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Rasch Model Analysis for IoT-based PJBL Hybrid Learning Design in MBKM Curriculum

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Abstract

Background of study: Even though the use of Project-Based Learning (PjBL) and the Internet of Things (IoT) in education is still growing, the integration of these two technologies in high-level education is still being explored, particularly in the use of the Merdeka Belajar Kampus Merdeka (MBKM) curriculum and the Indikator Kinerja Utama (IKU). This kesenjangan highlights the need for innovative teaching methods that integrate pedagogy and technology to meet the challenges of the digital age.

Aims: The purpose of this study is to analyze the need for developing collaborative hibrida learning designs that integrate PjBL and IoT technology in order to execute MBKM curricula and reach IKU pendidikan tinggi.

Methods: This study employs a survey methodology in which data is collected by a survey consisting of eighteen questions posed to university professors. Model Rasch with Winstep lunak perangkat is used for data analysis to assess the validity and reliability of research instruments.

Result: Results indicate a strong demand for a hybrid learning system that effectively combines PjBL with IoT to support collaborative and interactive learning. The instrument reliability achieved a Cronbach Alpha of 0.95, indicating excellent reliability, while the Person Reliability and Item Reliability were measured at 0.90 and 0.46, respectively. The findings suggest that all questionnaire items were fit for assessing the critical thinking capabilities of students across different institutions.

Conclusion: These results highlight the necessity of developing hybrid learning models to address educational challenges in the digital era, ensuring curriculum alignment and facilitating the achievement of MBKM goals. This study contributes to advancing higher education by providing actionable insights into learning design development that integrates cutting-edge technologies.

A. Introduction

The rapid advancement of technology and information has profoundly influenced various aspects of life, including the education sector (Mena-guacas et al., 2025). In response to these developments, educational institutions are challenged to adapt their learning processes and outcomes to ensure quality and relevance. One of the significant transformations required is the integration of digital technologies into learning

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designs, particularly to meet the needs of Generation Z students, who are characterized by their familiarity with digital tools and preference for collaborative learning environments. This shift necessitates innovative approaches that address issues such as curriculum implementation, learning motivation, assessment processes, accessibility, and educational outcomes (Hutson et al., 2022) (E. N. Hayati, 2024).

Hybrid learning, which combines online and offline learning environments, has emerged as a viable solution to address these challenges. Specifically, Project-Based Learning (PjBL) integrated with Internet of Things (IoT) technology offers an innovative approach to enhance collaborative learning experiences (Rosa et al., 2025). However, many educators lack the necessary understanding and tools to implement hybrid PjBL effectively. This gap hinders the achievement of critical educational goals, such as those outlined in the *Independent Learning Independent Campus* (MBKM) curriculum and the Key Performance Indicators (KPIs) for higher education institutions in Indonesia. These KPIs emphasize the importance of collaborative and participatory classes, practical student experiences, and international partnerships to improve accreditation and ensure global competitiveness. the Internet of Things (IoT) is a breakthrough that combines intelligent systems, frameworks, smart devices, and sensors (Choudhary, 2024). Furthermore, the Internet of Things (IoT) can exploit quantum and nanotechnology in hitherto inconceivable storage age, sensing, and processing speed (Bunyamin, 2023).

Previous studies on hybrid learning and Project-Based Learning (PjBL) have laid foundational insights into their individual benefits and applications. However, most of these studies have been fragmented, addressing either the pedagogical aspects of PjBL or the technological integration of Internet of Things (IoT) without exploring their combined potential in a cohesive hybrid learning design. Additionally, limited research exists on the alignment of these learning innovations with the specific requirements of the *Merdeka Belajar Kampus Merdeka* (MBKM) curriculum and the strategic Key Performance Indicators (KPIs) of higher education institutions in Indonesia. This gap highlights the need for a comprehensive approach that bridges innovative learning designs with the broader goals of curriculum implementation and institutional development.

The integration of Project-Based Learning (PjBL) with Internet of Things (IoT) technology is not only relevant in the local context, such as the implementation of the Merdeka Belajar Kampus Merdeka (MBKM) curriculum in Indonesia, but also aligns with global trends in educational transformation in the digital era. Internationally, technology-based education has seen significant growth as educational systems adapt to the demands of the Fourth Industrial Revolution and knowledge-based societies. The PjBL-IoT model supports active learning approaches focused on developing 21st-century skills such as problem-solving, collaboration, and digital literacy, which are increasingly emphasized in global education systems. International organizations like UNESCO and the OECD highlight the importance of pedagogical innovations that leverage technology to enhance student engagement and ensure real-world relevance in learning. Moreover, the adoption of PjBL-IoT in developed countries, such as the United States and Finland, has demonstrated its effectiveness in boosting student motivation, fostering interdisciplinary learning, and preparing learners for dynamic work environments. In this context, the development of hybrid learning designs based on PjBL-IoT represents a significant contribution toward aligning Indonesia's education system with global standards while facilitating the exchange of best practices in educational technology.

Project Based Learning model is a learning model that actively involves students both individually and in groups in achieving learning objectives by producing real products or works (Guo et al., 2020). By using Project Based Learning, learning is not merely memorizing concepts and teachers as the only source of information, but will bring students to actively participate, because students will be asked to do various tasks, such as working in groups, interacting with friends, and submitting opinions (Sastradiharja & Febriani, 2023).

In the context of education, IoT technology can be applied to enhance the learning experience and create a more interactive and adaptive learning environment. The Internet of Things (IoT) has proven to be a very effective solution in increasing efficiency and productivity in various industries (Alvendri et al., 2023). With IoT, data from various sources such as sensors, mobile devices, and teaching tools can be collected and analyzed in real time, providing deeper insights into students' learning processes. The use of IoT devices in education can increase student engagement by up to 25% because they provide accurate data to adjust learning methods by Khoir (2024). Hybrid Learning has an implementation model consisting of elements of face-to-face, personalization, blended learning, adaptive educational equipment, social distancing, flexible agendas, distance education, and health and safety factors (Naaziyah & Wati, 2024).

The novelty of this study lies in its integration of PjBL and IoT technology within a hybrid learning framework specifically tailored to support the MBKM curriculum and higher education KPIs. By leveraging the Rasch model for data analysis, this research offers a detailed and reliable evaluation of student and educator needs across diverse academic contexts. Furthermore, this study contributes to the body of knowledge by proposing an innovative hybrid learning design that not only enhances student engagement and critical thinking skills but also addresses systemic challenges in curriculum implementation and accreditation requirements. This research extends the theoretical and practical understanding of hybrid learning, providing actionable insights and a scalable framework that can inform future educational practices and policies in the digital era. research Surya, Relmasira, and Hardini (2018) which applies the PjBL learning model to improve student learning outcomes and creativity. From several previous studies mentioned above, researchers will look for research innovations so as not to repeat similar research. One form of research innovation is to create research that combines two components at once, namely hybrid learning, PjBL

Despite the potential of hybrid PjBL to address these challenges, there remains limited research that comprehensively explores its integration with IoT technology in the context of MBKM curriculum implementation. This study aims to fill this gap by analyzing the need for developing a collaborative hybrid learning design that integrates PjBL and IoT. By employing the Rasch model for data analysis, this study seeks to provide evidence-based insights into the design and implementation of innovative hybrid learning models to meet the demands of the digital era and achieve the targeted educational KPIs.

B. Research Methods

This study employed a quantitative survey design to analyze the need for developing a collaborative hybrid learning design integrating Project-Based Learning (PjBL) and Internet of Things (IoT) technology. The focus of this research was to align the learning design with the *Merdeka Belajar Kampus Merdeka* (MBKM) curriculum and the achievement of Key Performance Indicators (KPIs) in higher education institutions. The methodology involved several steps, beginning with research design using a survey approach to collect data on the needs and readiness of students and lecturers to implement a collaborative hybrid learning design. The Rasch model was utilized for data analysis to ensure valid and reliable measurements. The study selected its population and sample purposively, targeting students and lecturers from nine universities in Indonesia, including Bengkulu University, Dehasen Bengkulu University, Muhammadiyah University Palembang, PGRI Silampari University, Ratu Samban University, Musamus Merauke University, Tanjungpura University, STKIP PGRI Trenggalek, and Malikussaleh University. The sample consisted of individuals directly involved in the implementation and experience of hybrid learning. The instrument used was a needs analysis questionnaire containing 18 items. The questions were developed using a Likert scale with four response categories, ranging from "Strongly Disagree" to "Strongly Agree." The questionnaire was designed to assess the needs and expectations of students and lecturers regarding hybrid learning, PjBL, and IoT integration. Data collection was conducted over seven months, with the questionnaire distributed both online and offline to ensure broad participation from the target population. The respondents included 55 students and lecturers from the participating universities. Data analysis employed the Rasch model with the assistance of Winstep software. The analysis steps included testing instrument reliability using Cronbach's alpha, conducting item and respondent analysis with the Rasch model to evaluate the fit between questionnaire items and participant responses, and performing logit analysis to transform raw scores into logit values for identifying interactions between respondents' abilities and item difficulty levels. Additionally, Wright maps and other graphical tools were used for mapping and validation to analyze the distribution of respondents' abilities and item difficulty, ensuring the validity of the instrument.

The study adhered to ethical guidelines, including obtaining participant consent, maintaining confidentiality, and minimizing potential risks during the research process. This methodological approach provides a systematic and data-driven foundation for developing innovative hybrid learning designs that are relevant to the digital era and contribute to the advancement of higher education practices in the future.

Rasch Model Equation

The Rasch model for dichotomous data (correct/incorrect) is expressed as:

$$P(X_{ni} = 1 \mid \theta_n, \delta_i) = \frac{e^{\theta_n - \delta_i}}{1 + e^{\theta_n - \delta_i}}$$

Where:

a. $P(X_{ni} = 1)$: Probability that respondent answers item correctly.ni
b. θ_n: Ability of respondent.n
c. δ_i: Difficulty level of item .i
d. e: Natural logarithm base.

This equation describes the probability of a respondent with ability answering an item with difficulty correctly.$\theta_n \delta_i$

Estimation of Respondent Ability ()θ_n

The ability of a respondent in the Rasch model is estimated using the logit formula:

$$\theta_n = \ln\left(\frac{\text{Odds}_{\text{correct}}}{\text{Odds}_{\text{incorrect}}}\right)$$

Where:

$$\text{Odds}_{\text{correct}} = \frac{\text{number of correct responses}}{\text{number of incorrect responses}}$$

Estimation of Item Difficulty ()δ_i

The difficulty level of an item is calculated as the average logit of the respondents who answered the item correctly:

$$\delta_i = \frac{\sum_{n=1}^{N}(\theta_n)}{\text{N}}$$

Where:

a. N: Number of respondents who answered item correctly.i
b. θ_n: Ability of respondent .n

Instrument Reliability

The reliability of persons () and items () in the Rasch model is calculated using the following formulas:$R_p R_i$

$$R_p = \frac{\text{SD}_{\text{person}}^2 - \text{SEM}_{\text{person}}^2}{\text{SD}_{\text{person}}^2}$$

$$R_i = \frac{\text{SD}_{\text{item}}^2 - \text{SEM}_{\text{item}}^2}{\text{SD}_{\text{item}}^2}$$

Where:

a. $\text{SD}_{\text{person}}$: Standard deviation of respondent abilities.
b. SD_{item}: Standard deviation of item difficulty levels.
c. $\text{SEM}_{\text{person}}$: Standard Error of Measurement for persons.
d. SEM_{item}: Standard Error of Measurement for items.

Fit Statistics

The fit between the data and the Rasch model is evaluated using INFIT Mean Square (MNSQ) and OUTFIT Mean Square (MNSQ), calculated as:

$$\text{MNSQ} = \frac{\sum_{n=1}^{N} w_{ni}\,(X_{ni} - P_{ni})^2}{\sum_{n=1}^{N} w_{ni}}$$

Where:

a. w_{ni}: Weight for the response to item .ni
b. X_{ni}: Actual response (0 or 1).

c. P_{ni}: Probability predicted by the Rasch model.

Cronbach's Alpha

Internal consistency reliability is calculated using Cronbach's Alpha formula:

$$\alpha = \frac{K}{K-1}\left(1 - \frac{\sum_{i=1}^{K}\sigma_i^2}{\sigma_t^2}\right)$$

Where:

a. K: Number of items.

b. σ_i^2: Variance of each item.

c. σ_t^2: Total variance of the scores.

(Sumintono, 2014)

Rasch analysis is a mathematical modeling approach based on latent properties and achieves additivity of sticky conjoin (probability), conjoin means measuring persons and items on the same scale Bond and Fox (2007). The aim of Rasch's analysis is to maximize trait homogeneity and to allow for greater redundancy without reducing measurement information by item or rating level to produce a more valid and simpler measure. The basic requirements for the Rasch model that need to be considered are unidimensional, item fit, difficulty / ability estimation, reliability, and measurement information functions (Darmana et al., 2021).

Instrument items are assigned quantitative values as seen in Table 1 below:

Table 1. Interpretation of the Likert Scale

Percentage (%)	Category
1	Strongly disagree
2	Disagree
3	Agree
4	Strongly Agree

(S. Hayati et al., 2015)

There are four aspects of testing conducted to determinesexual harassment instruments, including (1) reliability and separation indexes, (2) dimension tests, (3) fit and misfit items, and (4) test information functions (Erwinda et al., 2020). Data analysis was carried out using the Rasch model and assisted by Winstep software developed by Linacre (2011). The Rasch model is able to see the interaction between respondents and items at once. In the Rasch model, a value is not seen based on the raw score, but rather a logit value that reflects the probability of an item's selection in a group of respondents. The reliability value between students and question items can be determined using Table 2.

Table 2. Reliability Values

No	Range	Category
1	< 0.67	Weak
2	0,67 – 0,80	Enough
3	0,80 – 0,90	Good
4	0,91 – 0,94	Very good
5	>0.94	Special

B. Sumintono (2016)

The Rasch Model measurement is a measurement model that is formed from considerations that take into account the validity and reliability of each prospective respondent who answers the item/question and the difficulty of the item/question for each question/item by Salma Hayati and Lailatussaadah (2016).

C. Results and Discussion

1. Results

At this stage, a needs analysis was conducted to develop a learning design based on Project-Based Learning (PjBL) that integrates Internet of Things (IoT) technology within a collaborative hybrid learning scenario. This approach was used to gain a deeper understanding of how IoT can support collaborative learning activities in hybrid environments, from both student and lecturer perspectives. The data collection technique employed in this study utilized questionnaires distributed to students and lecturers to assess their readiness and needs in implementing IoT-based hybrid learning. The research sample consisted of participants from nine universities, namely Bengkulu University, Dehasen Bengkulu University, Muhammadiyah University Palembang, PGRI Silampari University, Ratu Samban University, Musamus Merauke University, Tanjungpura University, STKIP PGRI Trenggalek, and Malikussaleh University. The questionnaire, comprising 18 statements, was distributed to students and lecturers across these nine universities. The results of the questionnaire analysis, which were completed by the lecturers, are presented in Figure 1. These findings provide insights into the readiness and needs of both students and lecturers in adopting collaborative hybrid learning models that incorporate IoT, serving as a foundational step for developing innovative learning designs tailored to modern educational demands

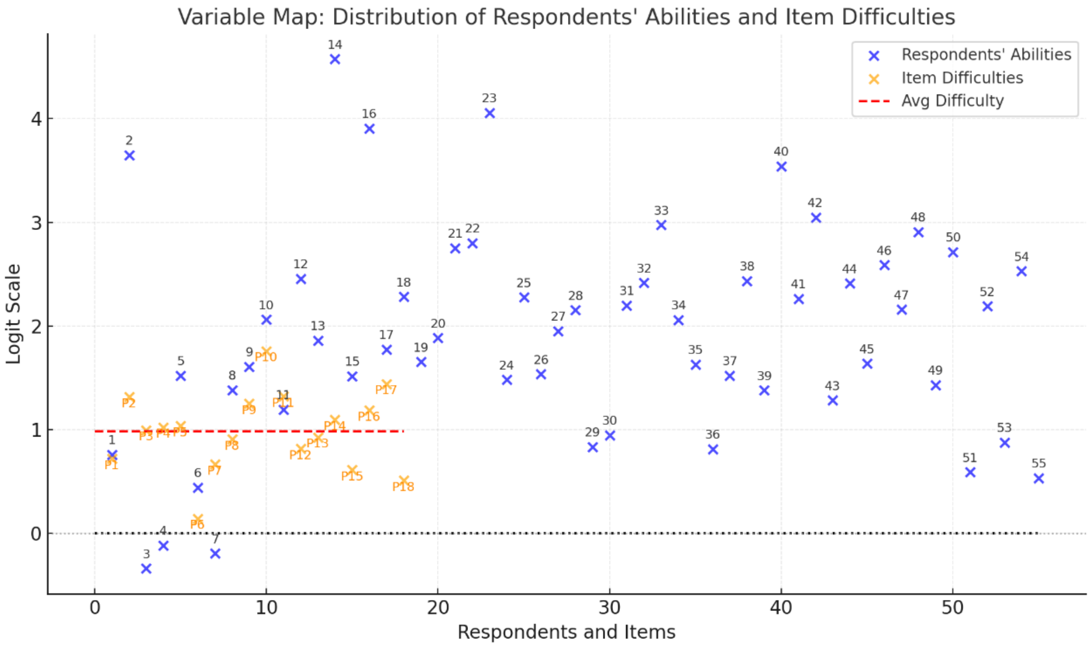

Figure 1. Output from Variable Maps

The Variable Maps in Figure 1 provide a visual representation of the distribution of respondents' abilities and item difficulty in the Rasch model. This analysis includes interactions between respondents and items, which are displayed in a logit scale. In the Distribution of Respondents (Person), namely the Respondent's Ability Level, that is, through the Respondents, they are grouped based on their ability level. On the logit scale, respondents at the top of the graph have a higher level of ability compared to respondents at the bottom. This data shows that respondents with high abilities (logit > 5): Numbers 15 and 18. Respondents with low ability (logit < 0): Numbers 55, 38, and several others. Next is the Distribution of Respondent Abilities. The distribution of respondents' abilities showed that most of them were in the logit range between 2 and 4. This distribution indicates that the majority of respondents have moderate ability, with a small number of respondents having very high or very low ability. In Item Difficulty, the Item Difficulty is seen as.

1. Items with high difficulty (logit > 0): Items P5, P18, P7, and P14.
2. Low-difficulty items (logit < 0): Items P1, P2, and P12.

Furthermore, on the Item Difficulty Spread, it is seen that most items are in the logit range between 0 and 3. This shows that the difficulty level of the questions is quite diverse, but not too extreme. Only some items are very difficult or very easy. For the Respondent and Item Suitability data, the Person and Item

Interaction on this graph shows that the respondents' ability and the difficulty level of the item are quite balanced, with most respondents having the appropriate ability to answer the existing items. Respondents with high abilities tend to be able to answer more difficult items. Respondents with low ability face difficulties in answering difficult items. The Misfit Area shows that some of the respondents at the top of the graph have much higher abilities compared to the highest item difficulty. This suggests that some items may be too easy for high-ability responders. Based on this, the Interpretation of Results on Instrument Reliability has a distribution of logits, which shows that the instrument is quite effective in measuring the ability of respondents at various levels. However, some items (such as P1 and P2) may need to be revised to increase the difficulty level so that it is more suitable for respondents with high abilities. Furthermore, the Suitability of Items with the Rasch Model shows that most of the items are in a normal logical range and balanced with the respondent's ability, so it can be concluded that the items have validity and can be used for the evaluation of IoT-based hybrid learning needs. Based on the above, the Variable Maps image above shows that the majority of respondents have moderate ability, which corresponds to the varying difficulty level of the item. This instrument is quite valid and reliable in measuring students' ability to develop hybrid learning designs based on PjBL and IoT. However, revisions to some items may be necessary to correct minor discrepancies between respondents with high ability and difficulty of items.

The FGD results have agreed on the need to immediately apply the blended learning and hybrid learning models, namely combining and combining various teaching models and methods, both online and offline, applying conventional and digital technology. Digital applications in learning models and digital applications in teaching methods. Combining various IoT-based learning models and methods, but still in a conventional environment (Yunarti et al., 2022).

Based on the table, the analysis of students' abilities with the Rasch model was carried out using the Winsteps application. The following are the output results of Ministep's analysis:

Table 3. Output Summary Measured Item

	Total				Infit		Outfit	
	score	Count	Measure	Model s.e	MNSQ	ZSTD	MNSQ	ZSTD
MEAN	57.8	18	2.48	0.55	1	-0.48	1.02	-0.49
WITHOUT	1	0	0.27	0.02	0.16	0.34	0.17	0.34
P.SD	7	0	1.81	0.12	1.08	2.3	1.11	2.31
S.SD	7	0	1.83	0.12	1.1	2.32	1.12	2.34
MAX.	71	18	6.59	1.03	6.31	5.15	6.32	5.12
MIN.	36	18	-1.84	0.36	0.04	-6.05	0.03	-5.96

Real rmse .65 true sd 1.69 separation 2.60 person reliability .87 |
|model rmse .57 true sd 1.72 separation 3.04 person reliability .90 |
| s.e. Of person mean = .27

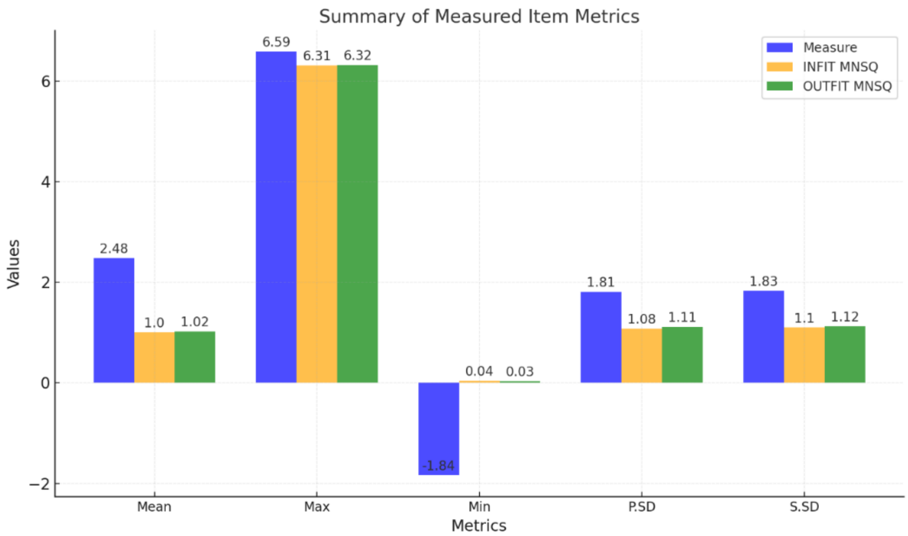

Figure 2. Summary of Measured Item Metrics

Table 3 and Figure above provides the results of the analysis of the Rasch model that evaluates the difficulty level of items in the questionnaire with the help of Winstep software. Judging from the descriptive statistical analysis on the MEAN (Average) value, the total average score is 57.8, with a mean of 2.48. This shows that the difficulty level of the items in the questionnaire is generally at a moderate to moderately difficult level. The average *Standard Error* (SE) model is 0.55, which indicates the level of accuracy of the item's measurements. The low SE indicates that this model is quite stable. For maximum and minimum values. The maximum logit is 6.59, indicating the item with the lowest difficulty. The minimum logit is -1.84, indicating the item with the highest difficulty. A wide range of logit values indicates that the questionnaire includes items with significant variations in difficulty, appropriate for a wide range of respondents' abilities. In the Analysis of Standard Deviation, the standard deviation of raw and logit scores shows that there is a diversity of respondents' scores. This variation is important to ensure that the instrument can differentiate the level of ability of the respondent. From the table above, it shows that the reliability of the person is 0.90, which belongs to the very good category. This means that respondents provide consistent answers to questionnaire items. *A separation* person of 3.04 indicates that respondents can be grouped into more than three categories based on their level of ability.

Furthermore, the reliability of the item is 0.87, which is also in the good category. This shows that the items in the questionnaire can be relied upon to measure the same construct consistently. *An item separation* of 2.60 indicates that the difficulty level of the item is clearly distinguishable. And the data from the alpha value of 0.95 shows that the instrument has excellent internal consistency, making it suitable for large-scale research. The INFIT and OUTFIT Mean Square (MNSQ) values show that the average INFIT and OUTFIT MNSQ values are 1 and 1.02, respectively. The INFIT and OUTFIT value ranges (0.04 to 6.32) indicate that most items match the Rasch model. However, there are some items with extreme values (MNSQ > 1.5 or < 0.5) that may need to be revised. Next On the Z-Standard (ZSTD) value, the ZSTD average is -0.48 for INFIT and -0.49 for OUTFIT. This value indicates that most items conform to the Rasch model and contribute significantly to the measurement. From the above data shows that the considerable variation in the difficulty level of the logit range items (-1.84 to 6.59) indicates that the questionnaire includes items with varying levels of difficulty. Furthermore, the suitability of most items has INFIT and OUTFIT values that correspond to the criteria of the Rasch model, namely MNSQ between 0.5 and 1.5. This indicates that the items in the questionnaire can be used without the need for major revisions. The strength of the instrument is indicated by a high Reliability value for person (0.90) and item (0.87) indicating that this instrument can consistently measure the development needs of IoT and PjBL-based hybrid learning designs. This shows that this research instrument has excellent quality, with high reliability and diverse distribution of item difficulty. Most of the items conform to the Rasch model, so they can be used to measure the development needs of IoT and PjBL-based hybrid learning designs with high validity.

Table 4. Output Summary Measured Person

					Infit		**Outfit**	
	Total score	**Count**	**Measure**	**Model s.e**	**MNSQ**	**ZSTD**	**MNSQ**	**ZSTD**
MEAN	183.7	55	0	0.33	0.99	-0.06	1.02	0.04
WITHOUT	1	0	0.11	0	0.07	0.25	0.09	0.29
P.SD	4.1	0	0.45	0	0.27	1.03	0.37	1.19
S.SD	4.2	0	0.46	0.01	0.28	1.06	0.38	1.22
MAX.	193	55	0.62	0.34	1.68	2.29	1.82	2.18
MIN.	178	55	-1.04	0.32	0.61	-1.76	0.54	-1.76

Real rmse .35 true sd .29 separation .83 item reliability .41 |
|model rmse .33 true sd .31 separation .93 item reliability .46 |
| s.e. Of item mean = .11
Person raw score-to-measure correlation = .98
Cronbach alpha (kr-20) person raw score "test" reliability = .95 sem = 1.79
Standardized (50 item) reliability = .95

Figure 3. Graph Summary of measured person Metrics

The table and figure above provides the results of the analysis of the rasch model related to the level of ability of respondents (persons) in answering research instruments. This data includes descriptive information, reliability, and data compatibility with the rasch model. The results of the descriptive statistical analysis obtained are mean (average) showing an average total score of 183.7, which shows that most of the respondents have moderate ability in answering items. Furthermore, *the mean measure* (logit) is 0. ini is the standard in the rasch model, where difficulty and ability are balanced on the logit scale. the maximum score value is 193 with a logit of 0.62, indicating the respondent with the highest ability. the minimum score is 178 with a logit of -1.04, indicating the respondent with the lowest ability. the range of respondents' ability is relatively narrow, from -1.04 to 0.62 logit, showed that the majority of respondents were in the almost homogeneous ability category. The standard deviation results showed that the variation in respondents' scores was small, with p.sd = 4.1 and s.sd = 4.2. This shows that the respondents' abilities are not significantly different. For data reliability, the person reliability value is 0.41, which is relatively low. This shows that the respondent's ability is not fully distinguishable by the existing items. Item Reliability indicates that the item's reliability value is 0.46, which indicates that the item's difficulty level is not yet fully reliable for distinguishing respondents' abilities. Cronbach's alpha data of 0.95 indicates that overall, the instrument has excellent internal consistency.

The 1.02. MNSQ fit value ranged from 0.61 to 1.68 for the infective and 0.54 to 1.82 for the outfit. some respondents had an extreme fit score (MNSQ > 1.5), which may indicate an inconsistent pattern of answers for the z-standard (ZSTD) shows the average ZSTD is -0.06 for infit and 0.04 for outfits, indicating that the majority of respondents fit the rasch model. A small percentage of respondents had ZSTD values outside the ideal range (-2 to +2), which may require further review. For additional correlation and reliability on the RAW Score-to-measure correlation shows that the correlation between the raw score and the logit size is 0.98, which indicates a very strong relationship between the two. This indicates that the logit is a valid representation of the respondent's ability. Standardized reliability has a standardized reliability value of 0.95 indicating that the results of this measurement have a very high level of reliability, especially for studies with an adequate number of items. From the data above, the distribution of respondents' abilities shows that most of the respondents have abilities that are around the average, with slight variation. This shows that the instrument is able to accurately measure the group of respondents with moderate ability. Although Cronbach's alpha showed excellent internal consistency, a low Person reliability value (0.41) suggests that items may be less able to distinguish abilities between respondents with different levels of ability. From these results, it can be concluded that this study shows that the instrument has good internal consistency, but the ability to distinguish the level of respondents' abilities still needs to be improved.

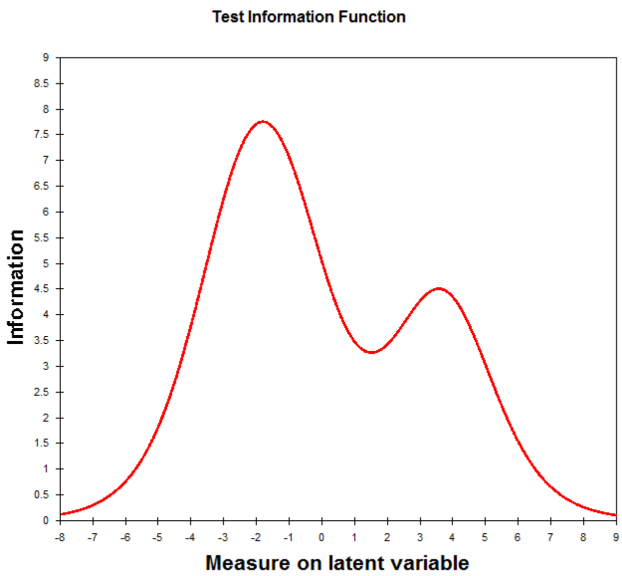

Figure 4. Distribution of Respondents and Question Items

This graph shows the Test Information Function (TIF), which depicts how much information the test provides at various levels of latent variables (in this case, the respondent's ability). The horizontal axis shows the "Measure on latent variable", which represents the respondent's ability level, while the vertical axis shows "Information", which is the amount of information provided by the test. The first peak occurs at a latent size of about −2-2−2, where the test provides maximum information (about 8.5 units). This shows that the test is very effective for measuring respondents with low ability. The second peak is around the latent size 333, with a lower level of information (about 5.5 units). This shows that the test is effective enough to measure high-ability respondents. The test provides very low information at extreme proficiency levels, which are below −6-6−6 or above 777. This indicates that the test is less effective at measuring respondents with very low or very high ability. The effectiveness range provides the most effective information on a latent size range of around −4-4−4 to 444, which covers most of the respondents' ability levels.

The test is designed to target respondents with average to moderately high or low ability. This is in accordance with the results that show that the majority of respondents are in this range of abilities. The test provides limited information for respondents with very low or very high levels of ability. This indicates the need for the addition of more difficult or easier question items in the future to increase the scope of the test. Focus on Key Capability Ranges: Because the TIF peak corresponds to the respondent's latent ability distribution, this test is well-suited to effectively measure the majority of the target population. This ensures the data collected is reliable for the targeted population. Furthermore, here is Table 5 of the results based on the statistics of the results:

Table 5. Item Statistic: Measure Order

Entry Number	Total Score	Total Count	Measure	Type S.e.	Infit		Outfit		Ptmeasur-al		Exact Obs %	Match Exp %	Items
					MNSQ	ZSTD	MNSQ	ZSTD	CORR.	EXP.			
5	178	55	0.62	.32|	1.56	1.97	1.55	1.79|	0.68	.76|	71.7	75.0|	P5
18	178	55	0.62	.32|	0.81	-.70|	0.7	-1.12	0.82	.76|	84.8	75.0|	P18
7	180	55	0.41	.33|	1.68	2.29	1.71	2.16|	0.66	.75|	67.4	75.5|	P7
3	181	55	0.3	.33|	1.18	.75|	1.08	.36|	0.75	.75|	71.7	75.8|	P3
14	181	55	0.3	.33|	1.06	.32|	1.1	.43|	0.75	.75|	84.8	75.8|	P14

15	181	55	0.3	.33|	1.03	.19|	1.03	.18|	0.73	.75|	78.3	75.8 |	P15
17	181	55	0.3	.33|	1.14	.62|	1.37	1.26 |	0.72	.75|	76.1	75.8 |	P17
4	182	55	0.19	.33|	0.76	-.95|	0.76	-.82|	0.76	.74|	78.3	75.9 |	P4
11	183	55	0.09	.33|	1.03	.21|	1.03	.19|	0.71	.74|	78.3	75.9 |	P11
6	184	55	-0.02	.33|	0.72	-1.12	0.67	-1.17	0.78	.73|	78.3	75.9 |	P6
8	184	55	-0.02	.33|	0.84	-.58|	0.78	-.72|	0.79	.73|	73.9	75.9 |	P8
13	184	55	-0.02	.33|	0.81	-.71|	0.77	-.75|	0.76	.73|	78.3	75.9 |	P13
9	185	55	-0.14	.33|	0.84	-.58|	0.78	-.69|	0.74	.73|	80.4	75.9 |	P9
10	185	55	-0.14	.33|	0.7	-1.25	0.57	-1.61	0.77	.73|	89.1	75.9 |	P10
16	186	55	-0.25	.33|	0.61	-1.76	0.54	-1.76	0.8	.72|	76.1	75.9 |	P16
12	190	55	-0.7	.34|	0.91	-0.31	1.82	2.18 |	0.66	.69|	80.4	75.8 |	P12
2	191	55	-0.81	.34|	0.97	-0.06	1.03	.21|	0.68	.68|	78.3	75.6 |	P2
1	193	55	-1.04	.34|	1.13	.63|	1.16	.55|	0.63	.66|	69.6	74.7 |	P1
MEAN	183.7	55	0	.33|	0.99	-0.1	1.02	.0|			77.5	75.7 |	
P.SD	4.1	0	0.45	.00|	0.27	1.0|	0.37	1.2|			5.3	.4|	

The measure column tells you the Logit Value for each item sorted from highest to lowest. For the 1st item, which is -1.04 logits, it tells. The most difficult problem, while the 5th item is the easiest item with 0.62 logits. the accepted infit and outfit Z-Standard (ZSTD) values are in the range of -2.0 to 2.0, but if the infit and outfit MNSQ values are accepted, then the ZSTD index can be ignored by Napitupulu (2017). The validity results can be viewed and analyzed using the Winsteps event in the Outfit order table to see the suitability of the question that functions in the Normal Category to be used as a measure of respondents' misconceptions using the criteria in the Table 6. To check for appropriate items (outliers or misfits) using the following review are:

Table 6. Criteria for Question Item Validity

Reference	Limit Value
Outfit Mean Square (MNSQ)	0.5 < MNSQ < 1.5
Outfit Z-Standard (ZSTD)	-2.0 < ZSTD < +2.0
Point Measure Correlation (Pt Mean Corr)	0.4 < Pt Mean Corr < 0.85

To find out the aspects of response discrepancy using an ideal example shown in Table 7 of person fit orders, for example in the table below:

Table 7. Person Misfit Order

Entry Number	Total Score	Total Count	Measure	Type S.e.	Infit |MNSQ	Infit ZSTD	Outfit |MNSQ	Outfit ZSTD	Ptmeasur-al CORR.	Ptmeasur-al EXP.|	Exact Obs %	Match| Exp %|	Person
22	54	18	1.4	.55 |	6.31	5.15	|6.32	5.12| A	0.46	.19|	11.1	81.7|	22
30	56	18	2	.54 |	3.31	3.43	|3.45	3.45 |B	0.23	.20|	33.3	79.2|	30

Entry Number	Total Score	Total Count	Measure	Type S.e.	Infit		Outfit		Ptmeasure-al		Exact Obs %	Match| Exp %|	Person
					|MN SQ	ZS TD	|MN SQ	ZSTD	CO RR.	EX P.|			
52	50	18	0.32	.47 |	2.88	3.22|	2.85	3.08|C	0.7	.20|	44.4	73.1|	52
51	57	18	2.29	.53 |	2.66	3.06|	2.76	3.05| D	0.39	.21|	38.9	76.3|	51
15	71	18	6.59	1.03|	1.07	.38|	2.1	1.17 |And	-0.38	.09|	94.4	94.4|	15
48	70	18	5.83	.75 |	2.1	1.65	|1.75	1.15 |F	0.16	.12|	94.4	88.9 |	48
1	62	18	3.5	.47 |	1.77	3.49 |	1.75	3.36 |G	0.27	.22|	44.4	59.6|	1
6	67	18	4.69	.53 |	1.68	2.30 |	1.73	2.09 |H	-0.1	.18|	77.8	72.2|	6
2	68	18	4.99	.57 |	1.16	.59|	1.6	1.47 |	I-.40	.16|	77.8	77.8|	2
17	62	18	3.5	.47 |	1.41	2.05	|1.44	2.14|J	0.14	.22|	44.4	59.6|	17
29	70	18	5.83	.75 |	1.06	.29|	1.42	.78|K	-0.15	.12|	88.9	88.9 |	29
25	61	18	3.27	.48 |	1.31	1.41 |	1.31	1.39 |L	0.3	.22|	55.6	62.7 |	25
13	58	18	2.55	.51 |	1.27	.85|	1.28	.85|M	0.21	.21|	66.7	72.7 |	13
55	47	18	-0.28	0.42	|1.20	.67|	1.07	.32|N	0.52	.23|	83.3	60.9|	55
11	63	18	3.72	.47 |	1.06	.43|	1.06	.41|Or	-0.01	.22|	33.3	58.1|	11
39	64	18	3.94	.48 |	1.02	.16|	1.01	.12|P	0.11	.21|	50	58.7|	39
54	63	18	3.72	.47 |	0.96	-.19|	0.98	-.08|Q	0.2	.22|	55.6	58.1|	54
5	67	18	4.69	.53 |	0.97	-.03|	0.93	-.15|R	0.23	.18|	72.2	72.2|	5
24	69	18	5.36	.64 |	0.97	.08|	0.87	-.12|S	0.23	.14|	83.3	83.3|	24
14	56	18	2	.54 |	0.94	.02|	0.94	.02|T	0.49	.20|	77.8	79.2|	14
18	71	18	6.59	1.03|	0.93	.23|	0.6	-.12|In the	0.33	.09|	94.4	94.4|	18
33	55	18	1.7	.55 |	0.9	-.04|	0.93	.02|V	0.1	.19|	83.3	81.1|	33
27	62	18	3.5	.47 |	0.89	-.57|	0.88	-.59|In	0.34	.22|	66.7	59.6|	27
19	55	18	1.7	.55 |	0.87	-.11|	0.87	-.10|w	0.18	.19|	83.3	81.1|	19
47	61	18	3.27	.48 |	0.86	-.64|	0.85	-.66|v	0.36	.22|	66.7	62.7 |	47
36	57	18	2.29	.53 |	0.79	-.43|	0.81	-.35|u	-.16	.21|	83.3	76.3|	36
40	52	18	0.81	.52 |	0.71	-.53|	0.8	-.29|t	-.72	.19|	88.9	79.2|	40
45	58	18	2.55	.51 |	0.75	-.70|	0.73	-.70|s	0.27	.21|	77.8	72.7 |	45
8	49	18	0.1	.45 |	0.71	-.72|	0.67	-.81|r	0.24	.21|	72.2	69.4|	8

Entry Number	Total Score	Total Count	Measure	Type S.e.	Infit		Outfit		Ptmeasur-al		Exact Obs %	Match| Exp %|	Person
					|MN SQ	ZSTD	|MN SQ	ZSTD	CORR.	EXP.|			
12	54	18	1.4	.55|	0.68	-.53|	0.69	.5|q	-0.12	.19|	88.9	81.7|	12
7	51	18	0.55	.50|	0.56	-1.02	0.53	-1.12p	0.3	.19|	83.3	76.4|	7
31	56	18	2	.54|	0.55	-1.06	0.54	-1.04th	0.03	.20|	88.9	79.2|	31
46	56	18	2	.54|	0.34	-1.87	0.28	-2.08n	0.72	.20|	88.9	79.2|	46
4	53	18	1.1	.54|	0.28	-1.88	0.27	-1.91m	0.16	.19|	94.4	81.0|	4
9	55	18	1.7	.55|	0.23	-2.18	0.2	-2.32|l	0.44	.19|	94.4	81.1|	9
28	55	18	1.7	.55|	0.23	-2.18	0.2	-2.32|k	0.44	.19|	94.4	81.1|	28
20	55	18	1.7	.55|	0.2	-2.35	0.17	-2.53|h	0.56	.19|	94.4	81.1|	20
50	55	18	1.7	.55|	0.2	-2.35	0.17	-2.53|i	0.56	.19|	94.4	81.1|	50
38	36	18	-1.84	.36|	0.09	-6.05	0.09	-5.96h	0	.28|	100	53.6|	38
3	54	18	1.4	.55|	0.04	-3.75	0.03	-3.77|g	0	.19|	100	81.7|	3
16	54	18	1.4	.55|	0.04	-3.75	0.03	-3.77|f	0	.19|	100	81.7|	16
23	54	18	1.4	.55|	0.04	-3.75	0.03	-3.77e	0	.19|	100	81.7|	23
41	54	18	1.4	.55|	0.04	-3.75	0.03	-3.77d	0	.19|	100	81.7|	41
43	54	18	1.4	.55|	0.04	-3.75	0.03	-3.77|c	0	.19|	100	81.7|	43
44	54	18	1.4	.55|	0.04	-3.75	0.03	-3.77b	0	.19|	100	81.7|	44
53	54	18	1.4	.55|	0.04	-3.75	0.03	-3.77|a	0	.19|	100	81.7|	53
MEAN	60.1	18	3.36	.76|	1	-.5|	1.02	-.5|			77.5	75.7|	
P.SD	8.3	0	2.58	.49|	1.08	2.3|	1.11	2.3|			22.1	9.9|	

The Rasch model can detect individuals with inappropriate response patterns. This means that there is a gap in the answers given according to their abilities compared to the ideal model. For the ZSTD device criteria, all students/respondents passed, while for the Pt Mean Corr device criteria, there was a response with a value of -0.40 but it was still classified as competent. Information about this feedback pattern can be found in more detail by looking at the rate graph. Rate graphs provide information about the immediate causes of different response patterns (Tyas et al., 2020). The results of the skalogram are presented in figure 5 below:

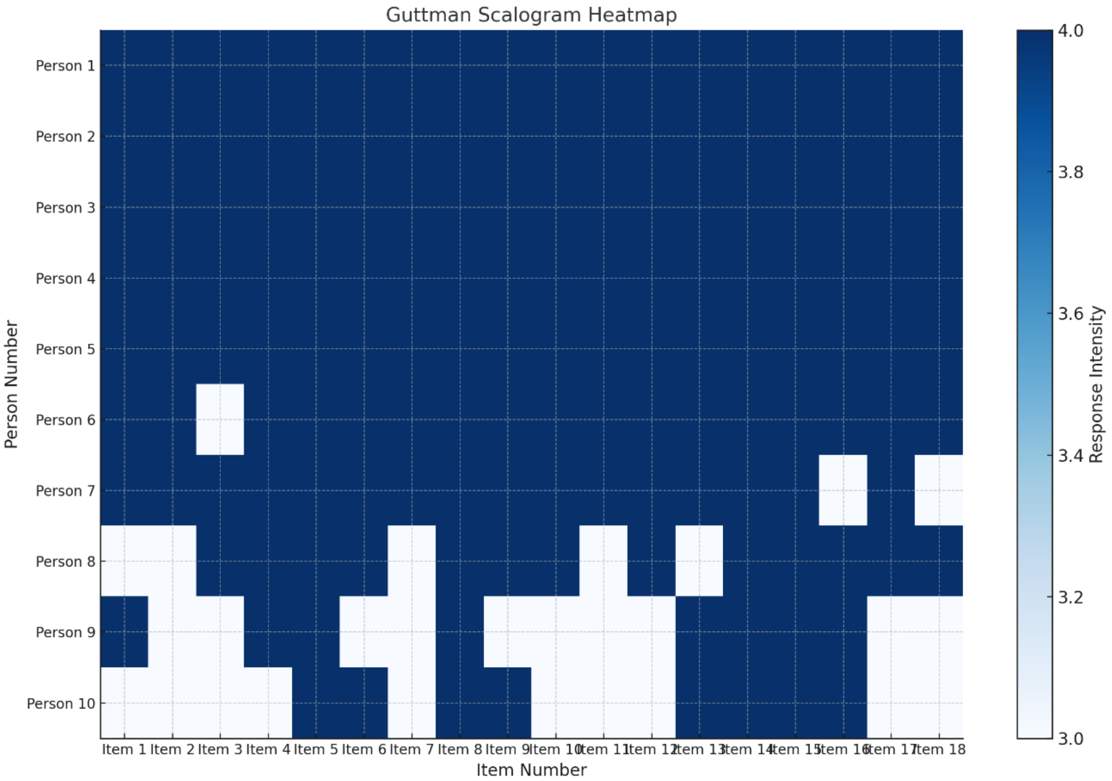

Figure 5. Guttman Scalogram Heatmap

Vertical axis represents the respondents (Person Number), ordered by their respective numbers. Horizontal axis represents the items answered (Item Number), arranged sequentially. Blue gradient colors indicate the intensity of responses, with higher values reflecting more intense responses, such as "strongly agree" in a Likert scale. White areas represent either missing responses or lower response values.

The Guttman Scalogram visualization above provides an overview of the response patterns across individuals (respondents) and items. The blue gradient in the heatmap shows the intensity or correctness of responses for each item. In a well-structured Guttman scale, higher-performing respondents (located near the top) should consistently answer items correctly, while lower-performing respondents (near the bottom) should only answer easier items correctly. The pattern in this visualization indicates partial adherence to a Guttman scale structure, where certain deviations can be observed. Perfect Patterns certain rows show consistent, intense responses across all items. This suggests these respondents possess the highest level of ability or agreement with the items. Deviations for respondents in the middle rows display a mix of correct and incorrect responses. This may indicate they are transitioning between levels of ability, as they fail to answer more challenging items but succeed with easier ones. Lowest performers rows near the bottom show sparse, lighter responses, indicating minimal agreement or ability to answer items. These respondents may only succeed in responding to the easiest items. For Item Difficulties Items arranged on the horizontal axis reflect the difficulty level or intensity. Items consistently answered correctly are likely easier, while items with more incorrect responses are likely harder. This pattern aligns with the hierarchical nature of Guttman scales, where items are progressively more difficult or intense.

Largely consistent response patterns indicated that the scale or instrument used in the research is fairly reliable in measuring respondents' abilities or agreement with the items. For the Identification of Item Difficulty Levels, this hierarchy of item difficulty ensures that the instrument effectively distinguishes respondents' abilities, contributing to the development of a sharper and more targeted instrument. For Theoretical Validity, it can supports the theoretical validity of the instrument, allowing the research to contribute to the development of stronger theories in the field. Research reliability, the instrument is reliable for reuse in other studies or for expanding the sample scope. IoT facilitates collaboration between students through connected learning environments. For example, using IoT platforms, students can work together virtually on projects, share ideas, and provide feedback to each other. Technologies such as smart whiteboards, wearable devices, or online collaboration applications enable students to communicate and interact easily, transcending the barriers of time and space. Collaboration between students promotes social skills, teamwork skills, and collaborative problem-solving abilities. Project-Based Learning learning model needs to be applied as one of the model variations in classroom learning activities, which is a solution to improve the quality of learning and can develop 21st century skills in students (Humaeroh et al., 2023).

Ariyanto Andy, Sutama (2022) Project Based Learning emphasizes three pillars, namely contextual, collaborative and learner autonomy. Contextual learning is carried out by students by learning about teaching aids through seeing, observing, trying and providing assessments of the teaching aids they have learned. From the data analysis of the research results, it is known that in the first cycle, the average value of student learning outcomes of 67.65% increased to 75.90% in the second cycle. Implementation of Project Based Learning Model Learning can also increase student learning activities where in the first cycle student activity by 67.65% increased to 80.30% in the second cycle (Khoiruddin, Ahmad, Suwito, 2021).

2. Discussion

2.1 Implications

Implications for Further Research This research provides a strong foundation for further developing PjBL and IoT-based hybrid learning designs. Further research can be focused on Testing the implementation of this learning design in the context of real classrooms to evaluate its effectiveness on learning outcomes. Further adjustments and developments on items that have extreme fit values to improve the accuracy of the instrument. Expansion of research to a wider population or across disciplines to measure the generalization of this hybrid learning model across different subject areas and Integration of other supporting technologies such as Artificial Intelligence (AI) or Big Data to enhance collaborative learning experiences.

2.2 Research contribution

These findings contribute significantly to the development of innovative learning methods that are relevant to the challenges of the digital era, as well as supporting the achievement of Key Performance Indicators (KPIs) of universities in Indonesia. This study demonstrates the potential of integrating Project-Based Learning (PjBL) with IoT technology to enhance critical thinking, engagement, and alignment with global educational trends. These findings provide a foundation for future research to expand the scalability of this model across disciplines and integrate advanced technologies like AI for more personalized and adaptive learning. By addressing these possibilities, this research contributes to shaping innovative and inclusive education systems for the future.

2.3 Limitations

This study acknowledges several limitations that may affect the generalizability and depth of its findings. First, the sample size, which includes 55 respondents from nine universities, while diverse, may not fully represent the broader population of higher education students and lecturers in Indonesia. A larger and more varied sample could provide more robust insights and reduce potential biases. Second, the research relied on a single instrument, a needs analysis questionnaire with 18 items, which primarily measured perceptions and readiness for implementing hybrid learning models. The use of additional data collection methods, such as in-depth interviews or focus group discussions, could enrich the data and provide a more comprehensive understanding of the contextual factors influencing hybrid learning implementation. Third, the study's scope is limited to the initial analysis of needs and perceptions, without testing the proposed PjBL-IoT hybrid model in actual classroom settings.

2.4 Suggestions

Future research should expand to include experimental or longitudinal studies to evaluate the effectiveness of this model in improving learning outcomes and addressing real-world educational challenges. These limitations highlight areas for refinement in subsequent studies to strengthen the applicability and impact of the findings.

D. Conclusion

This research successfully identified the need and potential for the development of a Project-Based Learning (PjBL)-based collaborative hybrid learning design that is integrated with Internet of Things (IoT) technology. Using the analysis of the Rasch model assisted by Winstep software, this study shows that the instrument used has an excellent level of validity and reliability, with a Cronbach Alpha value of 0.95. The reliability of the person (0.90) and the reliability of the item (0.87) showed that this instrument was able to measure the needs and readiness of students consistently for the development of this learning design. The results of the analysis showed that the majority of students had a positive response to the integration of PjBL and IoT, with a moderate to high level of ability that corresponded to the difficulty level of the items in the questionnaire. Although a small percentage of the items need to be reviewed to improve their conformity with the Rasch model, the overall instrument shows results that fit the distribution of students' abilities. The distribution of data shows that IoT-based and PjBL-based hybrid learning can be an effective solution to increase student engagement, develop critical thinking skills, and support the implementation of the Independent Learning Independent Campus (MBKM) curriculum.

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F. Author Contribution Statement

ER was responsible for conceptualizing the research, supervising the entire process, and conducting the main data analysis using the Rasch Model. PR, HK, and JF developed the survey methodology, developed the research instruments, and coordinated data collection at various partner universities. HB and MS contributed to the development of the theoretical framework related to the integration of IoT and Project-Based Learning and assisted in writing the draft manuscript. AJ provided critical review, technical insights in data interpretation, and research instrument validation. All authors have read and approved this final manuscript.

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