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Assessing the Knowledge and Skills of Prospective Physics Teachers in Designing 4C Skills-Oriented Learning: Rasch Analysis

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ABSTRACT: In 21st-century education, the ability to integrate 4C skills into learning designs and assess their effectiveness is paramount for prospective physics teachers, as it contributes to enhancing the quality of teaching and cultivating diverse student competencies. To this end, training sessions and lectures have been conducted to equip prospective physics teachers with the necessary skills for 4C-oriented learning. However, the evaluation of these competencies is crucial to ensure their mastery. This study aims to provide a more profound understanding of the extent to which prospective physics teachers integrate 4C skills in learning design and evaluate the effectiveness of the designed assessment instruments. A quantitative method with a survey design was conducted on 151 prospective physics teachers selected using a purposive sampling technique. The research instrument was a 21st-century learning knowledge test and a rubric for assessing teaching modules and LKPD (student worksheet). Rasch Model analysis was employed to determine the quality of the instrument and evaluate the prospective physics teachers' proficiency in developing learning. The findings revealed that the knowledge test instrument and the rubric for assessing teaching modules and LKPD met the criteria for good validity and reliability. Notably, in the knowledge domain, the instrument items exhibited a bias of 18.57%, based on the semester level. The evaluation results indicated that the prospective physics teachers' knowledge and skills in designing 4C skill-oriented learning were comparatively inadequate. These findings offer preliminary insights into the necessity to enhance the physics teacher education curriculum to align more closely with future demands. Consequently, it is imperative to integrate training, guidance, and practice based on 4C skills more systematically into the physics teacher education program.

Keywords: 4C skills, prospective physics teacher, Rasch analysis, learning design, education.

I. INTRODUCTION

The 21st century has been characterized by accelerated technological progress, an abundance of information, and pervasive globalization [1, 2]. This condition gives rise to a range of significant challenges, particularly in the face of intensified competition [3]. To ensure survival and competitiveness in this era, individuals must adapt their lifestyles, work practices, and interpersonal interactions [4]. This challenge has prompted educational institutions to prioritize the development of 21st-century skills in students, deemed essential for navigating the dynamic and evolving demands of global life [5, 6].

In contemporary learning environments, the educational process encompasses more than merely imparting knowledge; it is also concerned with cultivating a diverse array of competencies that are pertinent to the demands of the 21st century [5, 7]. Effective 21st-century learning is a process that is meticulously designed to equip students with the skills necessary to become successful citizens and to compete in the present and future [5, 7]. Consequently, there is an imperative for a shift in the paradigm of learning from an emphasis on the instructor to a focus on the learner. This transformation reflects the adoption of a novel learning paradigm [8, 9].

The Framework for 21st Century Learning by the Partnership for 21st Century Learning (P21) delineates three primary categories of 21st-century skills: life and career skills, learning and innovation skills, and information, media, and technology skills [10], [11]. The P21 Partnership asserts that the domain of learning and innovation skills encompasses four distinct competencies that students must possess to be adequately prepared to compete in the complex life and world of work in the 21st century [10, 12]. The framework delineates these competencies as the 4C skills, namely critical thinking, problem-solving, communication, collaboration, and creativity and innovation [5, 12].

Teaching 4C skills is important and cannot be ignored [13]. Teachers should not view 4C skills as additional subjects but as skills that can be integrated into all subjects. This is expressed by Radifan & Dewanti [2], that 4C skills training can be applied in various disciplines, including physics. Physics learning in schools has a central role in training students in 4C skills [13]. Physics studies matter, energy, and the interactions between the two [14]. Physics is closely related to natural phenomena encountered in everyday life, so the physics learning process has great potential in training 4C skills. Critical thinking skills are needed in physics learning to analyze experimental data and test hypotheses. Collaboration plays a role in teamwork when conducting laboratory experiments, while communication is an important aspect of presenting experimental results and scientific discussions. Creativity is also needed in designing innovative solutions to physics problems in real-life contexts. Therefore, physics learning is an integrated field that facilitates students' 4C skills, and many studies have been conducted on this topic. Maknun [15] examined how critical thinking skills can be improved through inquiry learning in physics, while Selviana et al. and Batlolona et al. [16, 17] showed the effectiveness of the problem-based learning model in improving critical and creative thinking skills in understanding physics concepts. Research by Putri et al. [18] showed that integrating a project-based approach in physics can improve students' 4C skills.

In order for the effective integration of 4C skills to be realized in physics learning classes, it is essential that teachers possess sufficient knowledge and skills to design such learning [8, 19], including prospective teachers. This competency is of paramount importance for educators to implement effective learning designs, thereby preparing a generation that is capable of competing in the face of increasingly complex global developments. In this regard, prospective physics teachers confront the challenge of integrating these competencies into their pedagogical practice, in addition to the progressively intricate demands of global education [8, 20].

Several studies have discussed teacher competency in implementing 4C skills in learning. Research found that teachers face challenges in obtaining the content and pedagogical knowledge needed to teach 4C skills in learning [21]. Herviani & Budiastuti's research also found that prospective teachers have difficulty in developing curriculum-based learning plans, including aspects of 21st-century skills [22]. Meanwhile, research by Susanti & Arista shows that many teachers have inadequate 21st century skills competency, especially in critical thinking and creativity [23]. A similar finding was reported by Setiawati & Djohar, who noted that most science teachers exhibited limited proficiency in planning and implementing science learning activities that are oriented around the 4C skills [24].

Although several studies have been conducted regarding the challenges faced by teachers and prospective teachers in integrating 4C skills in learning, studies that explore how prospective physics teachers' competencies integrate 4C skills in specific physics learning designs are still limited. In fact, the ability to teach 4C skills in physics classes is very necessary in the context of 21st century education reform. Physics teachers are not only required to teach physics concepts conceptually, but also to train students in critical thinking, collaboration, scientific communication, and developing creativity in science-based problem solving.

Therefore, the assessment of the Knowledge and skills of prospective physics teachers in designing learning oriented to 4C skills is crucial to determine the extent to which they are ready to face the demands of skill-based learning [25]. However, the main challenge in the evaluation process is how to design an assessment instrument that can accurately measure the level of competence of prospective teachers in this regard. Currently, there are tools, tasks, and questionnaires to assess 21st-century skills [26-29]. However, assessment instruments that focus on prospective teachers' knowledge and skills about 4C skills-oriented learning are still limited.

To overcome these challenges, an instrument supported by the Rasch measurement model was developed to evaluate the knowledge and skills of prospective teachers in designing physics learning oriented to 4C skills. The Rasch model provides a useful methodological tool to investigate the validity and measure the reliability of measurements, allowing researchers to collect data from several observed items to express the results as variables at the instrument level [30]. Rasch analysis can help researchers to expand the results and literature because it has several advantages, such as meeting the basic measurement requirements to convert raw data into a linear interval scale (logits) and allowing researchers to investigate student performance or ability and item difficulty using item-person maps [31, 32], which are not found in other analysis methods. The Rasch method is a psychometric technique developed to improve measurement accuracy so that researchers can construct instruments and monitor the quality of instruments down to the item level [33, 34]. The Rasch analysis approach has been recognized as one of the effective methods for assessing and measuring skills and knowledge objectively [35, 36]. Unlike deterministic methods, Rasch analysis uses a probabilistic approach that allows for more accurate identification of item characteristics. This approach allows for a more measurable and objective evaluation of the level of competency achievement in various dimensions [37, 38]. Additionally, although Rasch analysis has been applied in various educational fields to assess students' competencies and skills [39, 40], the use of the Rasch model to evaluate the knowledge and skills of prospective teachers in the context of physics education, especially those focusing on the 4C skills, has not been widely documented. The extant literature contains a paucity of studies that integrate the Rasch evaluation method with the development of 4C skills in physics education.

Therefore, this study attempts to address the gap by focusing on evaluating the competence of prospective physics teachers in designing learning based on 4C skills using the Rasch analysis approach. The objectives of this study are twofold: first, to assess the effectiveness of the assessment instrument designed using Rasch analysis, and second, to provide a deeper understanding of the extent to which prospective physics teachers have the knowledge and skills needed to integrate 4C skills into learning design. The following research questions have been formulated to guide this study: (1) How is the validity and reliability of the knowledge test instrument, the learning device assessment rubric instrument using Rasch modeling analysis?; (2) How is the classification of the level of difficulty of the Knowledge test items?; (3) Is there a DIF based on semester level?; (4) How are the results of the evaluation of the knowledge of prospective physics teacher students about 21st-century learning using Rasch modeling analysis?; (5) How are the results of the evaluation of the skills of prospective physics teachers in designing physics learning devices oriented towards 4C skills using Rasch modeling analysis?. The results of this study are expected to contribute to the development of a higher education curriculum for prospective physics teachers that is better and more relevant to future educational needs.

II. LITERATURE REVIEW

1. 21ST CENTURY LEARNING

21st century learning is based on four main principles, namely: (1) a student-centered teaching and learning process, (2) collaboration, (3) clear content, and (4) integration with the environment or society. In this context, 21st-century learning is no longer limited to structured knowledge packages. Instead, learning is flexible and without limits, adjusted to the interests of students. The role of the teacher has undergone a shift, and learning resources are no longer limited to textbooks or information provided by teachers. Technology has facilitated access to a wealth of information [41]. Teachers are no longer the sole repositories of knowledge; rather, they function as facilitators who guide students in constructing knowledge and developing the skills necessary to navigate the challenges of the 21st century [7, 12].

In the contemporary educational landscape, effective teachers in the 21st-century learning environment are those who demonstrate proficiency in the design and implementation of learning experiences that are conducive to active student engagement. These educators facilitate opportunities for interaction among students and between students and teachers, thereby fostering a collaborative learning environment. They employ a variety of instructional strategies to assist students in mastering learning materials or content, including the use of investigative questions and problem-solving exercises. These activities are often supported by relevant theoretical frameworks, and problem-solving activities are often facilitated through authentic, real-life projects. Furthermore, these effective teachers incorporate fundamental skills into applied skills that are essential for the 21st century [7]. The development of such educational environments necessitates that educators possess the knowledge and skills necessary to design learning experiences that utilize innovative strategies and modern learning technologies. A plethora of strategies have been developed to enhance learning content and skills while engaging students in real-life applications. One such strategy is problem-based learning (PBL), which has been shown to facilitate student engagement and skill development [6].

The PBL model is a learning model that involves students in the active resolution of problems through investigation and problem-solving activities. The problems presented at the outset of the learning process are selected from real-world problems, thereby establishing a tangible focus for the educational endeavor. The formulation of PBL problems must meet several main characteristics to serve as a focus in learning. These characteristics include the following: (1) the problems must be real-life problems; (2) the problems must be open and have many solutions; (3) the problems must develop previous experiences; (4) the problems must be solvable by students with the knowledge gained from the learning process; (5) the problems must be presented in narrative form; and (6) the problems must encourage teamwork [42].

Research shows that the PBL model has been proven to significantly improve various student skills. Student participation in class activities and problem-solving skills increased after the PBL model was implemented [43, 44]. The results of the study also found that PBL was able to improve critical thinking skills [45, 46], creative thinking [43, 47], and communication [48, 49]. Several research results found that there is a significant correlation between problem-based learning steps and critical thinking skills. This means that problem-based learning activities are believed to facilitate students in practicing their critical thinking skills [50].

The expectation of developing 21st-century skills through the PBL model creates demands for teachers and preservice teachers, such as difficulties in developing curriculum and selecting topics, managing and designing PBL, creating a culture of collaboration and interdependence, providing scaffolding during independent and group investigations, stimulating students' initiative and creativity in solving problems, and conducting various assessment techniques in measuring knowledge and skills [51, 52]. In fact, 21st-century teachers are required to have pedagogical skills that support the development of student's skills, starting from planning, implementation, and evaluation [53]. Therefore, training for teachers and preservice teachers is needed to develop their competence in pedagogical practices that are in line with 21st-century skills. Before conducting further research, it is necessary to assess the extent of preservice teachers' knowledge and skills in designing 21st-century skills-oriented learning so that aspects that need to be developed or improved can be identified.

2. 4C SKILLS

21st-century skills refer to the skills that today's learners are expected to have in order to succeed in facing challenges, problems, life, and a successful future career [54, 55]. Human resources who will survive and succeed in the 21st century are humans who have soft skills [56]. Strong skills in the form of creative thinking, critical thinking for decision-making and problem-solving, collaboration, and communication. Framework for 21st Century Learning [10] has identified 21st century skills as 4C skills, including critical thinking, creative thinking, communication, and collaboration skills.

Critical thinking skills are defined as the ability to solve problems through the process of analytical thinking, assessment, evaluation, and reconstruction, which ultimately enables the formation of rational and logical decisions [57]. There are five indicators that describe critical thinking skills: (1) reasoning, (2) hypothesis testing, (3) argument analysis, (4) likelihood and uncertainty analysis, and (5) problem-solving and decision-making [58]. Proficient critical thinkers have been shown to demonstrate a deeper understanding of science learning materials [58], the ability to solve complex real-world problems [59], and the capacity to become active and informed citizens [60].

Creative thinking is defined as a cognitive process that involves the generation of novel concepts, the development of original solutions to problems, and the capacity to produce diverse and unique ideas [61]. There are three main characteristics of creativity: fluency, flexibility, and original thinking [62]. Fluency, also known as fluent thinking skills, involves generating numerous ideas and questions, formulating alternatives in problem-solving and problem-posing, offering multiple methods or proposals for various tasks, and recognizing deficiencies in objects or situations. Flexibility, defined as the capacity for adaptable thinking, encompasses the ability to generate diverse concepts, responses, or inquiries, to perceive problems from multiple perspectives, to present numerous solutions in varied methods, and to transition between divergent ways of thinking and approaches. It further involves the capacity to interpret problems in various forms, such as images or narratives, and to apply concepts guided by different principles. Original thinking, in turn, is defined by the ability to express oneself in unconventional ways, propose problems that have not been previously identified, interrogate established methodologies, and conceptualize novel approaches. It entails a distinct mode of thinking that differs from the thought processes of others.

The United States National Research Council (NRC) asserts that communication skills constitute one of eight competencies in science and engineering, encompassing the aptitudes of information acquisition, evaluation, and dissemination [63]. Communicating is characterized by the composition of written or oral reports that synthesize the findings from information searches, the establishment of associations, and the identification of patterns. Scientific communication skills encompass a range of competencies, including information retrieval skills, scientific reading, active listening and observation, scientific writing, information representation, and knowledge presentation [64]. Additionally, scientific communication skills are defined as the ability to pose questions, articulate key concepts, deliver oral presentations, engage in discussions, and formulate arguments using data [65].

Collaboration skills are recognized as essential competencies that must be acquired by 21st-century learners [54]. Collaboration skills refer to the abilities to work effectively with diverse team members, demonstrate respect, and exhibit fluency and the willingness to make decisions necessary to achieve common goals [66]. Trilling & Fadel identified several collaboration skills, including: These skills include respect, willingness, and compromise [7].

4C skills can be taught and developed through various subjects, including physics. Studies show that research related to 4C skills in physics education continues to grow, and critical thinking and problem-solving skills have become the main focus of research in recent years [13]. These studies generally use a quantitative approach, including the application of innovative learning models, the use of learning media, and the development of assessment instruments to measure students' 4C skills. Several studies have shown that physics learning that applies student-centered strategies can significantly improve 4C skills [15, 17, 18, 67-69].

To support the improvement of 4C skills in physics learning, teachers and prospective teachers are required to be able to integrate these skills into their teaching approaches. Therefore, the education of prospective teachers plays an important role in equipping them with the Knowledge and skills in designing and implementing learning that supports the development of students' 4C skills [54]. For the training and courses provided to be on target, the initial step that needs to be taken is to explore the level of knowledge and competence of prospective teachers in integrating 4C skills into their learning design. The findings from this initial study will provide deeper insights into designing effective training programs for prospective teachers.

3. RASCH ANALYSIS IN PHYSICS EDUCATION

Evaluation in the education of prospective physics teachers is important to provide an overview of the success of the prospective teacher education program and curriculum that has been carried out. Evaluation requires accurate and reliable measurement instruments and is able to provide detailed and clear information so that it is useful in evaluating the success of the program and curriculum. Rasch analysis can be used to develop measurement instruments as well as to explore further information related to student investigations and items to assess the ability of prospective physics teacher students to create 4C skill-oriented physics learning plans.

Rasch analysis is a probabilistic model that describes the interaction between people (test takers or survey respondents) and test or survey items, which are influenced by two parameters, namely the level of item difficulty and the person's ability. Rasch analysis was first developed by Danish mathematician George Rasch, who is known for his objective measurement method [70].

The Rasch model is very effective for measuring the quality of test instruments empirically [71]. Rasch analysis can investigate the extent to which test items define unidimensional and consistent constructs (construct validity) through analysis of item fit, item correlation, and test unidimensionality. In addition, Rasch analysis also allows to obtain a predicted order of item difficulty, which can be compared with the patterns observed in the Wright map. The quality of the items can also be evaluated through item reliability, which can be reported in terms of person reliability (analogous to test reliability in classical test theory, such as Cronbach's alpha) and item reliability, which has no analogue in classical test theory. The Rasch model can also report the results of an investigation into whether instrument items have different meanings for different groups. This investigation is carried out by differential item functioning (DIF) analysis. Several physics education studies have used the Rasch model in test development, such as the development of a test to measure students' understanding of graphs in different contexts [72], the development of a test to measure conceptual understanding in mechanics concepts [73], and the development of a concept inventory for an introductory semiconductor physics course [74]. In addition to measuring the quality of test items, the Rasch model is also effective for evaluating student development. The Rasch model is used in student development on the concept of buoyancy [75], and the Rasch model is used to explore the development of energy concept learning from elementary school to high school [76].

III. MATERIAL AND METHOD

1. METHODS AND PARTICIPANTS

This study used a survey design using quantitative methodology. Survey research uses data obtained from individual samples so that it is easier to generalize knowledge about the population [77]. The sampling technique in this study used purposive sampling. The purposive sampling technique was chosen because it allows researchers to deliberately select participants based on certain criteria relevant to the topic being studied [78, 79]. This approach ensures that the samples taken have appropriate characteristics and can provide in-depth information about the studied phenomenon [80]. This sampling technique selected 151 prospective physics teacher students from universities in West Kalimantan to participate in this study. The inclusion criteria in determining the participant selection process were: (1) students have taken the physics learning planning (PPF) course; (2) students have at least 2x experience in designing physics learning devices; and (3) provide voluntary consent to be involved in the research. All students who have taken the PPF course were involved in filling out the knowledge test related to 21st century-based learning, while only 52 students were asked to submit 4C skills-oriented learning devices. This was obtained from the results of interviews with students, namely students who have produced at least two physics learning designs based on problem-based learning models, project-based learning models or inquiry learning models. Table 1 presents a complete description of the demographics of the participants in this study.

Table 1. Demographic data of the participants.

Demografis		Frequency (f)	Persentase (%)
Knowledge assessment Participants			
Gender	Male	17	17.17
	Female	82	82.83
Semester level	IV	49	49.50
	VI	28	28.28
	VII	22	22.22
Instructional material contributors			
Gender	Male	9	17.30
	Female	43	86.70
Semester level	IV	9	17.30
	VI	21	40.39
	VII	22	42.31

2. *INSTRUMENTS*

The instruments in this study include a multiple-choice test instrument to measure the knowledge of prospective physics teachers related to 21st-century learning and an instrument to measure the skills of prospective physics teachers in designing 4C skill-oriented learning. The skill instrument consists of a lesson plan document assessment rubric and a student worksheet assessment rubric. The knowledge test instrument was developed in stages. The first stage was carried out by reviewing existing instruments and analyzing the content needed by prospective physics teachers in designing 4C skill-based learning. Based on the review results, a draft of the instrument was then prepared.

Furthermore, the draft of the instrument was validated by five physics education evaluation experts. Based on the results of the expert assessment, several questions were changed, either in the form of deletions, additions, or editorial revisions. After the revision process based on validation, the number of questions used in this study was 70 (Table 2). The skill instrument in a lesson plan document assessment rubric and student worksheets were developed by adapting the teacher profession program performance test [24], which was then adjusted to the 4C skill assessment aspects. Five physics education evaluation experts then validated the draft assessment rubric. Based on the validation results, revisions were made to several aspects and assessment indicators in deletions, additions, or editorial improvements. The assessment rubric refined after the validation process is presented in Table 3 and Table 4.

Table 2. Knowledge test material.

Material	Number of questions	Code
characteristics of the 21st century	4	A1-A4
critical thinking skills	6	A5-A10
creative thinking skills	6	A11-A16
collaboration capabilities	4	A17-20
communication skills	5	A21-A25
21st century learning	6	B1-B6
physics learning design	19	B7-B25
problem based learning model	20	C1-C20
Total	70	

Table 3. Lesson plan document assessment rubric.

Assessment Aspects	Indicator	Score Range	Code
Learning objectives	• Description of Learning Achievements in Learning Objectives in accordance with high-level thinking aspects and 4C skills	1-3	TP1
	• The description of Learning Achievements in Learning Objectives refers to the competencies in the CP.		TP2
	• Description of Learning Achievements in Learning Objectives includes competencies and scope of material		TP3
	• The description of Learning Achievements in Learning Objectives is written using communicative and easy-to-understand language.		TP4
	• The verbs used in learning objectives can be observed and measured.		TP5
Learning Objective Achievement Criteria (KKTP)	• Description of Learning Objectives in KKTP	1-3	KK1
	• The KKTP formulation is in line with the Learning Objectives		KK2
	• KKTP formulation oriented towards 4C Skills		KK3
	• The formulation of KKTP can be observed and measured with a designed assessment.		KK4
Subject matter	• Suitability of the subject matter with the TP and the 4C skill indicators to be achieved	1-3	SM1
	• The logic of the arrangement or sequence of teaching materials		SM2
	• The truth of the teaching materials presented		SM3
Assessment Plan	• Assessment is aligned with and can measure learning objectives and 4C skill aspects.	1-3	RA1
	• Completeness of coverage of 4C skills assessment aspects		RA2
Learning Tools and Media	• The suitability of the selection of learning media with the model, learning objectives, and class conditions.	1-3	PM1
	• The suitability of the selected printed and electronic learning resources with the 4C skills competencies		PM2
	• Complete plan for the use of teaching materials and teaching aids		PM3
	• The suitability of LKPD with the PBL model and supporting the development of 4C skills		PM4
Learning Steps	• steps or syntax according to the problem-based learning model in sequence to practice 4C knowledge and skills	1-3	LP1
	• Demonstrate the application of active learning/scientific learning and oriented towards 4C skills training		LP2

Table 4. Student worksheet document assessment rubric.

Assessment Aspects	Indicator	Score Range	Code
Content aspects	• Suitability of LKPD material with students' cognitive development	1-4	KI1
	• Supporting the implementation of teaching and learning processes based on student activities		KI2
	• Developing students' high-level thinking skills and 4C skills		KI3
Language aspects	• Conformity of sentences with Indonesian language rules	1-4	KB1
	• Simplicity of sentence structure		KB2
	• Multiple interpretations of sentences in LKPD		KB3
Aspects of investigative activities	• Investigation activities provide direct experience in LKPD	1-4	KP1
	• Implementation of scientific work in LKPD		KP2
	• The questions in the LKPD provide clues to discovering concepts independently.		KP3
Problem Solving Activity Aspects	• Characteristics of real-world problems	1-4	KM1
	• Real-world problems can encourage students to think at a higher level.		KM2
	• Activities in LKPD support the problem-solving process		KM3
Presentation aspects	• Ease of activity steps in LKPD	1-4	KY1
	• Presentation of LKPD problems accompanied by direct objects		KY2
	• Placement of students in LKPD as learning subjects		KY3
Graphic aspects	• Suitability of font type and size in LKPD.	1-4	KK1
	• Balance of layout composition in LKPD		KK2
	• Suitability of illustrations/pictures/photos in LKPD		KK3
	• LKPD display design		KK4

3. PROCEDURES AND DATA ANALYSIS TECHNIQUES

Data collection was conducted online using the Google Forms platform. Students can access test questions and collect learning tools online, making the data collection process more manageable. Online surveys administered via Google Forms are expeditious and uncomplicated, with the resulting data able to be stored in an online spreadsheet [81]. All students agreed to participate as participants in this study. Their identity data was anonymized to maintain confidentiality.

The Rasch model was employed to analyze the data of this study using the Winstep software, version 5.7.4 [36]. In this model, respondents and items interact simultaneously. Rather than utilizing raw scores, this model generates logit values, which represent the probability of a respondent selecting an item. The calculation of these logit values entails the application of the logarithm function to the item's odds ratio, thereby converting the raw score into the item's logit value. The odds ratio, a quantitative metric, quantifies the degree of consensus among respondents regarding an item in comparison to those who do not agree [82, 83]. The utilization of logit values in this context ensures a more objective evaluation of items, as it converts ordinal raw scores into ratio data that adheres to all integer requirements.

Several Rasch measurement outputs contain parameters to determine the quality of the instrument and evaluate the knowledge and skills of prospective teachers. The first output, in the form of a summary of measurement results that describe the quality at the instrument level, contains; MNSQ mean value, ZSTD mean, Person-Item Reliability Index, Cronbach's Alpha, Person-Item Separation Index, and Unidimensionality. The Person-Item Reliability Index meets the acceptance criteria if its value ranges from 0.68 to 1.00 [32, 84]. Meanwhile, the reliability criteria are based on Cronbach's values, with an acceptable reliability index range in the range of 0.45–0.98 [85]. The person-item separation index is met if the separation index value is >2 logit in order to distinguish the levels of data groups [86]. Unidimensionality analysis describes the construct validity of an instrument that meets the criteria if the percentage of Explained Raw Variance is >20% for dichotomous data and >40% for polytomous data [84, 87], and the value of The Unexplained Raw Variance in first contrast is categorized as weak (>15%), moderate (10-15%), strong (5-10%), solid (3-5%), and extraordinary (less than 3%) [36, 88].

The second output, in the form of analysis results that describe the suitability of the instrument at the item level, consists of Item Fit Order and Person-Item Measure (JMLE Measure). The results of the Item Fit Order analysis are used to determine the suitability of the items with Rasch Modeling, which contains Infit-Outfit Mean-square (MNSQ), Infit-Ourfit Z-Standardized (ZSTD) and Point Measure Correlation (PTM CORR) data at the item level. The accepted instrument items met the MNSQ acceptance criteria in the range of 0.5 < MNSQ < 1.5; the ZSTD value was in the range of -2.0 < ZSTD < +2.0; and the PTM CORR had a positive value [83]. The results of the Item Measure analysis were used to determine the level of difficulty of the test items, which were grouped based on the logit value of the item (LVI) and categorized into very difficult (LVI ≥ M+SD), difficult (M ≤ LVI < M+SD), easy (M-SD ≤ LVI < M), and very easy (LVP < M-SD). The Person Measure value is used to determine the level of student knowledge and skills based on the logit value of person (LVP) and is categorized into very high (LVP ≥ M + SD), high (M ≤ LVP < M + SD), low (M-SD ≤ LVP < M), and very low (LVP < M-SD) [89].

The third output is the results of the DIF analysis to detect item bias based on groups or semester levels, namely semesters 4, 6, and 8 [90]. DIF analysis will provide information about measurement invariance by comparing the ability based on groups to detect fairness or bias problems between groups. The criteria for detecting DIF of an item are if the value of ∣DIF contrast∣ >1.00 logit, Rasch-Welch t value >2, and probability p<0.05 [91, 92], where if these three criteria are met then an instrument item is biased towards the semester group. The fourth output is a Wright Map to visualize item targeting to people and evaluate the width of the item difficulty distribution with the width of the respondent's ability distribution [93].

IV. RESULT AND DISCUSSION

1. RESULTS OF THE QUALITY ANALYSIS OF THE KNOWLEDGE TEST INSTRUMENT AND ASSESSMENT RUBRIC

1.1 Validity and Reliability of Knowledge Tests

The objective of validity is to ascertain the extent to which the test can measure the intended aspect. On the other hand, reliability demonstrates the consistency of the results obtained if the test is repeated under similar conditions [94]. The results obtained will provide an overview of the quality of the instruments used in this study and their level of reliability in providing accurate and reliable data. Consequently, this validity and reliability analysis is imperative to ascertain that the instruments employed can generate valid and reliable data. The summary of the results of the validity and reliability of the knowledge test using the Rasch model is presented in Table 5.

Table 5. Summary statistics of person and items for knowledge test.

Psychometrics attribute	Person	Item
Number (N)	99	70
Measure (logit)		
Mean	-0.22	0.00
SD, Standard Deviation	0.90	0.89
SE, Standard Error	0.09	0.11
Mean INFIT		
MNSQ	0.99	1.00

Psychometrics attribute	Person	Item
ZSTD	-0.13	-0.21
Mean OUTFIT		
MNSQ	1.04	1.04
ZSTD	0.05	-0.08
Separation	2.98	3.49
Reliability	0.90	0.92
Cronbach's Alpha	0.91	
Uni-dimensionality		
Raw variance explained by measures	24.9%	
Unexplained variance in 1st contrast	5.5%	

Table 5 presents the person data and item data that were used to measure the validity of the student knowledge test related to 21st century learning. Based on the results of data analysis using Rasch, it was obtained that the average value of Infit-Outfit MNSQ for both person and item had met the predetermined criteria (0.5<MNSQ<1.5), as well as the average value of Infit-Outfit ZSTD which met the criteria (-2.0 <ZSTD <+2.0), so that in general the Knowledge test instrument met the fit and valid criteria. In addition, the construct validity of the test instrument can also be confirmed from the results of the unidimensionality of the test. The raw variance value is 24.9%, and the first residual contrast is less than 15%, thus meeting the construct validity criteria [37]. Therefore, the construction of the instrument can effectively measure students' knowledge of 21st-century learning and one variable as a whole. In addition, the separation index value for person (2.98) and item (3.49) is more than 2 logits, indicating that the person and item groups can be divided into more than two categories.

The person-item reliability of the knowledge test instrument meets the very good criteria with a reliability index of 0.92 (item) and 0.90 (person). The consistency of the measurement can be seen from the results of Cronbach's Alpha reliability of 0.91 with a very good category [85]. Overall, the knowledge test instrument meets the criteria of construct validity and very good measurement reliability.

1.2 Validity and Reliability of Assessment Rubrics

The learning device assessment rubric consists of a lesson plan assessment rubric and a student worksheet assessment rubric. The summary results of the statistical analysis of the validity and reliability of the assessment rubric data are presented in Table 6. The results show that the lesson plan assessment rubric and the student worksheet assessment rubric meet the fit and valid criteria and meet the construct validity criteria.

Table 6. Summary statistics of person and items for assessment rubrics (lesson plan and student worksheets).

Psychometrics attribute	Lesson plan		Student worksheet	
	Person	Item	Person	Item
Number (N)	52	20	52	19
Measure (logit)				
Mean	-2.91	0.00	-1.01	0.00
SD, Standard Deviation	1.21	1.60	1.15	2.97
SE, Standard Error	0.18	0.36	0.31	0.68
Mean INFIT				
MNSQ	0.95	1.02	1.14	1.05
ZSTD	-0.16	0.12	0.26	0.18
Mean OUTFIT				
MNSQ	0.91	0.91	0.84	0.84

ZSTD	-0.05	0.03	-0.17	0.06
Separation	2.98	2.96	2.29	4.39
Reliability	0.72	0.90	0.84	0.95
Cronbach's Alpha	0.91		0.91	
Uni-dimensionality				
Raw variance explained by measures	45.9%		77.7%	
Unexplained variance in 1st contrast	11.8%		6.2%	

Table 6 shows that the average value of Infit-Outfit MNSQ meets the criteria, ranging from 0.84 to 1.14, and the average value of Infit-Outfit ZSTD ranges from -0.17 to 0.26. Construct validity (unidimensionality) is also met based on the raw variance value of more than 40%, as shown in the lesson plan (45.9%) and student worksheets (77.7%), and unexplained variance in 1st contrast of less than 15%. The lesson plan and student worksheet assessment rubrics have acceptable person reliability (0.72 and 0.84), although this value indicates that the number of items is insufficient to assess the skill aspect.

The person-item reliability on the learning device instrument and student worksheet is in the very good category. The consistency of measurement and person-item interaction on the lesson plan instrument and student worksheet is also in the very good category with a Cronbach's Alpha index of 0.91. These results indicate that the assessment rubric items for lesson plans and student worksheets are feasible and effective for measuring the skills of prospective physics teachers in designing lesson plans and student worksheets oriented towards 4C skills in physics subjects.

1.3 Suitability of Knowledge Test Instruments

Although the average MNSQ and average ZSTD values of the knowledge test instrument have met the criteria at the instrument level, at the item level there are still several items that do not meet the criteria as shown in Table 7.

Table 7. Item measure order (misfit) for knowledge test instrument

Item	Total Score	JMLE Measure	SE Model	Infit		PTM	
				MNSQ	ZSTD	Corr.	Exp
C11	9	2.41	0.36	1.21	0.84	*-0.07	0.25
B25	14	1.86	0.30	1.24	1.21	*-0.02	0.30
C19	21	1.31	0.26	1.29	1.92	0.02	0.35
C20	22	1.24	0.26	1.42	*2.77	*-0.11	0.35
B15	23	1.17	0.26	1.35	*2.39	*-0.01	0.36
B14	34	0.53	0.23	1.40	*3.61	*-0.03	0.39
B6	37	0.38	0.23	0.78	*-2.53	0.61	0.39
B16	37	0.38	0.23	0.82	*-2.07	0.56	0.39
B1	39	0.28	0.22	0.83	*-2.04	0.57	0.40
A24	41	0.18	0.22	1.19	*2.09	0.20	0.40
B20	41	0.18	0.22	0.79	*-2.62	0.62	0.40
A25	42	0.13	0.22	1.24	*2.62	0.15	0.40
B4	44	0.03	0.22	1.1	*2.46	0.17	0.40
B19	46	-0.07	0.22	0.81	*-2.54	0.60	0.40
B11	48	-0.16	0.22	0.78	*-2.93	0.62	0.40
C5	48	-0.16	0.22	0.78	*-3.02	0.63	0.40
A4	49	-0.21	0.22	1.45	*5.06	*-0.09	0.40
B13	55	-0.50	0.22	0.82	*-2.37	0.57	0.39
B8	56	-0.55	0.22	0.82	*-2.38	0.58	0.39
A18	63	-0.89	0.23	0.81	*-2.30	0.57	0.37

B9	66	-1.05	0.23	0.76	*-2.83	0.62	0.36
C2	67	-1.10	0.23	0.80	*-2.21	0.58	0.36

Based on Table 7, all items meet the MNSQ acceptance criteria (0.5<MNSQ<1.5), but 19 items do not meet the ZSTD criteria (-2.0 <ZSTD < +2.0) and six items have negative TPM CORR values. Items with a ZSTD value >2.0 indicate that the item experiences misfit or the deviation of the item's logit value is slightly far from the average ZSTD value according to the Rasch model. However, none of the items meet the three criteria for the MNSQ, SZTD and PTM CORR values. So overall, the knowledge test instrument items can be maintained for data collection.

1.4 Knowledge Test Difficulty Level

The test items' difficulty level is analyzed from the Item Measure (JMLE) value or, in this analysis, the logits value of the item (LVI) in Table 6. Using the average value of the item measure of 0.00 and the standard deviation (SD) of the item measure of 0.89 (see Table 5), 70 test items are grouped into four categories of difficulty levels. This categorization is reinforced by the item separation index of 3.49 (strata 3-4), which shows that the item difficulty index can be representatively divided into four categories, namely very difficult (LVI ≥ 0.89), difficult (0.00 ≤ LVI < 0.89), easy (-0.89 ≤ LVI < 0.00), and very easy (LVI < -0.89). A summary of the test difficulty level analysis is presented in Table 8.

Table 8. Summary of the level of difficulty of knowledge test items.

Category	LVI	Item	Number of Items
Very difficult	LVI ≥ 0.89	A8, A6, B15, B17, B22, B24, B25, C11, C19, C20	10
Difficult	0.00 ≤ LVI < 0.89	A3, A13, A16, A19, A23, A24, A25, B1, B6, B12, B14, B16, B20, C3, C8, C10, C12, C13, C15, C16, C17, C18, B21	23
Easy	-0.89 ≤ LVI < 0.00	A1, A4, A5, A7, A9, A10, A12, A15, A18, A20, A22, B2, B3, B4, B5, B7, B8, B9, B10, B11, B13, B18, B19, B23, C1, C4, C5, C6, C7	29
Very easy	LVI < -0.89	A2, A11, A17, A14, A21, C2, C9, C14	8

Table 8 shows that there are 10 test items categorized as very difficult, 23 items in the difficult category, 29 items in the easy category and 8 items in the very easy category. This shows that the test instrument used to measure the knowledge of prospective physics teachers about 21st century learning has a variation in difficulty levels that are normally distributed.

2. RESULTS OF EVALUATION OF KNOWLEDGE AND SKILLS OF PROSPECTIVE PHYSICS TEACHERS

2.1 Evaluation of Prospective Physics Teachers' Knowledge Regarding 21st Century Learning

Logit Analysis value of person (LVP) classifies the level of student knowledge in answering knowledge test questions including; LVP ≥ 0.68 is classified as very high, -0.22 ≤ LVP < 0.68 is classified as high, -0.9 ≤ LVP < -0.22 is classified as low and LVP < -0.9 is classified as very low. The results of the knowledge data of prospective physics teachers about 21st century learning in detail are presented in Figure 1.

Analysis of students' knowledge related to 21st-century learning (Figure 1) overall found that 18 out of 99 (18.18%) students were at a very high level, 29 out of 99 (29.29%) students were at a high level, 25 out of 99 (25.25%) students were at a low level, and 27 out of 99 (27.27%) students were at a very low level. These results indicate that most prospective physics teacher students are still relatively low in 21st-century learning. Based on the semester level, it was found that 35 out of 49 (71.43%) students in semester 4 were in the very high/high category, and 28.57% were in the low/very low category. Semester 6 students with a very high/high category were 32.14%, and 67.86% were in the low/very low category. There were 13.63% of semester 8 students in the high category, and no students were in the very high category. These results indicate that more than half of the 4th-semester students have very high and high levels of knowledge, while the 6th and 8th-semester students mostly have low and very low levels of knowledge.

The evaluation was also conducted to investigate whether the instrument items have different meanings for different groups, such as grade-level groups [95]. This investigation can be done with Differential Item Functioning (DIF) analysis to gather evidence that the measurement function of the instrument functions the same across student semester levels.

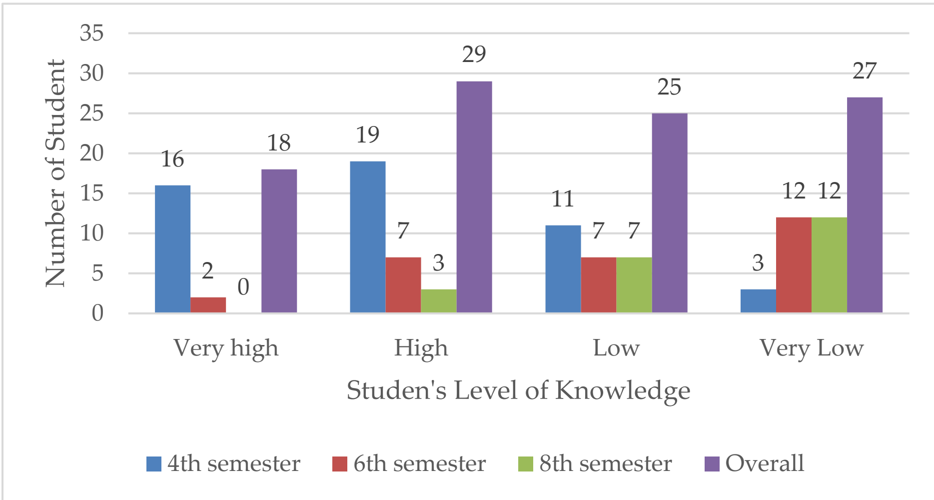

FIGURE 1. Categorization of knowledge level of prospective physics teachers.

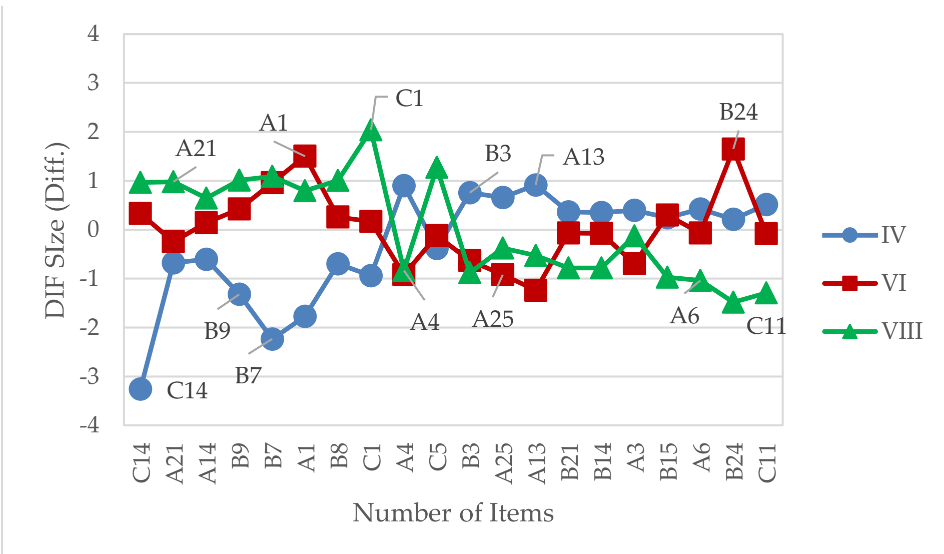

FIGURE 2. DIF analysis based on the level of semester (level IV=4th-semester, level VI=6th-semester, level VIII=8th-semester).

Based on the criteria for detecting DIF, from 70 test instrument items developed, 20 items were detected to be biased towards semester groups 4, 6 and 8. However, only 13 (18.57%) items met the three criteria, namely |DIF Contrast| >1.00 logit, Rasch-Welch t value >2, and probability p<0.05 (Figure 2). Thus, it was concluded that 18.57% of knowledge test instruments were biased towards semester groups. The items that were biased towards the semester level were six questions about 21st-century characteristic and 4C skills (Items A1, A4, A6, A13, A21, A25), four questions about 21st-century learning (Items B3, B7, B9, B24), and three questions about the problem-based learning model (Items C1, C11, C14). These results indicate that test items related to 21st-century characteristic and 21st-century learning tend to be more biased based on semester level. Test items on problem-based learning are less biased based on semester level, although one test item (C14) in this category has the highest DIF measure with a value of more than 3 logits. Test items C14, B9, B7, and A1 are more straightforward to answer correctly by 4th-semester students than by 6th and 8th-semester students. Test items A21 and C1 are more difficult to answer correctly by 8th-semester students compared to 4th and 6th-semester students. 6th-semester students find it easier to answer test item A25, but this is not so for 4th- and 8th-semester students. Meanwhile, test item B24 is more difficult to answer correctly by 6th-semester students compared to 4th and 8th-semester students.

2.2 Evaluation of the Skills of Prospective Physics Teachers in Designing Lesson Plans and Student Worksheets Oriented Towards 4C Skills

Person Measure data, or in the analysis called Logit value of person (LVP), is used to classify the level of student skills in making learning plans and student worksheets oriented to 4C skills. Student skills in making learning plans oriented to 4C skills are classified based on the categories of very high ($LVP \geq -1.7$), high ($-2.91 \leq LVP < -1.7$), low ($-4.12 \leq LVP < -2.91$), and very low ($LVP < -4.12$). While student skills in making student worksheets are classified based on the categories of very high ($LVP \geq 0.14$), high ($-1.01 \leq LVP < 0.14$), low ($-2.16 \leq LVP < -1.01$), and very low ($LVP < -2.16$). The results of student skills data in designing learning plans and student worksheets in detail are presented in Figure 3.

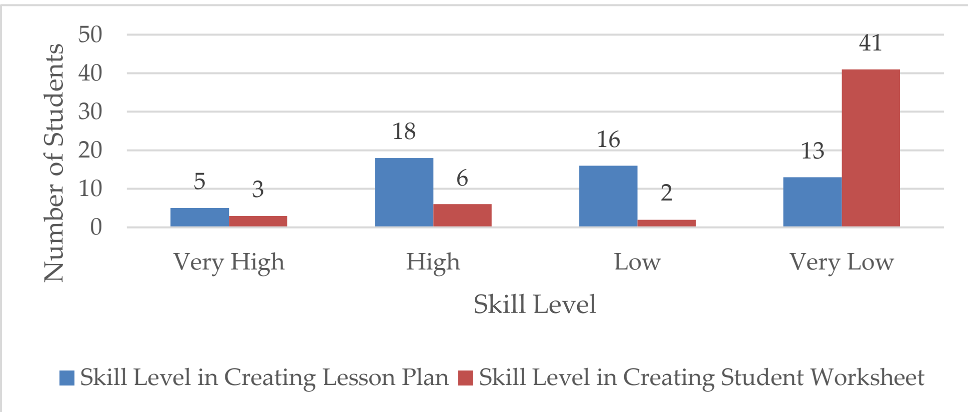

FIGURE 3. Skill levels of students in creating lesson plan and student worksheet.

Based on Figure 3, most students are still unskilled in compiling 4C skill-oriented lesson plans. As many as 5 out of 52 (9.61%) students are at a very high level, 18 out of 52 (34.61%) students are at a high level, 16 out of 52 (30.76%) students are at a low level, and 13 out of 52 (25.00%) students are at a very low level. These results indicate that most prospective physics teacher students are still less skilled in compiling 4C skill-oriented lesson plans. The same thing was found in student skills when creating 4C skill-oriented student worksheets. As seen in Figure 3, as many as 43 out of 52 (82.69%) students are at a low and very low level in creating 4C skill-oriented student worksheets.

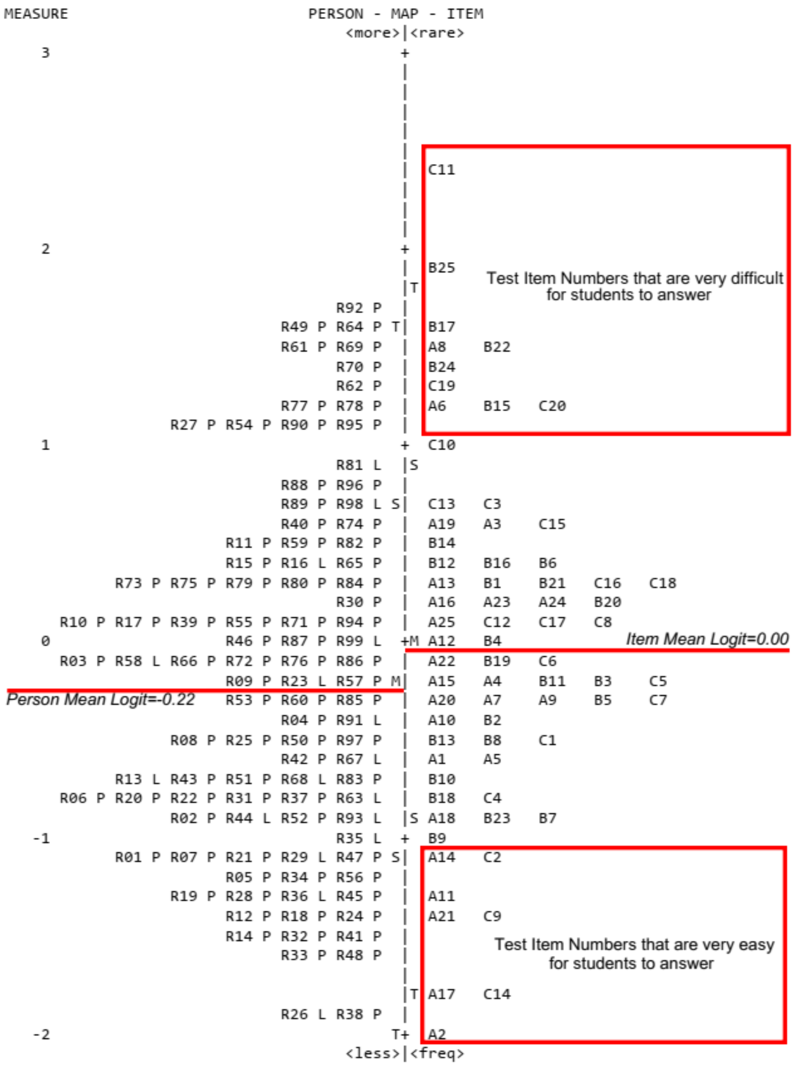

FIGURE 4. Wright's map of item-person in the test of knowledge regarding 21st century learning.

Next, the Wright Map visualization of the Rasch Model analysis results is presented. Wright Map is useful in visualizing item targeting to people and evaluating the width of the item difficulty distribution with the width of the respondent's ability distribution. Wright Map shows the interaction of respondents on the left side with items on the right side in the 21st-century skills knowledge and 4C skills test, as shown in Figure 4.

The Wright Map of Item-Person in Knowledge Test (Figure 4) shows that the average logit person is higher than the average logit item. This shows that, in general, students' ability to answer regarding 21st century learning knowledge test questions is slightly lower than the test instrument's difficulty level. However, the distribution of students' abilities is relatively balanced against the test items' difficulty levels. This can be seen from the distribution of respondents who do not accumulate in one category of item difficulty levels. Most students have adequate ability to answer tests on 21st-century skills and 4C skills. Another advantage of the Wright Map is that it can also be used to evaluate student knowledge individually. Although the distribution of student abilities is evenly distributed at each level of item difficulty, two 6thsemester students (R26L and R38P) require special attention because they have a logit value lower than two times the standard deviation. In addition, this Wright Map also highlights three test items, namely B25 and C11, which have very high levels of difficulty, and one item, A2, which is too easy. Not even a single student matches the items, meaning the chance of items B25 and C11 being answered correctly is far below 50% ($p<0.05$). Item A2 has a chance of always being answered correctly far above 50% ($p>0.05$), so it does not provide much diverse information in describing student abilities. Thus, the Wright Map provides important and valuable information for suggesting improvements to the learning process by considering the low level of student ability and evaluating extreme-value instrument items to be eliminated or revised so that the measurement becomes more effective.

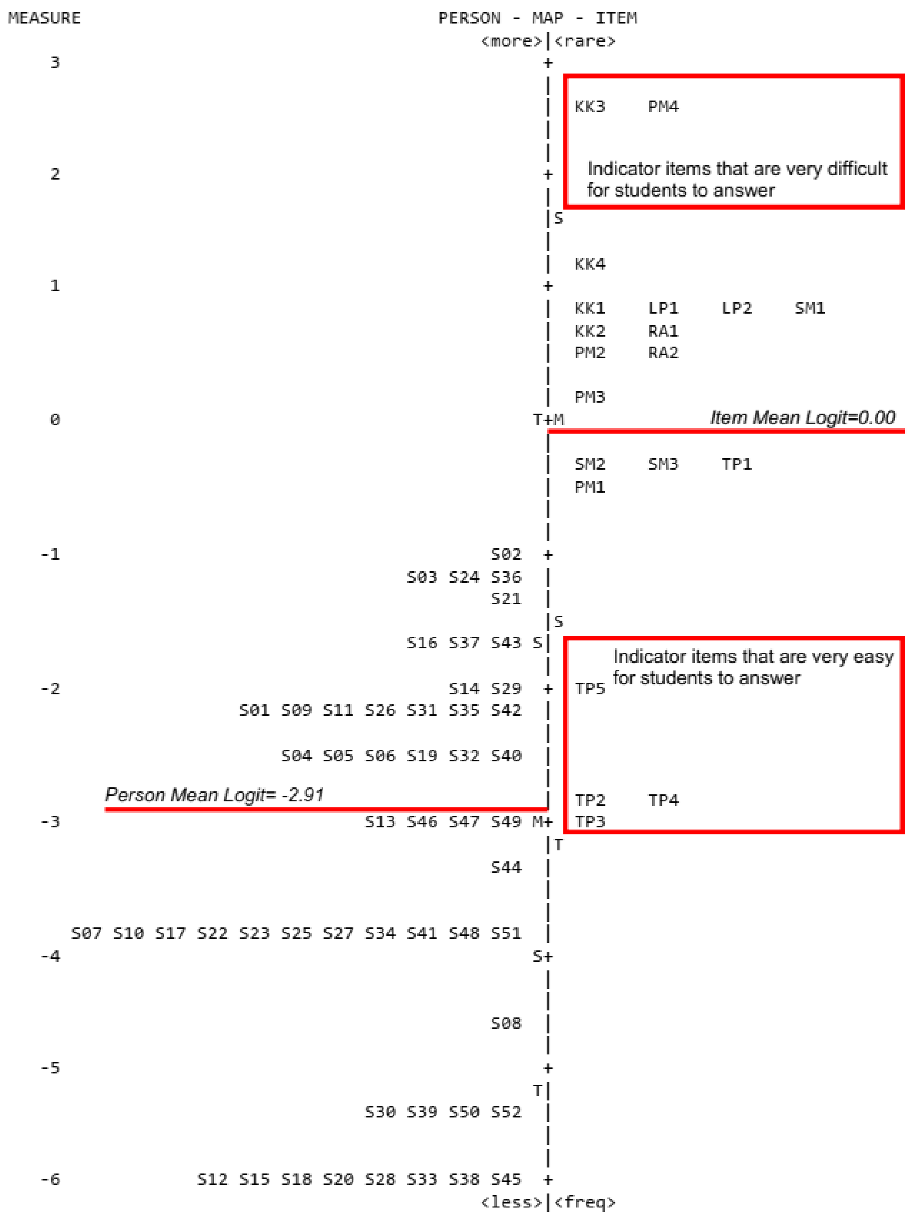

FIGURE 5. Wright's map of item-person in creating a 4c skill-oriented lesson plan.

The Wright Map visualization (Figure 5) is also displayed to evaluate respondents' interaction on the left side with items on the right side related to student skills in compiling a 4C skill-oriented learning plan. The item number in the Wright Map represents the assessment indicator for the learning plan designed by students.

Based on the Wright Map of Item-Person in Figure 5, it is known that the average person mean logit (-2.91) is far below the item mean logit (0.00). This shows that student's ability to prepare a 21st-century skill-oriented learning plan is far below the level of item difficulty or assessment indicators. This evaluation also shows that the distribution of students' abilities in preparing learning plans tends to be unbalanced or not evenly distributed at each level of item difficulty. 90.38% of students only understand or correspond to questions with easy difficulty (Indicators TP2, TP3, TP4 and TP5). These results show that most students can only design learning objectives well but have not been able to design other aspects of the learning plan, such as creating criteria for achieving learning objectives, determining subject matter, creating assessment plans, determining relevant learning media and creating learning steps. The indicators that are very difficult for students to achieve in preparing learning plans are indicators KK3 and PM4. This means that students are very unskilled and have difficulty in describing the criteria for achieving 4C skill-oriented learning and designing student worksheets that are by the problem-based learning model that supports the development of 4C skills. 13 students need special attention or extra guidance in learning to design 4C skill-oriented learning plans, especially for eight students (S12, S15, S18, S20, S28, S33, S38 and S45) with the lowest logit values in the Wright Map distribution. The results of this evaluation provide important information in describing students' abilities so that a more effective guidance process is needed for students in planning 4C skill-oriented learning plans. The ability to design 4C skill-oriented learning plans is an important skill that every prospective teacher-student must possess today.

3. DISCUSSION

The results of the study indicate that the student knowledge test instrument on 21st-century learning has met the criteria of validity and reliability based on Rasch parameters. Validity can be seen from the MNSQ (Mean Square) value for both person and item obtained ranging from 0.99 to 1.00, thus meeting the criteria of good fit. In addition, the quality of the questions also meets construct validity (unidimensionality) with a raw variance value of 24.9% and an unexplained variance in first contrast of less than 15%. This finding indicates that the test items exhibit a satisfactory fit with the Rasch model, devoid of any inconsistent response patterns [96].

In addition, this test instrument meets strong reliability criteria in measurement, as indicated by the Cronbach's alpha reliability value. This shows that the questions are well structured and the respondents' answers are consistent. A test must be reliable, which means that the test can produce consistent scores on different occasions (test-retest reliability) or when scored by different raters on the same occasion (inter-rater reliability) [85, 94]. The item-person reliability value also describes the reliability of item-person separation or good reproducibility [36].

The categorization of test items according to their difficulty level reveals a normal distribution proportion, with a smaller proportion of questions falling into the very easy and challenging categories compared to the easy and complex categories. This indicates that the majority of the questions are distributed between the easy and difficult categories, with fewer questions falling into the very easy and very difficult categories. This distribution reflects a balanced test design and takes into account the diversity of student ability levels so that, overall, the level of difficulty of the test items meets the requirements [37, 97].

The findings of the study demonstrated that the rubric instrument employed for evaluating students' competencies in designing 4C skill-oriented learning attained acceptable validity and reliability criteria based on Rasch analysis. The Rasch analysis revealed that all Rasch parameters exhibited very good criteria, ranging from 0.84 to 1.14 [70]. Each item at the level and subdimension of the instrument demonstrated a good reliability value above 0.70. This finding indicates that the instrument meets the reliability threshold established by Taber [85].

Based on the LVP analysis, students' knowledge related to 21st-century learning was classified into four categories (Figure 1). The results showed that 47 (47.47%) students had high knowledge, while 52 (52.52%) had low knowledge. This finding indicates that most prospective physics teacher students still do not have a good understanding of 21st-century learning. Interestingly, when viewed based on semester level, students in semester IV tend to have better knowledge than students in semesters VI and VIII. This shows that students in lower semesters understand 21st-century learning better than students in higher semesters. This may be because the material related to 21st-century learning is taught when students are in semester IV, so the retention of students in semester IV is better than students in semesters VI and VIII. Retention is a person's ability to remember concepts that are applied and intervened after a certain period since the initial learning time [98, 99]. Several factors influence a person's retention, including (1) the extent to which the concept has been conveyed to students, (b) how much the concept is meaningful and can be applied in everyday life, and (c) the duration of study time [98, 100].

In addition, the results of the differential item functioning (DIF) analysis detected measurement bias in the 21st-century skills and 4c skills knowledge tests based on semester level (4th, sixth and eighth semesters). The results showed that items on 21st-century skills and learning tended to be more biased based on semester level. Items on problem-based learning were less biased based on semester level. Furthermore, knowledge test items related to the topics of critical thinking skills, creative thinking skills, collaboration skills, communication skills, and physics learning design did not experience measurement bias. Although only 13 (18.57%) items were successfully predicted to have a high potential bias towards students' semester level, based on several previous relevant studies [32, 90, 92], there is no agreement on the maximum percentage of bias required in a test measurement instrument. Researchers can revise biased items or even delete these items. Nevertheless, information regarding DIF in this knowledge measurement instrument is useful in evaluating the performance of the instrument and contributes to conducting more effective measurements in the future.

Next, the study results related to prospective teachers' skills in designing 4C skill-oriented learning plans. Categorization of skills in designing learning plans was carried out by analyzing LVP. As a result, the skills of designing learning plans were classified into four categories, as shown in Figure 3. Based on these results, only 9.61% (5 students) were included in the very high category, 34.61% (18 students) were included in the high category, 30.76% (16 students) were included in the low category and 25.00% (13 students) were included in the very low category. These results confirm that prospective physics teachers must be educated and trained to improve their skills in designing 4C skill-oriented learning plans. Interestingly, the same results were also found in science teachers that most science teachers had low abilities in planning and implementing 4C skill-oriented science learning [24]. Students' difficulty in designing learning plans lies in formulating indicators/criteria for 4C skill-oriented learning and designing student worksheets using the problem-based learning model to support the development of 4C skills (Figure 5). This study also found that students' skills in designing student worksheets were mainly in the very low category, namely 78.84% (41 students). As many as 3.85% (2 students) were included in the low category, 11.54% (6 students) were included in the high category, and 5.77% (3 students) were included in the very high category. Overall, these findings indicate that many students still need to improve their skills in designing physics learning oriented towards 4C skills.

Previous studies also found that six out of ten teachers interviewed showed incompetence and lack of 4C skills. In addition, seven out of ten prospective teachers admitted to having limited knowledge in teaching 4C skills in learning [80]. The study also revealed that prospective physics teachers can use technology to guide students in improving communication and collaboration skills and encourage students to share ideas and knowledge [101]. However, most prospective physics teachers still have difficulty understanding physics concepts in depth, so they have not been able to develop comprehensive lesson materials. One of the basic skills that teachers must have to become effective teachers is knowing the subjects they teach and how to teach the subjects to students [102, 103].

Other findings in this study show that the logit value of students' ability to answer 21st-century skills and 4C skills knowledge test questions is slightly lower than the logit value of the difficulty level of the test instrument. However, the distribution of students' abilities in the 21st-century knowledge test and 4c skills is relatively balanced and well spread within two standard deviations of the respondents' mean logit value. This result differs from the test of students' skills in making 21st-century skills-oriented lesson plans. The Person-Item interaction in the Wright Map shows that students' average ability to make lesson plans is still very low. The distribution of students' abilities is uneven and unbalanced, even 90.38% of students can only complete indicators with a very low category when making lesson plans. In addition, the Wright Map in this study also provides useful information in evaluating the items of the student knowledge and skills test instrument. So that researchers can consider improving or deleting these items. The deletion of these items will not affect the overall performance of the instrument because the development of the test instrument covers the entire scale of respondents' abilities [95].

This finding shows that the knowledge and abilities of teachers and prospective teachers in designing and implementing physics learning that fosters students' 4C skills need to be improved. Therefore, teacher education institutions need to use these findings as a basis for designing professional development programs for prospective teachers. In this regard, training programs for prospective physics teachers in universities should place more emphasis on teaching 4C skills and encourage innovation in learning. Thus, future physics teachers can be better prepared to meet the demands of 21st-century teaching and learning.

V. CONCLUSION

In conclusion, this study has successfully tested the quality of the developed instrument and evaluated the knowledge and skills of prospective physics teachers in compiling learning devices based on 21st-century skills and 4C skills using Rasch analysis. The designed knowledge test instrument and skills assessment rubric have been proven to meet the Rasch Model parameter criteria, starting from validity and reliability, separation index, and construct validity (unidimensionality). So that this instrument can be used to predict and evaluate the knowledge and skills of prospective physics teachers, including its application to a broader range of relevant respondents. However, the evaluation results of student's knowledge and skills show that most prospective physics teachers still have limited knowledge of 21st-century learning and difficulty in designing learning that supports the development of 4C skills.

These findings provide initial insights into the need to improve physics teacher education curricula that are more relevant to future demands. The knowledge and skills of prospective physics teachers in designing 4C skill-oriented learning need to be improved. Therefore, training, guidance, and practice based on 4C skills need to be integrated more systematically into teacher education programs. This study is also one of the first studies to utilize Rasch analysis to assess the knowledge and skills of prospective physics teachers in Indonesia, so it can be a reference for research and development of similar evaluation instruments in the future.

VI. LIMITATIONS

This study has several limitations. First, the coverage of participants was limited to one region in Indonesia, so the findings may not be generalizable to a broader context. Second, there is the possibility that other variables influence the study results but are not fully controlled in this study, such as the test duration, the environment when filling out the test, and previous experience in working on similar instruments. Therefore, further research is recommended to expand the geographical coverage and consider more variables that can increase the validity of the findings.

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Author Contributions

All authors made an equal contribution to the development and planning of the study.

Conflicts of Interest

The authors confirm there are no conflicts of interest.

Data Availability Statement

Data are available from the authors upon request.

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