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Investigating Problem Solving and Mathematical Connections in Solving the Fermi-Dirac Equation

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Abstract: This study aimed to describe the problem-solving abilities and mathematical connections of the sixth-semester students of Physics Tadris in the Statistical Physics course, especially the Bose-Einstein Equation Material. This type of research is quantitative descriptive research. Data collection in this study used a cognitive test technique in the form of a description test to measure students' mathematical abilities, which amounted to 8 questions, of which four were used to measure problem-solving abilities, and four were used to measure students' mathematical connections. Data analysis was carried out descriptively to determine the profile of students' mathematical abilities and the distribution of predicate achievement on the ability of problem fractions and students' mathematical connections. The results showed that students' average problem-solving ability and mathematical connection were in the Pretty Good category.

INTRODUCTION

Physics is a study that is closely related to mathematical equations (Reyza et al., 2022; Sulman, Sutopo, et al., 2021). The mathematical abilities of physics students can make it easier for them to understand and apply equations in physics material (Smith et al., 2014; Wells et al., 2019). In the learning process, almost on average mathematical equations are needed to understand physics material. One of the physics subjects that uses a lot of mathematical equations is the statistical physics course, one of which is the Bose-Einstein equation. The Bose-Einstein equation relies heavily on mathematical equations in decomposing the maximum probability of particle movement. The student's ability strongly influences the thinking process in deriving the Bose-Einstein equation in statistical physics material, and the best mathematical thinking ability will provide much convenience for students in understanding and solving the Bose-Einstein equation. The benefits of students' mathematical thinking skills give educators confidence to pay attention to improving their mathematical thinking skills; in other words, a physics education student should have a maximum mathematical ability so that they can easily solve various phenomena in physics(Putra et al., 2021; Sulman, 2012; Sulman et al., 2022), especially on the derivation of the Bose-Einsten equation.

Analyzing the Bose-Einstein maximum distribution makes the ability to think a must-have for tadris physics students mathematically. At the same time, it is a significant asset in the statistical physics learning process, especially the derivation of the Bose-Einstein equation. Physics education students' ability in high-level mathematical thinking should be owned by physics education students in statistical physics learning so that lectures run more effectively and efficiently (Meiliani et al., 2021; Sulman, 2019; Sulman, Tanti, et al., 2021). In statistical physics learning, it should emphasise various basic mathematical abilities so that physics tadris students have no difficulty encountering various uses of mathematical equations in solving physics equations. In statistical physics learning, prospective physics teacher students have never received physics lessons that plan and implement lessons to higher thinking abilities and problem-solving skills (Reyza et al., 2022; Rozal et al., 2021; Sulman et al., 2022). Learning for tadris physics students always focuses on understanding mathematical concepts, which is the most essential ability of the mathematical abilities they must have.

The ability of a mindset that is formed from understanding mathematical concepts is crucial, but students will undoubtedly find it very difficult if the way of learning is not balanced with a process of habituation (Hwang et al., 2007; Zb, Novalian, Ananda, et al., 2021; Zb, Setiawan, et al., 2021) in solving a real statistical physics problem containing various basic mathematical abilities. The lecture process places great emphasis on the focus. Natural mathematical abilities are crucial to be developed and possessed by tadris physics students, namely critical thinking and mathematical connection skills. The process of statistical physics lectures In order to derive the Bose-Einstein equation, it always focuses on how to develop the mathematical abilities that physics tadris students must have, and lecturers should do this in teaching statistical physics courses; lecturers should be able to learn statistical physics by utilizing students' basic mathematical abilities, one of which is in the form of problem-solving problems or formula reductions such as the Bose-Einstein equation. The lecture process based on habituation in solving problems supported by mathematical ability in solving the maximum probability of the Bose-Einstein equation and adapted to everyday life can be done by giving steps or basic mathematical formulas that are linked to the formulation of the problem you want to study and a theoretical description of how the particles work. The boson in statistical physics is described as being carried out around learning in the classroom. In the statistical physics lecture process, in addition to meaningful learning, of course, the assessment process also needs to be carefully prepared, especially by the lecturers, so that lectures can run efficiently, especially the derivation of the Bose-Einstein equation so that the goals that students should want to achieve can be achieved maximally by students during their study. Lectures. The lecture process, of course, requires a measuring tool called an assessment (Chen & Chiou, 2014; Michalsky, 2020), In addition to an excellent statistical physics learning process, assessment in determining student abilities, especially in the cognitive domain, is very important to be measured and reviewed correctly.

The assessment process with an assessment is a material to be able to display and report the progress of learning outcomes (Halloun, 2007; Lu et al., 2021; Ramlo, 2008)

especially in the cognitive domain of students and can be used as input for evaluating the learning process, especially statistical physics. Educators' ability to develop, plan, discuss, implement, analyse results, re-reflect, and conclude from the statistical physics lecture process results is an essential point between the quality of the assessment and student achievement. In the lecture process that should be carried out or ideally in the assessment or assessment process, there is involvement between lecturers and students while deriving statistical physics equations.

The assessments carried out so far are believed to be after the statistical physics lecture process only unilaterally from the educators, although occasionally asking students for consideration, in other words, not maximal and in their entirety. If this happens continuously, it will impact students' statistical physics learning achievement. In addition, students should be involved in the assessment so that it does not conflict with the learning assessment standards in Indonesia, where the assessment is not only carried out as an assessor of the student's cognitive domain, but the assessment is used as an assessment of the student learning process. The assessment process for today is by the national assessment standards in Indonesia. Researchers understand that the assessment is carried out with supporting lecturers by involving students in the entire final process before giving grades (Defrianti & Iskandar, 2022; Ningsih, 2022; Suri et al., 2022). The final assessment of students' statistical physics in deriving mathematical equations will be reviewed from how students' mathematical abilities in the form of final semester tests, specifically on the Bose-Einstein equation and do not as a whole show students' mathematical abilities in statistical physics courses.

The assessment process carried out by lecturers is usually only limited to assessing the ability to memorize and remember a fact and does not assess students' high-level thinking and critical thinking. This research assessment in statistical physics will review the basic mathematical abilities that need to be emphasized in the ability to solve students' statistical physics equations, especially the Bose-Einstein equation. It is believed that regular assessments carried out during statistical physics lectures do not encourage students' creativity and innovation, so the learning strategies used and conventional assessments will create a distance between students and lecturers in the success of the learning process (Sulman et al., 2020; Zb, Novalian, Ananda, et al., 2021; Zb, Novalian, Rozal, et al., 2021). Based on the preliminary study results, many of the sixth-semester physics tadris students felt that they had not been involved in the assessment development. Students are only used as recipients or users of an assessment, and they feel they have never been involved in discussions and agree on the assessment criteria to be used, where the discussion is only about the learning process that will be carried out during statistical physics lectures. The facts in the field obtained in the form of a preliminary study give confidence to the researchers if they want actual learning outcomes, it is necessary to develop innovations (Malone, 2008; Ramlo, 2008; Smith & Wittmann, 2008) both as assessments so that the quality of learning and assessment is getting better and can show results. Actual learning by involving lecturers and students in lectures.

Involving tadris physics students with students is an alternative to using a classical collaborative assessment (Blanchin et al., 2020; Wan et al., 2020). he collaborative assessment process has to be done carefully(Hwang et al., 2007; Zhou, 2022). It can be done by involving all elements that affect the assessment, for example, students in discussions and agreeing on the assessment criteria that will be applied in a measurement. In addition, a physics assessment should be carried out in lectures to measure all abilities, including understanding physics material and the student's basic mathematical abilities. This is used to not focus on unidirectional assessments of low-level mathematical thinking but can be the basis for solving Bose-Einstein statistical physics equations. The Process of Using Collaborative Assessment in maximum probability research on the Bose-Einstein equation, especially in measuring students' basic mathematical abilities, will be applied with question instruments related to the measurement of the Bose-Einstein equation.

The Bose-Einstein equation in statistical physics is a form of the equation that looks at the maximum probability of the boson particle and the equation that is formed. All of this requires a good mathematical understanding. The lecture process carried out requires a form of explanation and understanding of mathematics that is formulated and associated with theoretical physics concepts. Students' mathematical abilities will make it easier for students to understand statistical physics concepts. If statistical physics lectures, especially the Bose-Einstein equation, with good basic mathematical skills, it will make statistical physics learning more effective and more accessible to improve students' learning abilities and understanding. The learning process is a collaborative assessment model used in statistical physics learning, especially the Bose-Einten equation material that is feasible to use and gets a positive response from students and lecturers, which will later be used as an instrument to measure the mathematical ability of students in Bose-Einstein material. The measurement of students' mathematical abilities is intended so physics tadris lecturers can find out the extent to which students' actual abilities are possessed and can be used as a guide to correct errors in solving problems in describing physics equations, and can use to improve the physics learning process. Based on the preceding, this research aims to see in detail how the problem-solving abilities and mathematical connections in statistical physics courses, especially Bose-Einstein material, are believed to improve the quality of student learning in statistical physics courses.

METHOD

The research process carried out is in the sixth semester of the Tadris Physics Study Program at UIN Sulthan Thaha Saifuddin Jambi for the 2021/2022 academic year. The type of research conducted is quantitative descriptive research. This is because this study aims to describe data in research and photograph a condition (Creswell, 2012; Cummings et al., 2004; Lehavi & Eylon, 2018). The condition analyzed in this study is the mathematical ability of students when studying the material on the Bose-Einstein equation in the statistical physics course. Data collection techniques in this study used a description test technique. The test instruments for problem-solving abilities and

mathematical connections all consist of 8 questions, where for each category, there are four critical thinking analysis questions and four mathematical connection questions. Each predetermined mathematical ability test will be given to two classes, VI A and VI, totalling 31 Tadris Physics students. The question instrument used is validated and has met all the indicators of the student's mathematical ability to be measured. In addition, the instrument has been tested so that it meets valid and reliable criteria. The student test results data were then analyzed descriptively to determine the profile of students' mathematical abilities and the distribution of predicate achievement for each measured mathematical ability. The research process uses the reference Very Good, Good, Pretty Good, Not Good and Very Not Good, which is taken with a Likert scale (Higgins & Thompson, 2002; Riduawan, 2018; Sudijono, 2019) where all student scores are taken from the actual value of the final exam results obtained. Moreover, it is not corrected or added to other assessment processes. The assessment categories in this study 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 data obtained from the Analyst Test of students' problem-solving abilities and mathematical connections showed the data in general, named after the research was carried out, especially on mathematical abilities, especially for mathematical connectivity abilities in statistical physics material at the time of deriving the Bose-Einstein equation which had been tested on 31 tadris physics students. Some facts can be seen where in the Profile of Mathematical Mathematical Connection Ability Students tadris physics starts. Values are taken from actual data before grades are added to other assessments, with categories determined using a rating scale where the results of the assessment are presented in Table 2.

Table 2. Mathematical connection ability analysis

No	Percentage	Total students	Category
1	81-100	2	Very good
2	61-80	1	Good
3	41-60	22	Pretty Good
4	21-40	5	Not Good
5	0-20	1	Very Not Good

Based on Table 4, researching the mathematical connection ability of physics students obtained data in connecting students' mathematical equations in solving the Bose-Einstein equation derivation where the criteria obtained by students were in the pretty good average category. The data obtained can be described as follows: 2 students whose mathematical communication skills are very good, then one student is in a good category, 22 students have their mathematical communication skills in the pretty good

category, while five students are in the Not Good category and there is one student who is in the Very Not Good category.

In the process of research that has been carried out, it produces a fact that can be explained clearly that classically, students' mathematical connection abilities are, on average, in a pretty good category when viewed from the five categories that the researchers determined from the analysis using mathematical connection questions, especially on the Bose-Einstein material. The questions used to measure mathematical communication skills using essay description questions, which amount to 4 questions. The questions given or referred to are the content of mathematical problems in the Bose-Einstein equation, which plays a role in deriving the mathematical equation. Mathematical connection ability is the ability possessed by students who play a role in connecting one equation or knowledge with other knowledge. Connecting knowledge requires a good understanding between the knowledge obtained as new knowledge and the ancient knowledge obtained in the past or elsewhere so that the knowledge possessed is no longer disconnected but becomes mutually exclusive information. Related to making it easier to analyze new knowledge, which indirectly causes the lecture process to be more effective and efficient (Mestre et al., 2011; Miller et al., 1988; Sulman, 2019). good mathematical connection will also increase student interest in learning and learning motivation; where we know that a good lecture process is a lecture process that is not only able to provide learning material but can increase student learning interest (Zb et al., 2020; Zehirlioglu & Mert, 2020; Zhang & Zhang, 2018)

The statistical physics learning process with the Bose-Einstein equation material provides a clear picture of students' mathematical connection abilities, which is believed to be able to improve students' analytical understanding and also make it easier for students to understand mathematical problems and concepts in statistical physics, especially the derivation of the Bose-Einstein equation. The mathematical communication ability possessed by students has not yet reached the expected value, which is still in a pretty good category, so maximum changes are needed for all related physics subjects or to support the statistical physics learning process. The significant change in students' mathematical connection abilities in reducing the Bose-Einstein equation will increase students' motivation and interest in learning to be better and more maximal, which indirectly increases students' enthusiasm for studying statistical physics more deeply. In addition to mathematical connection skills, this study also observes students' mathematical problem-solving abilities, which are believed to play an essential role in solving Bose-Einstein equations. The mathematical problem-solving ability in detail based on categories can be seen in Table 3.

Table 3. Analysis of mathematical problem solving skills

No	Percentage	Total students	Category
1	81-100	0	Very good
2	61-80	4	Good
3	41-60	21	Pretty Good
4	21-40	6	Not Good
5	0-20	0	Very Not Good

Based on Table 3, the research process of mathematical problem-solving abilities of physics students obtained data in terms of students' mathematical problem-solving abilities in solving the derivation of the Bose-Einstein equation, where the criteria obtained by students were in the pretty good average category. The data obtained can be described as follows students whose mathematical problem-solving abilities are very good are 0 people or no students are in that category. Four students are in a good category, 21 students have mathematical solving abilities in the pretty good category, while six students are in Not Good category. There were no physics tadris students who were in the very Not Good category. The research process resulted in the fact that classically, students' mathematical problem-solving abilities were, on average, in the fairly good category. This statement is obtained when viewed from the five categories that the researcher determined. The questions used to measure mathematical problem-solving skills use essay description questions, totalling four. The questions given or referred to are the content of mathematical problems in the Bose-Einstein equation, which plays a role in deriving the mathematical equation. Students' mathematical problem-solving ability is believed to make it easier for students to understand mathematical problems and concepts in statistical physics, especially the derivation of the Bose-Einstein equation. Process The problem-solving ability has been influenced by improving student performance to be more careful and enthusiastic in analyzing physics equations. Increased student enthusiasm with a tendency to analyze for the better makes students in the learning process more focused on understanding the Bose-Einstein equation step by step, whereas, with the ability to solve mathematical problems, students become more accustomed to solving very influential mathematical equations. To the learning process.

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 creatively mathematically using essay description questions, which amount to 4 questions. The questions given or referred to are the content of mathematical problems in the Bose-Einstein equation, which plays a role in deriving the mathematical equation. The ability to think creatively and 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 Bose-Einstein equation. The ability to think creatively is believed to significantly impact solving the bose-Eisen equation and can increase student learning outcomes to the maximum.

CONCLUSION

Based on the explanation and understanding of mathematical concepts, mathematical communication, mathematical connections, problem-solving, critical thinking and creative thinking, 31 students were in the pretty good category. This means that the actual ability of students still needs improvement and improvement. 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 a standard in the assessment of each category.

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