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The Analysis of Mathematical Critical Thinking Ability and Mathematical Creativity: Judging from the Process of Deriving the Fermi-Dirac Formula

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Abstract: This study aims to see and simultaneously describe the ability to think critically and creatively in student physics teacher candidates in the Fermi-Dirac course. Descriptive quantitative was used as the method of this research. Data collection in the study used tests on the cognitive domain in the form of a description of 8 questions where four measured critical thinking skills and four questions measured creative thinking skills. The data analysis process was carried out qualitatively and then described to determine the students' mathematical critical thinking and creative thinking skills, which were then assessed in distribution based on the categories that had been created. The data and facts that the researchers found after the study showed that the average mathematical thinking ability of students was in the Good Enough category, and the average mathematical communication ability of students were also in the Good Enough category.

INTRODUCTION

The Physics lecture process is a learning that is closely related to a student's interest in learning and also the ability to think critically and creatively in a lesson (Ningsih, 2022; Reyza et al., 2022). Mathematical critical thinking and creative thinking skills possessed by physics students can add insight and make it easier for them to interpret an equation more deeply (Hernández-Torrano & Ibrayeva, 2020; Shaw, 2014; Zandvakili et al., 2019). In the lecture process, the ability to think critically, mathematically, and mathematically creatively in reviewing a unique physics equation while learning statistical physics is very much needed, and almost on average mathematical ability in terms of critical and creative thinking plays a significant role in describing and describing physical equations, one of which is statistical physics. In this study, the physics material being reviewed is the Fermi-Dirac equation material. The Fermi-Dirac equation relies heavily on mathematical equations in parsing the maximum probability of particle movement, namely fermion particles. The process of critical and creative thinking in deriving the Fermi-Dirac equation is believed to be very influential. It impacts student success in solving equations in statistical physics courses in general

and, in particular, on the Fermi-Dirac equation in statistical physics courses, which can create creativity and effectiveness in the process of Lectures..

The lecture process with good critical and creative thinking skills will, of course, be based on a skill that is continually honed and used with the support of mathematical abilities (Hadar & Tirosh, 2019; Sulman et al., 2020) in solving Fermi-Dirac equations, with basic mathematical abilities which are related to the formulation of the problem to be studied and a theoretical description of how the fermion particles in the Fermi-Dirac equation are described and analyzed in statistical physics lectures. In the lecture process, both critical and creative thinking becomes the essential thing that must be measured (Baki et al., 2009; Craft, 2003; Legesse et al., 2020). The measurement process, especially the Fermi-Dirac equation precisely for critical and creative thinking in the form of mathematical understanding, should be carried out and become a measure of success in solving the Fermi-Dirac equation. The measurement process can be carried out using a collaborative assessment (Sri Hastuti, 2021; Sulman, Sutopo, et al., 2021) with question instruments related to the measurement of the Fermi-Dirac equation, which is reviewed primarily when students perform or derive the equation.

Mathematical critical thinking ability is an ability possessed by students in terms of studying (Lin et al., 2015; Sulman et al., 2020; Tuan Soh et al., 2010) or making an analysis of a form of an idea or idea to improve the existing quality of students in the learning process, especially students' mathematical abilities while mathematical creative thinking ability is an ability to be able to answer a question with a new technique or a fast way to solve physics equations that require basic mathematical principles that make students more accessible and more acceptable validity (Hadar & Tirosh, 2019; Sulman, 2019; Sulman et al., 2022). The importance of critical and creative thinking skills that the researcher described above is a reference that students' understanding, especially physics tadrís, must be fully encouraged to mathematical critical thinking skills and mathematical creative thinking skills so that statistical physics lectures can run optimally, especially in reducing the Fermi Dirac equation in the eyes Statistical physics course.

The lecture process, especially when the Fermi-Dirac equation in statistical physics, requires a good mathematical understanding, one of which is the ability to think mathematically critically and mathematically creatively. The ability to think critically and mathematically can all become a unit called students' mathematical ability. Mathematical skills that are owned and honed by students will be a way for students to understand the Fermi-Dirac equation better. The lecture process in deriving the Fermi-Dirac equation is a must to have the mathematical ability. Mathematical abilities in the form of critical and creative thinking skills are believed to improve learning outcomes and, at the same time, foster interest and hone students' thinking patterns in dealing with theoretical physics problems. Interest, motivation, and self-regulation in physics learning significantly affect learning outcomes (Sulman, 2012; Sulman et al., 2022; Sulman, Tanti, et al., 2021). In the process, the ability to think critically and creatively should become the essential foundation for students in describing physics equations and, in this case, the Fermi-Dirac equation. The importance of the role of critical and creative thinking makes an indication that these two understandings must be measured and in this

case, what is measured is the ability to think critically and creatively in mathematical abilities, especially the Fermi-Dirac equation. The measurement of students' mathematical abilities, especially for critical and mathematical thinking, is intended so that teachers can find out how far the students' capacity in terms of their basic mathematical abilities can be and can be used as a stimulus to better support and encourage students to be able to understand the Fermi-Dirac equation for the better.

Students' mathematical critical thinking and mathematical creative thinking skills should be improved and developed to maximize students abilities in facing global demands. Students' mathematical critical thinking and mathematical creative thinking skills can be an indicator of whether students are already at the level of learning that is following the lecture process being carried out or vice versa. The understanding that the researcher describes is the reason for observing the ability to think critically mathematic and mathematically creatively so that there are obstacles and the actual abilities of prospective physics teacher students in understanding and solving Fermi-Dirac material so that the statistical physics lecture process can run better.

METHOD

This research was conducted by observing and testing students in the sixth semester of Physics at UIN Sulthan Thaha Saifuddin Jambi in the 2021/2022 academic year. The type of research used was descriptive quantitative (Creswell, 2003, 2012). In this study, we will look at students' general thinking ability and creativity in Fermi-Dirac physics lectures. Data collection techniques in this study used a test technique of descriptions of as many as eight questions. Four questions were to see students' mathematical critical thinking abilities and four ways to see students' mathematical creative thinking abilities—ability test instrument. The question instrument used is a sequence in understanding the process of deriving Fermi-Dirac material so that if students understand, they can answer the questions given; it indirectly shows students' understanding of the Fermi-Dirac equation. The sample used in this study uses a saturated sample where the whole community is the subject of research (Sulman, 2019). The sampling process using the sample is expected to make all observed samples genuinely represent the research as a whole.

The question instruments used were validated by those in the field of statistical physics. In addition, the instrument has been tested so that it meets valid and reliable criteria (Meiliani et al., 2021; Putra et al., 2021; Zb et al., 2020). The research instrument has often been tested and is in the correct category, with high reliability of 0.977. Data on student test results regarding critical and creative thinking skills and mathematical abilities were reviewed when the Fermi-Dirac formula was derived. The results were then analyzed quantitatively and presented descriptively to determine prospective physics teacher students' critical and creative thinking skills—distributed achievement predicate on each ability that is being observed.

Observation of students' critical thinking skills and creative mathematical abilities will be focused on classical data processing by taking values and then entering them into predetermined assessment categories. The results of the assessment based on the

categories that have been determined will be the researcher's decision regarding the critical mathematical thinking and mathematical creative thinking skills possessed by prospective physics teacher students. The data obtained during the study were processed using the percentage technique using the proposed formula $P = F/N \times 100\%$. The increase in student activity is low, relatively high or very high is determined based on the established criteria, which can be seen in table 1:

Table 1. Scoring category Student grade

No	Percentage	Category
1	81-100	Very good
2	61-80	Good
3	41-60	Pretty Good
4	21-40	Not Good
5	0-20	Very Not Good

RESULT AND DISCUSSION

The research process on critical mathematical thinking and mathematical creative thinking skills was obtained from several data showing students' understanding or ability based on five categories of assessment from 8 questions that were tested. Of the eight questions that have been made, four are used to measure students' mathematical critical thinking skills, and four questions to measure students' mathematical creative thinking abilities. Analyst The test after the research was carried out specifically on mathematical critical thinking skills on the material of the Fermi-Dirac equation, which has been tested on 31 students who are prospective physics teachers. Some of the data and facts obtained in looking at the mathematical critical thinking abilities of physics tadriss students are presented in Table 2 below:

Table 2. Analysis of Mathematical critical thinking skills analysis

No	Percentage	Total students	Category
1	81-100	3	Very good
2	61-80	3	Good
3	41-60	20	Pretty Good
4	21-40	5	Not Good
5	0-20	0	Very Not Good

Based on Table 2, the students' scores based on the categories that were used as the basis for the critical thinking ability test for physics students obtained data in terms of students' mathematical critical thinking skills in solving the derivation of the Fermi-Dirac equation where the criteria obtained by students were in a pretty good category. The data obtained can be described as follows, students whose mathematical problem-solving abilities are very good are three students who are in that category, then three students are in a good category, 20 students have mathematical critical thinking skills in the fairly good category, while 5 students were in a Not Good category and there were no physics tadriss students who were in the very not Good category.

The data obtained from the study indicate that the critical thinking skills of physics tadriss students are in a pretty good category, whereas about 20 students already have critical thinking abilities in a pretty good category. However, because the student is

already in the final level as a prospective physics teacher, the good enough category is not enough to understand further statistical physics courses, and of course, it will be one of the obstacles in understanding the Fermi-Dirac material in statistical physics. The category of student understanding needed to understand the Fermi-Dirac equation should be in the very good category, and at least be in a good category, so that the lecture process can run optimally and effectively. A maximal and effective lecture process is needed in an effort to make learning patterns run in accordance with what will be directed to achieve lecture goals (Rozal et al., 2021; Zb, Novalian, Rozal, et al., 2021; Zb, Setiawan, et al., 2021).

The research process resulted in that classically, students' mathematical critical thinking skills were, on average, in a pretty good category. This statement is obtained when viewed from the five categories that the researcher determined. The questions used to measure the ability to think critically mathematically use essay description questions, totaling eight questions. The questions given or referred to are the content of mathematical problems in the Fermi-Dirac equation, which plays a role in deriving mathematical equations in statistical physics lectures. The ability to think critically mathematically in solving students' mathematical problems is believed to make it easier for students to understand the problems in statistical physics, especially the derivation of the Fermi-Dirac equation.

The data in the research shows that students' mathematical thinking skills are not maximal, but the presence of mathematical thinking skills will make students have more ideas and insights. The ability to think mathematically will encourage students to use several scientific methods in analyzing phenomena and problems; students will be more motivated to seek answers to the phenomena that have been given in understanding the Fermi-Dirac equation. The research facts also indicate that the students' mathematical critical thinking skills are not maximal, where more than five students have mathematical thinking skills in the very poor category. The lack of good students' mathematical critical thinking skills, especially in answering or studying statistical physics formulas, will make students experience problems in solving the Fermi-Dirac equation, so indirectly, students experience difficulties in understanding statistical physics material whose courses are in the category of subjects. Prospective physics teachers study at a high level. The ability to think critically for today in the industrial era 4.0 is an obligation that students must have so that they are not left behind with future learning changes that are increasingly running rapidly and by the times. This should be the basis for the importance of mathematical thinking skills to be possessed by students in the statistical physics lecture process.

In addition to mathematical critical thinking skills, this study also observes how creative thinking skills are in statistical physics problems for tadrís physics students on the Fermi-Dirac material, which researchers believe also plays an important role in making it easier to solve some theoretical equations. The value of mathematical creative thinking skills in detail based on categories can be seen in Table 3 below.

Table 3. Analysis of mathematical creative thinking skills

No	Percentage	Total students	Category
1	81-100	4	Very good
2	61-80	2	Good
3	41-60	20	Pretty Good
4	21-40	1	Not Good
5	0-20	4	Very Not Good

The research process that has been carried out Based on Table 3 above, it was found a fact that from the number of students taking statistical physics courses from 2 classes totaling 31, especially the ability to reduce the Fermi-Dirac equation metrics, prospective physics teacher students obtained data that the student scores for aspects of the assessment of creative thinking based on predetermined categories which are carried out as the basis for the creative thinking ability test in solving the derivation of the Fermi-Dirac equation where the criteria obtained by students are in the average category quite nicely. The data obtained can be described as follows, students whose creative thinking skills in solving mathematical equations of statistical physics are in the very good category four students, then two students are in a good category, 20 students have mathematical critical thinking skills in the moderate category. Good, while one student is in not Good category and four physics tadris students are in the very poor category. The research process resulted in the fact that classically, students' mathematical creative thinking skills were, on average, in a pretty good category. This statement is obtained when viewed from the five categories that the researcher determined. The questions used to measure the ability to think creatively mathematically using cognitive domain questions are essay description tests, totaling eight questions. The questions given or referred to are the content of mathematical problems in the Fermi-Dirac equation, which play a role in deriving the mathematical equation. In other words, it is devoted to the mathematical ability of students.

The research process that has been carried out in assessing students' creative abilities indicates that, in fact, students still do not have the ability to think creatively mathematically in deriving the Fermi-Dirac equation, so the statistical physics lecture process becomes a bit monotonous and is believed to be caused by the lack of student's creative thinking skills. The lack of student's creative thinking skills causes students to become more aware of the understanding given by the lecturer in analyzing questions and questions regarding the derivation of the Fermi-Dirac equation. From the data found in the field, there are still about four students who have an understanding of creative thinking in the very bad category, and this is certainly a serious concern in the lecture process because the statistical physics material is in the courses in the final semester of students, namely semester VI which should have basic abilities. Students are in the very good category or minimally in the good category. Students' abilities, especially good basic skills, will make lectures run more effectively and efficiently (Meiliani et al., 2021; Zb et al., 2020; Zb, Novalian, Ananda, et al., 2021; Zb, Novalian, Rozal, et al., 2021), so that the lecture process given is in accordance with the target of implementing lectures, especially the statistical physics course on the Fermi-Dirac material.

The mathematical creativity of students in the study of statistical physics, especially in the Fermi-Dirac material, is not only needed to improve the cognitive domain of students but is also used to increase student interest and motivation in lectures so that students can be encouraged to try to master the Fermi-Dirac derivation process which should arise from the student's personality. So that the learning process will be better and more enjoyable. The mathematical creative thinking process is expected to be able to encourage students to become educators in the future who can bring real changes to the educational environment, where the education needed in the future is not only for educators who have cognitive abilities but students who have good creativity so that they are not left behind with the changing times, which runs significantly and is in line with very rapid technological developments (Azizah & Dewi, 2022; Defrianti & Iskandar, 2022; Sari et al., 2022).

In the research process that has been carried out, mathematical critical thinking skills and mathematical creative thinking skills used in solving Fermi-Dirac equations in statistical physics courses are very important to be instilled in students. In the research process that has been carried out, valuable information is obtained that in solving the Fermi-Dirac problem, students' mathematical critical thinking and mathematical creative thinking skills are believed to make it easier for students to understand problems and derive equations in statistical physics courses, especially the derivation of the Fermi-Dirac equation. The ability to think critically, mathematically, and mathematically creatively based on the results of research that has been obtained is believed by researchers to have a significant impact on solving the bose-Eisen equation while at the same time increasing student learning outcomes for better and maximal and will indirectly realize more effective lectures.

CONCLUSION

The research process that has been carried out and analyzed in reviewing students' mathematical critical thinking skills and also students' creative thinking skills in students who take statistical physics courses, especially observations on the material for the derivation of the Fermi-Dirac equation, shows information where students' abilities, both mathematical critical thinking skills and abilities both mathematically creative are in the pretty good category. The data obtained from the study results indicate that there is still a need for improvement and improvements in statistical physics lectures and other physics courses that have a relationship with statistical physics so that the lecture process can run more effectively and optimally. Research improvements for future researchers should pay more attention to essential indicators in the statistical physics lecture process and must review the questions used that have standards in the assessment of each category that will be researched, as well as prepare all variables that can affect student learning outcomes.

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