Dirac equation material, it can be stated that the didactic design to be designed is a didactic with a special STEAM approach in deriving the Fermi-Dirac equation. The STEAM approach to statistical physics learning is transformed into a form of learning that is more real and realistic online coupled with Art in the form of animated media that can increase student interest and motivation to learn (Honey et al., 2014; Meiliani, Tanti, & Sulman, 2021; Robinson, 2020; Weinberg & Sample McMeeking, 2017) one of them is the process of compiling the maximum configuration which is given in a more realistic form in the study of statistical physics in the material of the Fermi-Dirac equation which is specialized in the derivation of mathematical formulations.

Didactic Design Plan for Prospective Analysis

This research design was carried out in the planning process through three phases: prospective analysis, metapeda didactic analysis, and prospective re-examination. The third process is carried out with consideration and accuracy from several perspectives and points of view, thereby reducing the impact of bias that can arise, which are not present and should not interfere with the research process (Creswell, John W; Poth, 2017; Groenewald, 2004).

The process that occurs is the prospective analysis process. At this process or stage, the use of the STEAM approach in the online lecture process can create an effective lecture scenario where real (real) media users, with the help of the animation media they have can be understood more easily by students than concept without the help of animation media (Kuzmickaja, Wang, Graziotin, Doder, & Abrahamsson, 2015; Putra et al., 2021; Weinberg &

Sample McMeeking, 2017). In creating effective statistical physics lectures, students are equipped with lecture guides in lecture contracts or online instructions before the study. The WhatsApp Group also assists them in providing instructions during the online lecture process (Zb et al., 2020). The learning approach that was decided to use was STEAM with several methods that are felt to increase student activity amid the Covid-19 pandemic, namely questions and answers, discussions, and assignments so that the limitations of online lectures can be minimized so that the implementation process can run smoothly good.

Overall, in the lecture process, students are guided to understand the concept of permutations in advance. This is so that students can easily and actively begin to formulate the Fermi-Dirac equation. During the discussion process, the formation of the right combination of permutations, the lecturer observes and takes notes during the discussion process, and at the same time, the lecturer conducts the assessment process. The statistical physics material studied in the sixth semester is only focused on the conceptual derivation of the Fermi-Dirac formula. In achieving the indicators reflected in the Semester Lecture Plan (RPS), it is designed to be a description of the acquisition activities, which include activities of lecturers in teaching, students, and predictions of student responses accompanied by anticipation of their didacticism. Lecture process activities are allocated for two meetings. At the first meeting, students are directed to: Understand the concept of permutations and factorials and understand the Stirling equation so that it can eliminate factorials. Then the media used for the first meeting were chairs and people sitting in chairs, shown online with animated media. Meanwhile, at the second meeting,

students were directed to achieve indicators: formulating the maximum configuration of the equations that could be formed and then ending with implementing the final Fermi-Dirac mathematical equation. Video animation media added to STEAM makes the lecture process more interesting. The design of the first and second meetings has three phases of core activities, namely: exploration, elaboration, and confirmation. The lecture process in three stages from each meeting will be described as follows:

First Meeting Lecture

a. Exploration

At this stage, the lecturer gives several questions that can see or explore students' initial abilities regarding the Fermi Dirac equation to share, for example: "Do you know about fermion particles? Can you describe the state and system in the Fermi Dirac equation? What is the maximum configuration that can be obtained? Can you see the animation media for the arrangement of the Fermi-Dirac maximum configuration. The process at this stage, students with the guidance of the lecturer will be able to identify which one is called a system and which one is called an assembly and also the environment; students then use their initial mathematical abilities regarding the factorial system to make initial understanding of how fermion particles can be arranged this is done face-to-face online which is used to increase students' creativity, motivation and interest in learning (Hernández-Torrano & Ibrayeva, 2020; Shute & Rahimi, 2021; Sulman, 2019)

b. Elaboration

At this stage, the lecturer carries out a process of activities: (1) Doing questions, who are interested in the picture of the arrangement of people and chairs? Then, inform the students that

we will begin to analyze which is the system, assembly, and environment; (2) asking students to try to analyze the structure in a simple way using the factorial technique; (3). Ask students to make the maximum composing configuration of the images or animations presented; (4). Students are asked to analyze using simple mathematics, one of which is the Stirling approach and integral and differential equations; (5) Students discuss and conduct discussions on the understanding and animations that have been given (6) Ask students to analyze groups (Lecturers will be the catalyst and motivator, as well as monitor, assess and provide guidance if necessary); and (7) Asking students to present the results that have been discussed (a lecturer who will direct if needed or a fatal error occurs). Meanwhile, students carry out activities to answer the lecturer's questions. In the next process, students then read and understand the maximum configuration that has been completed, which is then followed by a discussion to answer the final mathematical equation of the Fermi Dirac equation and ends with the activity of presenting the results of the discussion by their respective groups which will later be carried out with the help of an online conclusion drawing process. WAG group to combine the thoughts that emerged during the online discussion.

c. Confirmation

At this stage, the Lecturer in charge of the Statistical Physics course will carry out a confrontational process of answers in the form of commenting on the results of student discussions (both in the form of justifying answers, adding answers and also additional questions in seeing the quality of student abilities directly) and directing students to make conclusions; this is used as an effort made by lecturers to be able to view the data comprehensively or perfectly so

that they can present the findings to the maximum (Fidan & Tuncel, 2019; Sulman, Tanti, et al., 2021; Sulman et al., 2020).

Second Meeting Lecture

a. Exploration

At the exploration level, the lecturer asks a question that can explore students' real abilities in online learning; for example, how is the system exchange and assembly of fermion particles shown in the animation all systems occupied by a situation or vice versa? Then the lecturer continues the question of whether we can find the maximum form of the equation? It is possible that we can formulate the maximum configuration form. Then the question continues with whether, according to students, all particle movements in the system can constantly run so that a generalization can be made to make a statement or conclusion. In this lecture process, students are expected to be able to take an understanding of the process of moving boson particles and be able to take answers in a simple form and apply them in everyday life, which is then continued to answer these questions, let's look at the animation that has been prepared which will later be used as a reference by students together.

b. Elaboration

At this stage, Lecturer: In this process, students are asked to increase their understanding by reading and analyzing several references and other sources that are considered relevant in increasing their understanding of the Fermi-Dirac equation. This implementation process is carried out in groups so that it can ask for opinions from all individuals who most likely have different understandings. In the discussion process, will form a complete understanding of how to configure the maximum arrangement of the Fermi-Dirac equation; then, students are asked to convey the results of their discussions

through each group deciding who will present online, and the other group listening and analyzing the answers of the group that is currently presenting (the lecturer will analyze the answers given which will then carry out the assessment process, and also bias add or straighten the material presented which is considered completely irrelevant or deviant After the discussion and presentation process is carried out Students are given questions about the Fermi-Dirac equation, then students carry out a discussion process in answering these questions which then try to present the answers and other groups listen and draw conclusions from the answers given with the help of the lecturer.

c. Confirmation

At this confirmation stage, the lecturer conducts a discussion process as well as comments on the answers that have been given to students specifically, wherein, seeing the maximum configuration, one must use a mathematical approach, namely the Stirling approach, which aims to eliminate the value of factorial in other words to simplify the existing equations, which then proceed with directing students to perform differential techniques on each component of the equation that has been formed so that conclusions are obtained about the mathematical formulation of the Fermi-Dirac equation.

Metapedadidactic Analysis

The first indicator for didactical design: is the ability to understand simple mathematical symbols such as permutations or combinations, factorials, Stirling approaches, integrals, and differentials and form a formulation by carrying out the integration process. In the lecture process, several activities that cannot be fully controlled and are independent of the researcher's control include: (1) although in the lecture

process, students are enthusiastic about recalling both basic mathematical concepts such as permutations to analyze systems and assemblies, in the processing time is given to remember it is too long for most students and only a small number of students can remember basic material quickly and accurately, (2) The provision of animated media that is too pictorial causes students to sometimes lose focus on the material given (Putra et al., 2021; Sulman, Tanti, et al., 2021) (3) Reference sources for books are too small so that students focus on the references given by the lecturer, (4) when students show the results of their analysis with presentations, students are very difficult to ask to present, and must be appointed to come forward first, which may be caused by the habit of many unusual students to present their conclusions. (5) During the online learning presentation, signal loss often occurs. The different living conditions of students and the various technologies used make it difficult for problems or analysis of understanding lecture concepts during online lectures to run optimally.

Based on the analysis of several phenomena that researchers found during the lecture process in deriving the Fermi-Dirac equation, a conclusion was drawn to revise the didactical process at the second meeting, namely: (1) students are required to re-learn basic mathematics by testing relevant questions, (2) reducing images that are not relevant to the material of the Fermi-Dirac equation that deviate too far from the material being studied, (3) requiring students to find additional relevant sources or literature and lecturers checking the literature that has been taken, (4) giving grades to students who want to present the results of the analysis as an additional value, (5) asking students to find a better place for the signal during the lecture.

Second Meeting Lecture

The improvements made by researchers on the didactic design at the first meeting, where the facts found during the lecture at the second meeting resulted in quite good chances in the lecture process. The process of student responses to the obstacles that occur during the lecture process at the first meeting can be taken by the lecturer by providing anticipation that has been well planned.

Meanwhile, students' responses during the lecture process that was unexpected, either intentionally or unintentionally, can be anticipated by giving a didactic response according to the existing situation and conditions, with considerations that are adaptively able to reduce or eliminate all these obstacles.

Retrospective Analysis

Retrospective analysis is carried out by observing the processes that occur during the study based on the analysis of the facts obtained, wherein the didactic design that has been given, there are still differences between theory and practice; this is presumably because new students are experiencing the online lecture. The perspective of the condition of the lectures is much better with the previous statistical physics lectures at the beginning of the lecture being conducted online [5]. In the lecture process, students have been compelled to always think systematically, starting from a phenomenon that is continued into an equation.

Students during the lecture process are actively involved during group discussions. They have an inner urge to be able to search for various relevant literature both in their initial mathematical abilities and with the study of the main material, namely the Fermi-Dirac equation. The implementation of the second didactic shows the fact that there is significant

progress compared to the meeting in the first lecture. Students feel the more innovative lecture process, this is because lectures in formulating the Fermi Dirac equation do not start from a formulation but start from a phenomenon in life, and a modelling process is carried out for the system, assembly, and state of a maximum configuration of fermion particles so that students are more comfortable, not too tense and arouse interest and motivation to solve this Fermi-Dirac equation.

When asked to work on the Stirling approach process in simplifying student equations and then proceed to derive all equations using the differential

technique, students focus on the lecture process that is carried out. In addition, in presenting the equations of the discussion results, students were very enthusiastic because they were given additional value for those who presented. However, it can be seen that there were students' misconceptions in presenting the answers they analyzed. From the lecture process carried out when deriving statistical physics equations, we can observe the obstacles and mistakes made by students in reducing these equations. The percentage of student errors after the application of the didactic design can be seen in Table 5.

Table 5 Percentage of Achievement of Derivation of the Fermi-Dirac Equation

Indicator Criteria for Creative	Achievement Rate (%)
Asking about the concept of permutations, the Stirling approach, differential	87
Lecture Results of the Fermi-Dirac Equation with the STEAM Approach	73
Lecture Reflection on the Fermi-Dirac Equation with the STEAM Approach	73
Implementing the Fermi-Dirac Equation Lecture starting with the phenomenon	70

Based on table 5, where the percentage of student achievement in the Fermi-Dirac equation material on indicator 1, 87% is categorized as very good, indicators 2 and 3 are in a good category, 73% achievement is in a good category, and the fourth 4 is 70% good achievement. The results of this diagnostic test provide the fact that some students are quite good at deriving the

Fermi Dirac equation from a phenomenon can implement quite well where all measuring indicators show an average in the good category. The creativity of statistical physics lectures on the Fermi equation formulated using STEAM approach can be seen in Table 6.

Table 6 Percentage of Achievement of the Fermi-Dirac Equation Creativity Level

Indicator Criteria for Creative	Achievement Rate (%)
Asking about the concept of permutations, the Stirling approach, differential	87
Lecture Results of the Fermi-Dirac Equation with the STEAM Approach	78
Lecture Reflection on the Fermi-Dirac Equation with the STEAM Approach	75
Implementing the Fermi-Dirac Equation Lecture starting with the phenomenon	75

Based on Table 6 above, where the percentage of achievement of creativity in the Fermi-Dirac equation material on indicator 1 is 87% in the very good category, indicator 2 is 78% in the good category, Indicators 3 and 4 are 75% in the good category. Observations show that most students can show creativity in the Fermi-Dirac equation with indicators including asking questions, results, reflection, and implementation through the STEAM approach. Thus, the STEAM approach can help reduce students' statistical physics learning barriers in deriving the Fermi-Dirac mathematical equation. STEAM has helped optimize the philosophy that views physics and mathematics assisted by art or animation media as art in the online lecture process as a unit of human activity. Several connections are made between education, mathematics, physics, and everyday experience. Physics is seen as a science that cannot be separated from Mathematics, where both are seen as a unit in analyzing a natural phenomenon. The STEAM approach can be said to realize the lecture process as an orderly system based on achievement and the process that occurs during lectures. The STEAM process that builds concepts from real situations helps students build an equation by combining previous knowledge so that they get a strong and quality understanding.

The process of Lectures on statistical physics using the STEAM Approach leads students to continue studying physics from the perspective of deriving formulas by starting from more concrete and easy-to-understand phenomena and applying high abilities or self-confidence. The STEAM approach is different from the traditional instructional design model, which focuses on the student's habitual processes during online lectures. A conducive environment in online courses plays an essential role in the

smooth running of student lectures. The natural habitat for students in current learning that is appropriate and effective is the STEAM approach.

Based on the results of the development of the first and second didactic designs, during the lecture process on the Fermi-Dirac equation material, it can be concluded that the STEAM approach is quite well used as a learning approach in statistical physics lectures, especially the Fermi-Dirac equation material in the middle of a pandemic or online. The steps that are considered necessary to be a concern for lecturers in lectures are as follows: (1) analyzing the suitability of the concept and application of statistical physics material with the STEAM approach with the semester lecture plan (2) Making improvements to the process of students' initial mathematical abilities so that there is no need repeating basic lessons for too long; (3) preparing appropriate and effective teaching materials during the online lecture process (4) has formed groups of students with heterogeneous nature (5) Using the Art stage in STEM, namely Asking students to analyze animated videos given in lectures to be able to bring up requests and motivation (6) Asking students to do the Stirling approach in simplifying the equations that have been made (6) Asking students to analyze, identify and record conclusions followed by the delivery of results; (7) ask students to be able to present the fermi-dirac equation that they have written; (8) carry out the process of confirming the correct concept and correcting the wrong concept; (9) provide real-life problem solving exercises online to sharpen understanding and application; (10) Asking students to find a location that is really good in terms of comfort, both environment and internet signal.

This study's results align with research results (Mullet et al., 2018; Robinson, 2020) which state that

STEAM has the power to increase learning activity so that the didactic design proves student learning and teaching principles that have good criteria. In line with that, (Shute & Rahimi, 2021; Yazan & De Vasconcelos, 2016; Zb et al., 2020) provide suggestions about the need for special planning and enjoyable learning both amid the covid-19 pandemic and normal conditions (Sulman, Yuliati, Kusairi, & Hidayat, 2022), such as including the Art component in STEAM so that the lecture process becomes more enjoyable (Zb, Novalian, Ananda, Habibi, & Sulman, 2021). And quality. Limitations of this study are that it must be supported by signal quality facilities and infrastructure that, on average, experience problems and appropriate supporting applications in conducting online lectures. The STEAM approach combines a complete scientific study process with the help of technology in the online lecture process.

The proven STEAM approach in increasing creativity in statistical physics courses, especially the reduction of the concept of the Fermi-Dirac equation carried out during online lectures, has proven to be a solution in the world of education, especially physics learning which can reduce learning barriers experienced by students, especially lectures in various conditions. The research obtained is expected to be applied in other physics courses, which have been proven to increase student enthusiasm and creativity and are also very practical and fun.

CONCLUSION

The STEAM approach has proven to be quite good in increasing the creativity of statistical physics lectures on the concept of the Fermi-Dirac equation material online, proven to reduce the learning barriers experienced by students. Learning statistical physics through the STEAM approach can bring

up learning creativity with an achievement level of 87% asking questions in the very good category, 78% learning outcomes in the good category, 75% reflection in the good category, and 75% analysis in the good category on the Fermi-Dirac equation material because learning is based on real meaning in the online lecture process, learning interactions want more exciting and multi-faceted direction between students and lecturers, students and learning resources and no longer focus on lecturers. Students and lecturers can use recommendations from this research to apply in a practical and fun statistical physics course on the concept of the Fermi-Dirac equation using the STEAM approach.

REFERENCES

- Audunson, R. A., & Shuva, N. Z. (2016). Digital library education in europe: A survey. *SAGE Open*, 6(1). <https://doi.org/10.1177/2158244015622538>
- Baki, A., Çatlioğlu, H., Coştu, S., & Birgin, O. (2009). Conceptions of high school students about mathematical connections to the real-life. *Procedia-Social and Behavioral Sciences*, 1(1), 1402–1407. <https://doi.org/10.1016/j.sbspro.2009.01.247>
- Creswell, John W ; Poth, C. N. (2017). A book review: Qualitative inquiry & research design: Choosing among five approaches. In *Russian Journal of Sociology* (Vol. 3). <https://doi.org/10.13187/rjs.2017.1.30>
- Cropley, D. H., & Patston, T. J. (2019). *Pre-publication version: Cropley, D. H. and Patston, T. (2019). Supporting Creative teaching and learning in the classroom: Myths, models, and measures, In C. Mullen (Ed.), Creativity Under Duress in Education? Resistive Theories, Practices, and Actions* ., 15, 267–

- 288.
- Fidan, M., & Tuncel, M. (2019). Integrating augmented reality into problem based learning: The effects on learning achievement and attitude in physics education. In *Computers and Education* (Vol. 142). Elsevier Ltd. <https://doi.org/10.1016/j.compedu.2019.103635>
- Groenewald, T. (2004). A Phenomenological research design illustrated. *International Journal of Qualitative Methods*, 3(1), 42–55. <https://doi.org/10.1177/160940690400300104>
- Hernández-Torrano, D., & Ibrayeva, L. (2020). Creativity and education: A bibliometric mapping of the research literature (1975–2019). *Thinking Skills and Creativity*, 35(September 2019), 100625. <https://doi.org/10.1016/j.tsc.2019.100625>
- Honey, M., Pearson, G., & Schweingruber, H. (2014). STEM Integration in K-12 Education. In *STEM Integration in K-12 Education*. <https://doi.org/10.17226/18612>
- Kuzmickaja, I., Wang, X., Graziotin, D., Doderio, G., & Abrahamsson, P. (2015). In need of creative mobile service ideas? Forget adults and ask young children. *SAGE Open*, 5(3). <https://doi.org/10.1177/2158244015601719>
- Legesse, M., Luneta, K., & Ejigu, T. (2020). Analyzing the effects of mathematical discourse-based instruction on eleventh-grade students' procedural and conceptual understanding of probability and statistics. *Studies in Educational Evaluation*, 67, 100918. <https://doi.org/10.1016/j.stueduc.2020.100918>
- Lehavi, Y., & Eylon, B.-S. (2018). Integrating science education research and history and philosophy of science in developing an energy curriculum. In *History, philosophy and science teaching* (pp. 235-260). Springer, Cham. https://doi.org/10.1007/978-3-319-62616-1_9
- Margot, K. C., & Kettler, T. (2019). Teachers' perception of STEM integration and education: a systematic literature review. *International Journal of STEM Education*, 6(1). <https://doi.org/10.1186/s40594-018-0151-2>
- Meiliani, M., Tanti, T., & Sulman, F. (2021). Student resources on newton's law concepts reviewing from gender: Identification using open-ended question. *Indonesia Journal of Science and Mathematics Education*, 04(November), 324–332. <https://doi.org/10.24042/ijsme.v4i3.10177>
- Mullet, D. R., Kettler, T., & Sabatini, A. M. (2018). Gifted students' conceptions of their high school stem education. *Journal for the Education of the Gifted*, 41(1), 60–92. <https://doi.org/10.1177/0162353217745156>
- Muwonge, C. M., Ssenyonga, J., Kibedi, H., & Schiefele, U. (2020). Use of self-regulated learning strategies Among Teacher Education students: A latent profile analysis. *Social Sciences & Humanities Open*, 2(1), 100037. <https://doi.org/10.1016/j.ssaho.2020.100037>
- Putra, M. I. J., Junaid, M., & Sulman, F. (2021). The ability of the question and answer (q&a) method with the help of learning videos against student learning outcomes amid the covid-19 pandemic. *EDUKATIF: Jurnal Ilmu Pendidikan*, 3(5), 2160–2169. <https://doi.org/https://doi.org/10.31004/edukatif.v3i5.768>
- Robinson, L. (2020). The STEM selfing

- process: Nondigital and digital determinants of aspirational stem futures. *American Behavioral Scientist*, 64(7), 950–972. <https://doi.org/10.1177/0002764220919150>
- Rozal, E., Ananda, R., Zb, A., Fauziddin, M., & Sulman, F. (2021). The effect of project-based learning through youtube presentations on english learning outcomes in physics. *AL-ISHLAH: Jurnal Pendidikan*, 13(3), 1924–1933. <https://doi.org/10.35445/alishlah.v13i3.1241>
- Ryckman, T. (2015). Why history matters to philosophy of physics. *Studies in History and Philosophy of Science Part A*, 50(1), 4–12. <https://doi.org/10.1016/j.shpsa.2014.09.010>
- Sarsengeldin, M., Satabaldiyev, A., Meirambek, Z., & Guvercin, S. (2013). Interdisciplinary connections and their influence on mathematical education of students. *Procedia - Social and Behavioral Sciences*, 89, 866–871. <https://doi.org/10.1016/j.sbspro.2013.08.946>
- Scott, T. F., & Schumayer, D. (2017). Conceptual coherence of non-Newtonian worldviews in Force Concept Inventory data. *Physical Review Physics Education Research*, 13(1), 1–12. <https://doi.org/10.1103/PhysRevPhysEducRes.13.010126>
- Sergis, S., Sampson, D. G., & Pelliccione, L. (2018). Investigating the impact of flipped classroom on students' learning experiences: A self-determination theory approach. *Computers in Human Behavior*, 78(August), 368–378. <https://doi.org/10.1016/j.chb.2017.08.011>
- Shute, V. J., & Rahimi, S. (2021). Stealth assessment of creativity in a physics video game. *Computers in Human Behavior*, 116, 106647. <https://doi.org/10.1016/j.chb.2020.10.6647>
- Sulman, F. (2019). Application of cooperative problem posing and prior motivation towards students learning outcomes. *Indonesian Journal of Educational Research (IJER)*, 4(2), 93–96. <https://doi.org/10.30631/ijer.v4i2.126>
- Sulman, F., Sutopo, S., & Kusairi, S. (2021). FMCE-PHQ-9 assessment with rasch model in detecting concept understanding , cheating , and depression amid the covid-19 pandemic. *Tadris: Jurnal Keguruan Dan Ilmu Tarbiyah*, 6(2), 297–309. <https://doi.org/10.24042/tadris.v6i2.9273>
- Sulman, F., Tanti, T., Habibi, M., & Zb, A. (2021). Pengaruh media animasi berkarakter islami terhadap hasil belajar pengetahuan bumi dan antariksa. *Edumaspul: Jurnal Pendidikan*, 5(1), 135–146. <https://doi.org/10.33487/edumaspul.v5i1.1044>
- Sulman, F., Taqwa, M. R. A., Aminah Zb, A. Z., Rafzan, R., & Fikri, A. (2020). The effect of mathematical connections on the mastery of probability material. *Edumatika : Jurnal Riset Pendidikan Matematika*, 3(2), 147–157. <https://doi.org/10.32939/ejrpm.v3i2.645>
- Sulman, F., Yulianti, L., Kusairi, S., & Hidayat, A. (2022). Hybrid learning model: its impact on mastery of concepts and self-regulation in newton ' s second law material. *Kasuari: Physics Education Journal*, 5(1), 65–74. <https://doi.org/https://doi.org/10.37891/kpej.v5i1.273>
- Sumirattana, S., Makanong, A., & Thipkong, S. (2017). Using realistic mathematics education and the DAPIC problem-solving process to enhance secondary school students'

- mathematical literacy. *Kasetsart Journal of Social Sciences*, 38(3), 307–315.
<https://doi.org/10.1016/j.kjss.2016.06.001>
- Sutopo, S. (2016). Students' understanding of fundamental concepts of mechanical wave. *Jurnal Pendidikan Fisika Indonesia*, 12(1), 41–53.
<https://doi.org/10.15294/jpfi.v12i1.3804>
- Weaver, J. P., Chastain, R. J., DeCaro, D. A., & DeCaro, M. S. (2018). Reverse the routine: Problem solving before instruction improves conceptual knowledge in undergraduate physics. *Contemporary Educational Psychology*, 52, 36–47.
<https://doi.org/10.1016/j.cedpsych.2017.12.003>
- Weinberg, A. E., & Sample McMeeking, L. B. (2017). Toward meaningful interdisciplinary education: High school teachers' views of mathematics and science integration. *School Science and Mathematics*, 117(5), 204–213.
<https://doi.org/10.1111/ssm.12224>
- Wells, J., Henderson, R., Traxler, A., Miller, P., & Stewart, J. (2020). Exploring the structure of misconceptions in the force and motion conceptual evaluation with modified module analysis. *Physical Review Physics Education Research*, 16(1).
<https://doi.org/10.1103/PHYSREVP>
- HYSEDUCRES.16.010121
- Yazan, B., & De Vasconcelos, I. C. O. (2016). Three approaches to case study methods in education: Yin, Merriam, and Stake. *Meta: Avaliacao*, 8(22), 149–182.
<https://doi.org/10.22347/2175-2753v8i22.1038>
- Zb, A., Novalian, D., Ananda, R., Habibi, M., & Sulman, F. (2021). Distance learning with steam approach: Is Effect On The Cognitive Domain? *Jurnal Educative: Journal of Educational Studies*, 6(2), 129–140.
- Zb, A., Novalian, D., Rozal, E., Sulman, F., & Habibi, M. (2021). STEM approach in online lectures: how does it contribute to cognitive aspects? *Indonesian Journal of Science and Education*, 5(2), 88–97.
<https://doi.org/10.31002/ijose.v5i2.4365>
- Zb, A., Setiawan, M. E., Rozal, E., & Sulman, F. (2021). Investigating hybrid learning strategies: does it affect creativity? *Jurnal Kependidikan: Jurnal Hasil Penelitian Dan Kajian Kepustakaan Di Bidang Pendidikan, Pengajaran Dan Pembelajaran*, 7(4), 868–875.
<https://doi.org/10.33394/jk.v7i4.4063>
- Zb, A., Setiawan, M. E., & Sulman, F. (2020). Pengaruh e-learning berbasis schoology berbantuan whatsapp group terhadap hasil belajar ditengah pandemi covid-19. *Al-Khidmah*, 3(2), 55–60. <https://doi.org/10.29406/al-khidmah.v3i2.2282>