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VALIDITY AND RELIABILITY ANALYSIS OF A MECHANICAL EXECUTIVE COMPETENCY INSTRUMENT FOR THE HVAC INDUSTRY USING THE RASCH MEASUREMENT MODEL

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ABSTRACT

The heating, ventilation, and air conditioning (HVAC) industry needs a workforce with technical skills, knowledge of the newest technologies, and problem-solving abilities. Without a clear competency model, graduates' or employees' ability levels are difficult to align with industry standards, which affects the effectiveness of HVAC systems that are critical in various sectors and the quality of services they provide. As a result, this model is the primary guide when designing curricula, training, and assessments to ensure that the HVAC workforce can meet industry demands consistently and competitively. Thus, this research is developed to examine the empirical evidence on validity and reliability of the survey item of the mechanical executive competency by using Rasch Measurement Model Analysis to make the constructed item applicable to the formal large scale research setting. A total of 30 students with HVAC background from University Tun Hussein Onn Malaysia involved in this study. Beforehand, this research item has been validated by three competency and research experts from various faculties. WINSTEP software version 3.69.1.1 was used to analyse the data, and the results showed that the survey item had great reliability across four constructs. Based on the Person Reliability of 0.91 and Item Reliability of 0.88, it was concluded that the constructed instrument is reliable and can be used on a large scale. It is anticipated that by assuring the instrument's strong validity and reliability, researchers would be able to use or adapt this excellent instrument in their research. Several aspects of students' technical and interpersonal skills are at a moderate level and the finding obtained are significant to provide useful input for policymakers, educational institutions, and the sewerage industry, and help address the issue of unemployment and skill mismatch in Malaysia as a whole

Keywords: *Competency, HVAC industry, Rasch Measurement, Validity, Reliability*

1. INTRODUCTION

Skill mismatch has been quieted an issue that needs to be addressed in any industry in any country to align with the technological changes of industrial revolution and produce high skill workers [1],[2]. Major challenges facing the HVAC industry include the quick development of new technology and the workforce's lack of training to acquire the newest abilities [3]. Furthermore, graduates' competencies fall short of job market criteria due to a disconnect between academic training and industrial demands [4]. The absence of a particular competency model that can be used as a guide to match training, industry demands, and evaluation in the heating, ventilation, and air conditioning (HVAC) sector is another problem. In considering the growing emphasis on utilizing evidence-based data for decision making or to define conclusion for certain feedback, researchers have been using quantitative approach for the study and Rasch modelling measurement model applied during pilot

study. Instrument reliability is essential in research which is implemented to ensure that the research conducted is using reliable and consistent instruments.

A previous survey found an imbalance between the knowledge and skills of TVET graduates and what is needed in the job market, based on industry feedback [5]. This imbalance can lead to an increase in low-skilled or semi-skilled workers compared to high-skilled workers in Malaysian industries each year, even before the COVID-19 pandemic [6]. Stakeholder initiatives such as the KPT Career Development Generator Program, Teaching Factory, and Technical and Vocational Education and Training (TVET) Transformation aim to produce holistic, balanced graduates suitable for industry needs and to address the skills imbalance. These initiatives focus on deepening knowledge, skills, behaviour, and habitual behaviour, which are essential for sustainable career prospects.

This study's literature was chosen based on three primary criteria: (i) relevance to HVAC skill and TVET employability, (ii) recency, emphasizing articles from 2020 onward, and (iii) inclusion in peer-reviewed and indexed journals. This methodology guarantees that the review remains both contemporary and indicative of the study field. The literature selection and synthesis method adheres to known protocols for systematic and structured reviews, prioritizing transparency, rigor, and critical assessment of sources [7], [8].

As such, this study's primary concern is the necessity of matching technological capabilities to industry demands to ensure that technical graduates particularly those in HVAC are adequately equipped to enter the workforce. To quantify the level of these competencies objectively, it is necessary to create accurate and trustworthy evaluation tools. The gap between technical education and industry demands will persist in the absence of pertinent competency models and precise measurement tools.

Despite the growing focus on the employability of TVET graduates, there is still an absence of empirically proven competency assessment tools tailored to the HVAC sector. This disparity results in enduring skill mismatches between graduates and industry demands, especially in technical and interpersonal skills [9], [10]. While previous research has examined competency frameworks and employability abilities, there has been insufficient focus on creating psychometrically validated measures specifically designed for the HVAC sector. This project aims to create and validate a dependable competency measurement tool through a rigorous quantitative methodology.

1.1 Understanding Competency Between Industry and Educational Institution in Malaysia

In the workplace, four main characteristics determine the quality of team members: knowledge, skills, behaviour, and habitual behaviour. All these aspects can influence individual performance and contribute to organizational success and productivity [11]. However, many organizations primarily select employees based on basic knowledge and skills, neglecting the importance of personality elements [12]. Aspects of employee behaviour and habitual behaviour help employees adapt to situations or problems within an organization. Inability to adapt can lead to job-hopping, a common issue among Generation Z in Malaysia. According to Zahari & Puteh, [13], interpersonal relationships closely related to behaviour and habitual behaviour influence the desire to switch jobs. Therefore, it is crucial for students or job seekers to strengthen not only knowledge and basic skills but also personality elements, incorporating behaviour and habitual behavior into their daily lives.

Based on the background of the problem, several issues have been discussed related to the needs of the HVAC industry that are not met by new graduates, especially for HVAC mechanical engineering graduates. Most employers require candidates to have relevant work experience in addition to their academic qualifications. According to Mokhtar et al., [14], hiring is often based on work experience alongside graduate skills, as these factors significantly increase the probability of being called for employment. Recently, there has been a growing emphasis on developing graduate skills that align with industry needs, particularly through the government's approach to empowering TVET. Among the main skills that graduates need are employability skills, such as problem-solving and interpersonal skills, as well as related competencies and skill improvement [15].

However, the question remains whether new graduates, especially in engineering, are prepared to face work pressure or challenges in the HVAC sector, which is considered 3D job—dirty, difficult, and dangerous. Therefore, this study will

be significant in examining how graduate skills meet the needs of industry, particularly in the HVAC sector. By understanding the level of competence and skills required for HVAC mechanical engineering graduates and mechanical engineering technology students, this study aims to improve the development of job structures related to the HVAC industry from the very beginning.

1.2 Research Objective

The objective of this research is to evaluate the validity and the reliability evidence for the survey instrument that will be apply to the engineering student of MTUN specifically to the final year HVAC mechanical engineering student by using Rasch modelling measurement model. This process is vital as the consistency of the constructed item and the respondent of the pilot test can be defined through the Rasch measurement model whereas the item quality of the instrument is in doubt [16]. One of the advantages of the Rasch measurement model is to get meaningful measurements according to which every instrument's component must sufficiently match the measurement model [17].

Therefore, this study applied a systematic quality assessment of the survey items to investigate the HVAC sector mechanical executive competency by using Rasch Measurement Analysis. Apart of that, this study was conducted to fulfil the following objectives which are to identify the level of technical skills possessed by mechanical students to work as mechanical executives in the HVAC sector and to identify the level of interpersonal skills possessed by mechanical students to work as mechanical executives in the HVAC sector and closely follows the conceptual framework adapted from related competency theory and model shown in figure 1.

This study seeks to assess the validity and reliability of a competency assessment tool for HVAC mechanical engineering students utilizing the Rasch Measurement Model. In this study, 'competency' denotes the amalgamation of information, technical abilities, attitudes, and habitual behaviors that empower individuals to perform proficiently within a particular occupational environment [18], [19]. The designation 'HVAC mechanical executive' pertains to entry-level specialists tasked with the operation, maintenance, and oversight of HVAC systems in industrial environments. The Rasch Measurement Model is a probabilistic framework employed to convert ordinal survey data into interval-level measures, hence guaranteeing a reliable and valid evaluation of latent components [20], [21].

2. METHODOLOGY

The researcher clearly discusses the steps taken to achieve the targeted objectives and goals. The research methodology is the main step for the researcher in fulfilling the research objectives by conducting a thorough and effective study based on the theoretical analysis carried out during the literature review section, which is closely related to the principles and knowledge in addressing the research questions. This also outlines the procedures formed from the phases of designing, planning, and applying the research procedures. All the explanations in this chapter aim to obtain results that will be used to formulate and conclude the research through a structured method, ensuring the implementation of the study from start to finish. Fundamentally, this chapter will also detail the approaches and methods used to identify the sample population, select, and design the instruments, and ensure the validity and reliability of the research instruments, as well as the methodology for data collection and data analysis.

This study employed a quantitative survey approach to facilitate the objective measurement of competency constructs among participants. The Rasch Measurement Model was chosen for its strength in assessing item reliability, concept validity, and measurement accuracy, rendering it particularly appropriates for instrument development research. Prior studies have shown that Rasch analysis offers a robust psychometric basis for the validation of instruments, especially within educational and social science research domains [20], [21].

The study aims to examine the competence levels of HVAC mechanical engineering students and engineering technology students, particularly in meeting job demands as mechanical executives in the HVAC sector during the era of Industrial Revolution 4.0. This study was conducted through a survey of students from the Malaysian Technical University Network (MTUN) in the southern zone, involving two universities: University Tun Hussien Onn Malaysia in Johor and University Technical in Melaka. Final-year students who have completed most of their studies were selected as the study population.

Besides, to reduce extraneous variation and improve the dependability of the results, various control procedures were instituted. This includes the selection of a homogeneous sample of final-year HVAC students, expert validation of the instrument before data collection, and consistent protocols during questionnaire administration. These indicators are crucial for maintaining consistency and minimizing potential bias in quantitative research [22], [23].

The choice of MTUN for this study corresponds with its objective to educate and cultivate highly trained human resources for the advancement of the nation's industry. The study aims to assess the level of student proficiency in both interpersonal and technical abilities, specifically pertaining to employment in the HVAC industry. Data were collected and analyzed through a quantitative methodology, utilizing questionnaires as the principal tools to fulfill the study's objectives. Prior to the distribution of the questionnaire to the 189-study sample, as determined by the Krejcie & Morgan table [24] for requisite sample size based on population size, the researcher will formulate the research instrument grounded in a conceptual framework derived from pertinent theories and frameworks associated with the research problem.

This instrument is grounded in the study of prior studies deemed to have a substantial correlation with the competencies of mechanical executives in the HVAC sector. The full process of constructing the research instrument, specifically the questionnaire, will be elucidated in the subsequent section. The Rasch Measurement Model, implemented through Winstep Software, was utilized as a method for data extraction and analysis following the survey. The study methodology is well described in Figure 2.

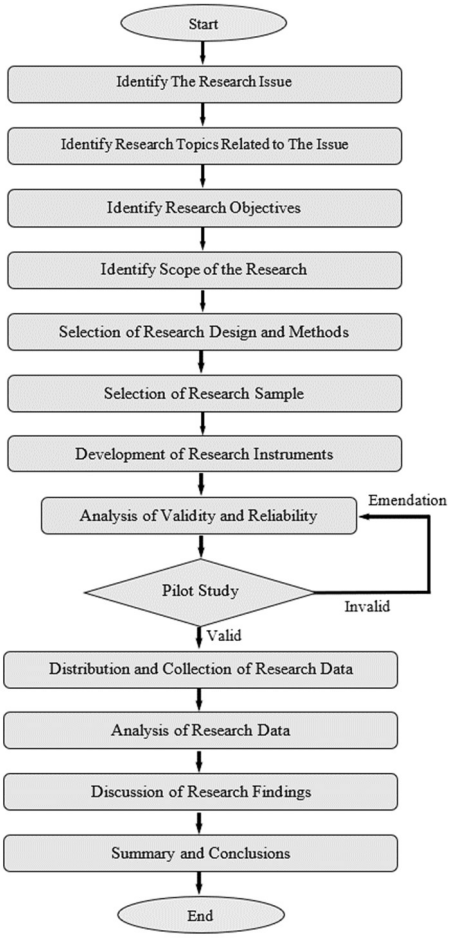

Figure 2: Research Procedure

2.1 Survey Instrument

A survey of the HVAC sector mechanical executive competency has four main dimensions which are B: Respondent Existing Knowledge, C: Respondent Basic Skills, D: Respondent Attitude and E: Respondent Habit. The researcher has adapted various competency model including Iceberg Model of competence, Spencer's Competency Theory and others [25], [26]. Related item of those dimensions has been constructed align with the Malaysian Assessment Skills Framework and Industrial Skills Framework for the related HVAC industry that could be applicable to the engineering student of MTUN specifically. The distribution of constructed items is as follows in Table 1. Beforehand, the constructed item has been validated by the competency and research experts from various faculty of University Tun Hussein Onn Malaysia, and the constructed item has been improved based on their comment.

Table 1: Constructed Survey Instrument Items

Construct	Items	Total
B: Respondent Existing Knowledge	B1 – B17	17
C: Respondent Basic Skills	C1 – C18	18
D: Respondent Attitude	D1 – D14	14
E: Respondent Habit	E1 – E14	14
Total Items		63

2.2 Sample

The survey questionnaire is distributed to 30 well-targeted respondents of third year Mechanical Engineering students with HVAC background from University Tun Hussein Onn Malaysia. According to Amirrudin et al., [27], a total of 30 respondent adequate for respondent to held pilot study for this research and enough to access the constructed items quality.

3. FINDINGS

This research adapted the five-point Likert scale for the survey items to investigate the HVAC sector mechanical executive competency. Rasch Measurement Model may be applied in a variety of ways to assess the quality of the items in social science research instruments. A few of the studies that the measurement model provides and fitted to this research are (i) assessing internal consistency, (ii) assessing item polarity, (iii) assessing item fit and (iv) assessing item dependency [28]. Either than that, two achieve the other objective which are to identify the level of technical skills possessed by mechanical students to work as mechanical executives in the HVAC sector and to identify the level of interpersonal skills possessed by mechanical students to work as mechanical executives in the HVAC sector will be thoroughly presented in this part.

The determination to include or exclude items in the instrument was founded on recognized Rasch measuring standards. Cronbach Alpha values exceeding 0.90 signify exceptional internal consistency, whereas item fit statistics necessitate Mean Square (MNSQ) values between 0.4 and 1.4 and standardized Z values (ZSTD) within the interval of -2 to +2. Furthermore, Point Measure Correlation (PT-MEA CORR) values must be positive, and residual correlations should not exceed 0.70 to guarantee item independence. These criteria are extensively acknowledged in validation studies of Rasch-based instruments [18], [20].

3.1 Assessing Internal Consistency

In assessing the internal consistency of a constructed instrument several parts need to be taken into which are Cronbach Alpha Score, item reliability, person reliability, item separation and person separation. Upon the Rasch measurement modelling on the survey instrument, the Cronbach Alpha Score, α is at 0.94 as shown in Table 2. With the score value of 0.94, the instrument internal consistency of Cronbach Alpha is at excellent range as thoroughly shown in Table 3 [29].

Based on the analysis of person separation, the constructed survey item of HVAC mechanical executive competency is at 3.19, indicating that the items are sensitive towards three levels of sample ability whilst the recommendation by Fisher, [30] states that the item and person separation should be at least at two levels. For the analysis of item separation, the constructed survey item is at 2.10 and shows that at least two levels of the item hierarchy can be confirmed by the sample. On the other hand, for the item and person reliability, the constructed survey item of HVAC mechanical executive competency is at 0.88 and 0.91 respectively, which both indicate a very good item and person consistency during the pilot test being held.

Table 2: Summary Statistics of the Instrument

Summary Statistics	**Value Obtained**
Cronbach Alpha	0.94
Person Separation	3.19
Item Separation	2.10
Person Reliability	0.91
Item Reliability	0.88

Table 3: Cronbach Alpha Score, α Interpretation

Cronbach Alpha Score	Consistency Interpretation
$0.9 > \alpha \geq 1.0$	Excellent
$0.7 > \alpha \geq 0.9$	Good
$0.6 > \alpha \geq 0.7$	Acceptable
$0.5 > \alpha \geq 0.6$	Poor
$\alpha \geq 0.5$	Unacceptable

3.2 Assessing Item Polarity

Item polarity checks have been performed on every item in the constructed survey item of HVAC mechanical executive competency, and the Point Measure Correlation (PT-MEA CORR) value must be positive [31]. This kind of analysis in instrument item polarity will guarantee that every item assessed is in line with its goal. As per Mokshein et al., [32], negative item polarity is gained if responses to the item are negatively correlated with the instrument construct. So, to gain the item that positively correlated with the instrument construct, any item that have the negative PT-MEA CORR should be omitted while other to be retained. From the analysis that has been held, two items, B4 and B3 should be omitted from the constructed instrument as the Point Measure Correlation are negative as listed in Table 4.

Table 4: Instrument Item Polarity by PT-MEA CORR

Entry Number	Point Measure Correlation, PT-MEA CORR	Item	Result
7	-0.16	B4	Omitted
6	-0.07	B3	Omitted
5	0.02	D14	Retained
58	0.26	E6	Retained
48	0.15	D10	Retained
9	0.29	B6	Retained
46	0.22	D8	Retained
12	0.07	B9	Retained
8	0.18	B5	Retained
26	0.21	C6	Retained

3.3 Assessing Item Fit Measure

Verifying the Cronbach's Alpha values for survey item of HVAC mechanical executive competency by themselves was inadequate to guarantee that the instrument could be applied to formal research. As such, an outfit item fit values check had been performed on every item in survey item of HVAC mechanical executive competency. Bond & Fox [20] mentioned that item fit analysis is a measurement of point measure correlation, mean square error (MNSQ) and standard fit analysis (ZSTD). In addition, when assessing the item consistency, it is notable that outfit MNSQ and ZSTD are more significant compared to infit to measure that item construct.

To retain the item, both infit and outfit MNSQ should be in range of 0.4 and 1.4 while the ZSTD value should be within -2 to +2. Linacre & Wright, [21], did mention that the MNSQ under the value 0.4 means that the item is easily foreseen by the respondent while the MNSQ value more than 1.4 means the item is too confusing. Any item that does not comply these criteria should be omitted or purified. Table 5 shows the unfit item that should be omitted following the criteria for MNSQ value for both infit and outfit MNSQ. There are 5 Item that MNSQ value for over 1.4 which are B4, B3, D14, E6 and B6 while 2 items that MNSQ value for less than 0.6 which are C10 and E10. All these items will be omitted due to non-comply to the criteria stated and all other items are having the reasonable predictability when applied to the respondents.

Table 5: Fit Statistics Analysis

Entry Number	Infit		Outfit		Item	Result
	MNSQ	ZSTD	MNSQ	ZSTD		
7	1.32	1.3	1.97	3.1	B4	Omitted
6	1.62	2.1	1.86	2.6	B3	Omitted
5	1.24	0.9	1.63	2.1	D14	Omitted
58	1.30	1.4	1.45	1.8	E6	Omitted
9	1.31	0.9	1.42	1.1	B6	Omitted
30	0.58	-1.4	0.56	-1.4	C10	Omitted
62	0.57	-1.5	0.56	-1.4	E10	Omitted

3.4 Assessing Item Dependency

Winstep generates the greatest standardized residual correlation table between two items to determine the dependent item of the constructed item. Furthermore, to guarantee accuracy while constructing a measurement, standardized residual correlation is a crucial component of item measurement [10]. The Rasch measurement analysis in assessing item dependency will ensure that no duplicate items exist inside the same construct.

According to Boone, [18] and Mokshein et al., [32], the correlation value is less than 0.7 should be retained whilst one item should be drop if the correlation value is more than 0.7. The items can be chosen appropriately based on the infit (ZSTD) value close to 0 and the infit (MNSQ) value close to 1 to keep the items. Table 6 demonstrate the highest correlation between pairs for the Rasch measurement analysis, and six items are chosen to be omitted as the correlation value is more than 0.7 and not adhere to the infit (ZSTD) value and the infit (MNSQ) value requirement stated. The omitted items for correlation dependency are B3, B4, D8, D9, E11 and E8.

Table 6: Standardized Residual Correlation Analysis

Items Pair						Correlation	Result
Items	Infit MNSQ	Infit ZSTD	Items	Infit MNSQ	Infit ZSTD		
B3	1.62	2.1	B4	1.32	1.3	0.74	Both Omitted
D8	1.37	1.3	D9	1.12	0.5	0.71	Both Omitted
E11	1.15	0.4	E8	1.14	0.5	0.70	Both Omitted
B1	1.04	0.2	B3	1.62	2.1	0.61	B3 Omitted
E2	1.05	0.3	E5	0.82	-0.7	0.61	Both Retained

3.5 Core Competency Analysis Based on Existing Knowledge

In the research conducted to assess respondents' existing knowledge of the competency of mechanical executives in the HVAC sector, the researcher developed 14 items. Overall, based on Figure 3, the analysis results indicate that the students' existing knowledge is at a moderate level, with an overall mean value of +0.36 logit. The maximum measurement value is +1.15, while the minimum is -0.67 logit. Accordingly, the total range of the measurement is +1.82. As shown in Figure 3, several respondents are at a high logit value, indicating that these students have a high level of competency in terms of their existing knowledge to work as mechanical executives in the HVAC sector. Out of 30 respondents, 7 are at a high level, 20 at a moderate level, and 3 at a low level of competency based on their existing knowledge.

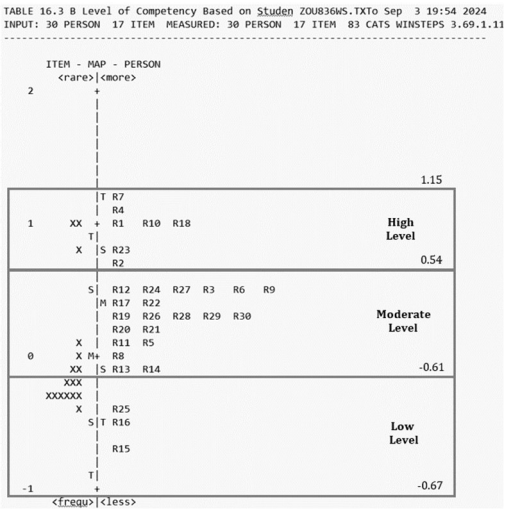

Figure 2: Person map for competency level based on existing knowledge

3.6 Core Competency Analysis Based on Basic Skills

On evaluating respondents' basic skills of the competencies required for mechanical executives in the HVAC sector, the researcher developed a set of 18 items. The findings, illustrated in Figure 4, reveal that students' basic skills are generally at a moderate level, with an overall mean score of +0.97 logit. The highest recorded value is +2.45 logit, while the lowest is -0.17 logit, resulting in a total measurement range of +2.62. Figure 4 also highlights that several respondents fall within the higher logit range, signifying a strong level of competency in their basic skills relevant to working as mechanical executives in the HVAC industry. Among the 30 respondents, 5 demonstrated a high level of competency, 16 were at a moderate level, and 9 exhibited a low level of competency based on their existing knowledge.

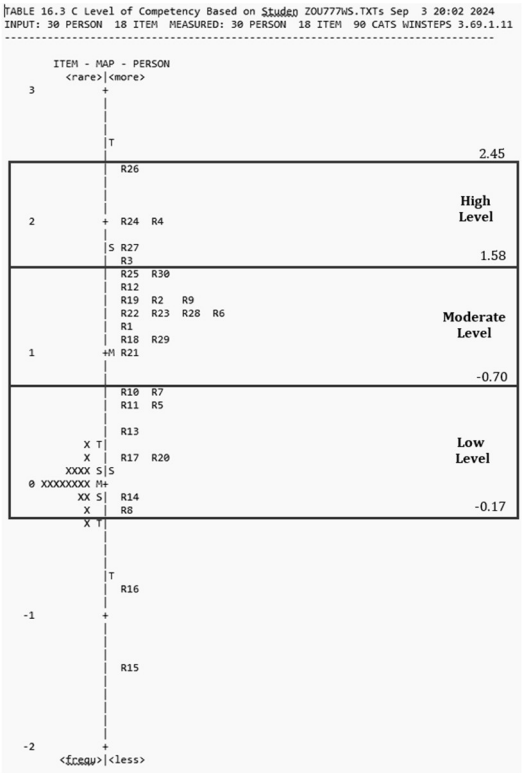

Figure 4. Person map of competency level based on basic skills

3.7 Core Competency Analysis Based on Behavioural Attitude

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In assessing respondents' behaviours related to the competencies required for mechanical executives in the HVAC sector, the researcher developed an 11-item based on the conceptual framework. As depicted in Figure 5, the results show that students' basic skills are generally at a moderate level, with an overall mean of +0.65 logit. The highest value recorded was +1.67 logit, while the lowest was -0.46 logit, yielding a total measurement range of +2.13. Figure 5 further illustrates that several respondents fall within the higher logit range, indicating a strong proficiency in the behaviours necessary for mechanical executives in the HVAC sector. Of the 30 respondents, 11 demonstrated a high level of competency, 8 fell into the moderate range, and 11 showed a low level of competency based on their basic skills.

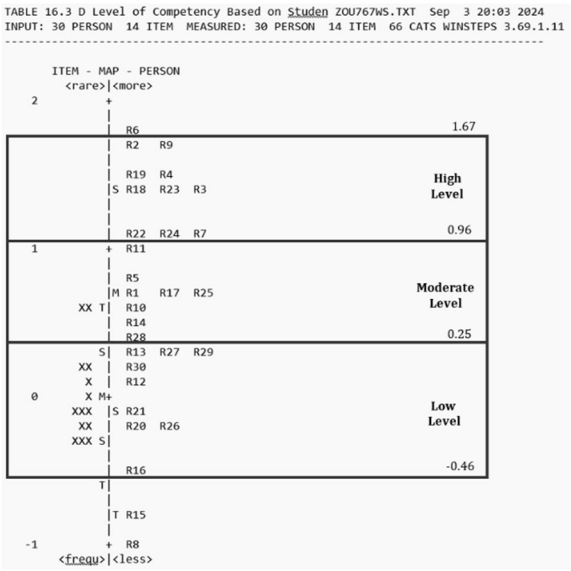

Figure 5: Person map of competency level based on bbehavioural attitude

3.8 Core Competency Analysis Based on Habitual Behaviour

To evaluate respondents' habitual behaviour related to the competencies required for mechanical executives in the HVAC sector, the researcher developed an 11-item framework based on a conceptual model. As shown in Figure 6, the results indicate that students' habitual behaviour is generally at a moderate level, with an overall mean score of +0.74 logit. The highest recorded value was +2.27 logit, while the lowest was -0.93 logit, giving a total measurement range of +3.20. Figure 6 also highlights that several respondents are within the higher logit range, signifying strong habitual behaviour competencies necessary for mechanical executives in the HVAC sector. Among the 30 respondents, 9 demonstrated high competency levels, 15 were at a moderate level, and 6 exhibited low competencies based on their habitual behaviour.

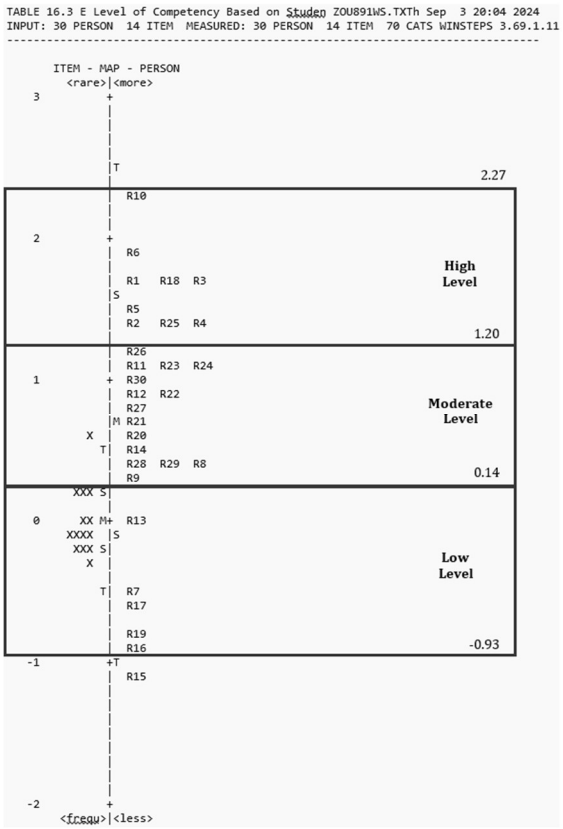

Figure 6: Person map of competency level based on habitual behaviour

4. DISCUSSION

After all, based on the analysis that have been taken by using Rasch Measurement Model, each item that will be eliminated will be examine by referring to the expert views and comments to reach the standard. This standard may help the researcher to make sure the instrument is reliable and valid to be apply to the formal respondent which are mechanical technology and engineering students of MTUN University. Following the analysis that have been taken and discussed in findings, 11 total items that do not meet the pre-requisite for the analysis if item internal consistency, polarity, item fit, and item dependency will be omitted as shown in Table 7.

Table 7: Omitted Item Summary

Construct	Omitted Item	Total item

B: Respondent Existing Knowledge	B3, B4, B6	11
C: Respondent Basic Skills	C10	
D: Respondent Attitude	D8, D9, D14	
E: Respondent Habit	E6, E8, E10, E11	
	Remained Item	52

Based on the findings of the study, several aspects of students' technical and interpersonal skills are at a moderate level, which is interesting to discuss. The analysis found that items related to students' teamwork and leadership skills have the highest mean scores. Engineering and technology engineering students recognize that they can contribute positively to every group activity and can identify improvement opportunities by providing innovative solutions. Students engaged in computer-supported collaborative learning environments can contribute actively to group activities and identify improvement opportunities through collaborative problem-solving and the co-construction of innovative solutions with peers [33]. This helps enhance communication, collaboration, and problem-solving skills.

In ensuring that the operation and maintenance of HVAC systems are carried out efficiently and effectively, it is important for workers to master leadership and teamwork [34]. According to Halili et al., [19] these two skills are crucial employability skills not only in the HVAC sector but also in an individual's career. However, emphasis should be placed on communication skills and professional networking, as several items in this aspect are at a moderate level. This is because, although the HVAC mechanical engineering curriculum has integrated communication skills, students may perceive technical skills as more important than communication and professional networking skills. This perception can reduce their motivation to actively develop communication skills. According to Sabil et al., [35], students should step out of the confines of their institutions; instead, active and extensive involvement in industry activities, external institutions, and communities can enhance the quality of a student.

The findings of this study provide empirical evidence supporting the validity and reliability of the mechanical executive competency instrument developed for the HVAC sector. The high Person Reliability value (0.91) indicates that the instrument can distinguish respondents across different competency levels, while the Item Reliability value (0.88) confirms that the items are sufficiently stable and consistent to define the underlying competency constructs [36]. These results demonstrate that the instrument meets the fundamental psychometric requirements for large-scale application, particularly within technical and vocational education contexts [37]. The use of the Rasch Measurement Model further strengthens the robustness of the instrument by ensuring that each item contributes meaningfully to the measurement construct. Through systematic analyses of item polarity, item fit, internal consistency, and item dependency, poorly functioning items were identified and removed. This purification process enhances the one-dimensionality and measurement precision of the instrument, which is essential when assessing competencies that directly affect workforce readiness and industrial performance in the HVAC sector.

The analysis of core competency domains revealed that students' technical and interpersonal competencies were generally at a moderate level. This finding suggests that while students possess foundational skills necessary for entry-level roles in the HVAC industry, there remains a gap between current competency levels and the expectations of industry employers. Competencies related to applied problem-solving and professional communication require further reinforcement to ensure graduates can adapt effectively to real-world industrial challenges [38]. From an educational perspective, these findings highlight the importance of integrating competency-based assessment tools into curriculum design and training evaluation. A validated and reliable instrument allows educators and institutions to objectively measure student readiness, identify competency gaps, and align instructional strategies with industry demands [39]. This alignment is crucial in reducing skill mismatch and improving graduate employability, especially in technically demanding sectors such as HVAC.

At the policy and industry level, the validated instrument offers a practical framework for workforce assessment and development. Policymakers and industry stakeholders can utilize the instrument to support data-driven decisions related to training programs, certification standards, and talent development initiatives [40]. By standardizing competency measurement, the HVAC industry can ensure consistency in workforce quality, which directly impacts system efficiency, service reliability, and safety standards. Despite its contributions, this study is not without limitations.

The pilot study involved a relatively small sample size drawn from a single institution, which may limit the generalizability of the findings. Future research should extend the application of the instrument across multiple institutions and industrial settings, as well as incorporate additional Rasch analyses such as dimensionality testing and rating scale calibration [41]. Such efforts would further enhance the instrument's applicability and strengthen its role as a comprehensive competency assessment tool for the HVAC industry.

This study distinguishes itself from previous research by incorporating the Rasch Measurement Model in the creation of a domain-specific HVAC competency instrument inside the TVET framework. This research enhances the area by offering a psychometrically validated measuring methodology, whereas prior studies predominantly concentrated on finding competency aspects or employability abilities using descriptive or exploratory methods. Employing Rasch analysis guarantees that the instrument adheres to stringent criteria for reliability and validity, thereby providing a more formidable tool for competency evaluation [16], [28].

5. CONCLUSION

Summing up important concerns with the use of the Rasch Model Analysis, including item polarity, measure value, standardized residual correlation, summary statistics, and outfit (MNSQ) and outfit (ZSTD) values have been done effectively within the constructed survey items to investigate the HVAC sector mechanical executive competency. The results, the summary statistics can be concluded that the constructed survey items are adequately reliable and strongly acceptable. Nevertheless, in the context of other analysis, it has been necessary to exclude eleven items due to the assessment of the item polarity, item fit measure, item dependency and expert opinion.

Subsequently, this research also has some limitation which is focusing only on the HVAC sector mechanical executive competency. In the future, it would be delightful if the sample included broad sector or other developing sector such as e-sports, e-commerce, services and green technology. Furthermore, the constraints of the research are the research analysis excluded the one-dimensionality and rating scale calibration, and this could be implemented in future study.

Overall, based on the analysis of the study findings, it can be concluded that the competency level of mechanical students to work as mechanical executives in the HVAC sector is moderate in all aspects, including their technical and Interpersonal skills. However, emphasis should be placed on existing knowledge in their field of study and their behaviour in the workplace. The combination of these two aspects is crucial to ensure effectiveness and success in the rapidly growing mechanical industry. Education and training in the mechanical field should equally emphasize the development of technical and Interpersonal skills, especially in HVAC mechanical engineering and mechanical engineering technology programs, despite the significant differences between these two programs.

Comprehensive education programs should include practical and theoretical training, as well as opportunities to develop Interpersonal skills through co-curricular activities, group projects, and industrial training. With this approach, graduates will be better prepared to face workplace challenges and contribute effectively to their organizations. With commitment from all parties, we can ensure that the workforce in the mechanical field is not only technically proficient but also possesses the Interpersonal skills needed to face future challenges and contribute to the advancement of the industry and society. In conclusion, the study has successfully achieved its objectives as stated in the introduction. Improving competency in both technical and Interpersonal skills in the mechanical field requires collaborative efforts from various parties to address issues of unemployment and skill mismatches in this rapidly developing industry.

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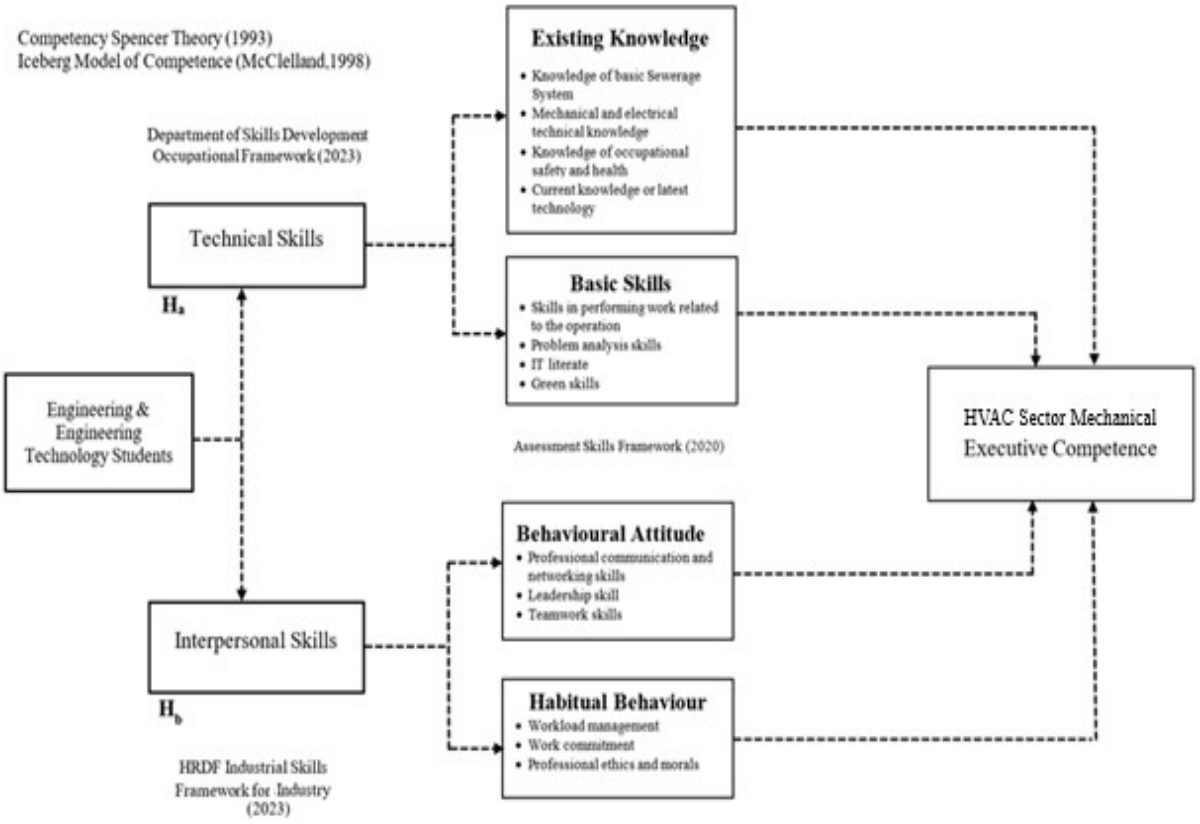

Figure 1: Research Conceptual Framework