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Development and Validation of Standardized Assessment Tools for Evaluating Nursing Students' Knowledge of Intramuscular Injection: Implications for Educational Accreditation and Curriculum Quality

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ABSTRACT

Background: Intramuscular injection is considered one of the nursing students' fundamental courses during their study. The intramuscular injection procedure is considered a daily routine task for nurses in any health workplace. Measuring knowledge gain about the intramuscular injection after the students underwent the intramuscular injection teaching courses is crucial to check the effectiveness of the applied teaching methods. ***Purpose:*** This study aims to develop and validate a multiple-choice questions' examination to measure the intramuscular injection knowledge gain for nursing students. ***Methods*:** A Delphi method was employed to create the tool's items. Six nursing content specialists working as nursing lecturers were recruited (using judgmental sampling) to develop a multiple-choice question-based examination using the Delphi method. The 15-item multiple-choice question' examination was proctored and time-limited (30 min). The multiple-choice questions examination was created and validated using multiple validation processes, instrument reliability (internal consistency), construct validity (Item Response Theory), and face validity with pilot sample examination results. ***Results*:** The multiple-choice questions were created, validated, and showed good reliability and a valid method to measure the intramuscular injection knowledge gain. The developed multiple-choice questions' instrument identified four domains: location of intramuscular injection, responsibility of the nurse, complications of intramuscular injection, and methods of intramuscular injection. Item Response Theory analysis indicated that all items had acceptable difficulty (-3 to +3) and discrimination (>0.25) parameters, with unidimensionality confirmed across all domains. The internal consistency of the tool was acceptable (KR-20 = 0.776). ***Conclusion*:** The created multiple-choice questions' examination is considered a valid and reliable tool to measure the intramuscular injection knowledge gain for year-2 nursing students. ***Implications for Nursing*:** This validated multiple-choice questions' tool provides nurse educators with a reliable, standardized method to assess the effectiveness of their intramuscular injection teaching, enabling targeted curriculum improvements and ensuring that students possess the essential theoretical knowledge for safe clinical practice.

Keywords: Multiple-choice questions' development, Multiple-choice questions' validation, Item response theory (IRT) analysis, Intramuscular injection teaching methods.

What does this paper add?

1. Specialized Assessment Tool: A rigorously validated 15-item MCQ exam, specifically designed to measure nursing students' theoretical knowledge of intramuscular injection, developed through expert consensus and advanced psychometric methods.
2. Comprehensive Knowledge Coverage: The tool systematically assesses four essential Intramuscular Injection (IMI) domains: injection sites, nursing responsibilities, potential complications, and injection procedures, ensuring holistic evaluation of theoretical and clinical knowledge.
3. Advanced Psychometric Validation: Application of Item Response Theory analysis confirms excellent discrimination and appropriate difficulty levels for all items, establishing robust measurement properties.
4. Practical Educational Application: The study provides educators with an efficient, reliable instrument to evaluate teaching effectiveness, identify knowledge gaps, and enhance curriculum development for improved clinical readiness and patient safety.

Introduction

Intramuscular Injection

Intramuscular injections (IMIs) represent the parenteral distribution of medicine into the body's major muscles through the skin and sub-cutaneous tissue using the appropriate syringe and needle for preventative (vaccinations) and therapeutic (antibiotics and hormones) purposes (Song et al., 2023). Due to the increased vascularity of muscle tissue and subsequent increase in drug absorption when administered intramuscularly, this approach is preferred over intravenous and sub-cutaneous methods (Gurung et al., 2022). In less developed countries millions of injections are given annually (Shahid, 2025). In contrast to the 5%-10% utilized for prophylactic purposes, almost 90% of injections are provided for therapeutic purposes. In the medical settings across the world, administering injections is one of the most often utilized psychomotor skills. It is an intricate psychomotor job that calls for skill and expertise from the practitioner (Khraisat et al., 2020). The deltoid and/or gluteal muscles are the areas for intramuscular injection that are most frequently advised (Al-Attar et al., 2022).

Lack of adequate knowledge about intramuscular injections among nurses can have serious clinical consequences (Fekonja et al., 2021). Incorrect administration of IMI may lead to complications, such as nerve injury, tissue necrosis, abscess formation, bleeding, infection, and reduced therapeutic effectiveness of the medication (Sasmal et al., 2021). Inadequate understanding of injection sites, proper technique, and dose calculation increases the risk of patient harm and can compromise safety in clinical settings (Alshyyab et al., 2024). Furthermore, insufficient knowledge may lead to decreased patient trust, anxiety, and dissatisfaction with care, highlighting the critical need for comprehensive theoretical and practical education on IMI for nursing students to ensure safe and effective clinical practice (Groves et al., 2023).

Performing intramuscular injections correctly and accurately is crucial to ensure patients' safety and obtain the drug's therapeutic effects (Sah & Maskey, 2020). As the procedure is the nurses' responsibility, nurses should possess strong knowledge of intramuscular injections (Eraydin & Karagozoglu, 2022). In practice, only a few questions are included in the test or examination about intramuscular injections, 88% highlighted a gap between theoretical instruction and clinical application (Almass et al., 2025).

Multiple Choice Questions (MCQs)

Multiple Choice Questions (MCQs) represent a communal way of written exams in medical schools. It is appropriate to measure knowledge and comprehension in basic and clinical sciences (Dangprapai et al., 2020; Nojomi & Mahmoudi, 2022). MCQ tests are deployed on their own or in conjunction with other types of test tools for educational assessment. One of MCQ tests' advantages is that they could be self-administered and could be used for self-assessment. The MCQs consider an exemplary method for measuring knowledge and comprehension and could be designed to measure application and analysis (Abdel-Hameed et al., 2005; Larrañaga et al., 2022; Philip, 2021). MCQs are planned with a question and a set of answers. In formatting, the correct answer is called the "key" and the other answers are called the "distractors" (Ghidinelli et al., 2021; Rodriguez-Torrealba et al., 2022).

The nature of MCQ tests makes them less likely to be affected by subjective bias from the marker, and consequently more reliable. A significant advantage of MCQ tests is that they allow comprehensive coverage of

the topic area (Sideris et al., 2022). The examiner can focus on specific parts of the course. The MCQ test results could be statistically analyzed to provide information on the facility (difficulty) and the test items' discrimination power. Particularly where there is a language problem, MCQ tests reduce reliance on skills of writing and self-expression. For all these reasons, MCQ tests are increasingly being used in health professionals' educational assessment, including nursing education (Douthit et al., 2021).

Cognitive skills' acquisition provides trainees with a theoretical foundation to perform and improve technical skills (Kohls-Gatzoulis et al., 2004; Sudak & Reiser, 2021). A test is needed to ensure enough theoretical knowledge, and testing also enhances later retention of information, which is also known as the testing effect (Choi & Lee, 2020; Kromann et al., 2009). Important decisions regarding type, format, content, validity, reliability, and cost-effectiveness need to be made when developing a test (Haghighian Roudsari et al., 2020; Schuwirth & van der Vleuten, 2003). Written tests are more cost-effective and reliable than other assessment types, and written tests can have different formats. Multiple-choice questions (MCQs) have several advantages; these include the MCQs that can assess a large area of knowledge, are reproducible, have high reliability, and have relatively lower answering and score time (Polat, 2020; Schuwirth & van der Vleuten, 2003).

Any test employed to measure IMI knowledge might not include the complete knowledge about intramuscular injections, which comprised the anatomy of the muscles, the injection sites, the procedure, the complication, … and so on. Thus, to measure the new teaching methods' effectiveness on knowledge of intramuscular injections, multiple-choice questions were designed as the tool, based on a comprehensive review of the literature. There is currently no universally adopted, globally validated standardized tool specifically designed to measure knowledge gain for Intramuscular Injections (IMIs) among second-year nursing students. The current study aims to develop and validate a multiple-choice questions' examination to measure the intramuscular injection knowledge gain for nursing students.

Methods

Study Design

In developing this MCQ test, three phases were needed to be conducted as follows:

Phase 1: Development of the test.

Phase 2: Validity and reliability of the test.

Phase 3: Application of the test.

Phase 1: Development of the MCQ Test

Firstly, a literature review was carried out before establishing the MCQs, reviewing existing handbooks available and used by nursing degree students (year two). Also, the principles and guidelines of a curriculum for the nursing degree students, according to the American Nursing Association (ANA) (ANA, 2025), were reviewed.

Using the advice from Case and Swanson literature, the MCQs were made after multiple interviews (Case & Swanson, 1998). Items with one best answer were formed, as well as a lead-in question, and four options (a, b, c, and d). Only one option was the correct one, while the three other options were wrong, although they were content-related.

Six nursing content specialists from the Nursing Department, School of Health Sciences, Universiti Sains Malaysia were recruited. Using the Delphi method, items were established accordingly to be tested later, the items cover all information about IMI, and different domains were constructed to group the items. The MCQs were developed in English, as English is the language of instruction and teaching at the university.

Phase 2. Validity and Reliability of the Test

In the second phase, evidence of validity was collected for the developed MCQs. Six nursing content specialists (from the Nursing Department, School of Health Science, Universiti Sains Malaysia) evaluated the MCQ items using the Delphi method, in which all items were reviewed, commented on, and refined iteratively until consensus was reached. Each expert rated every item on a 5-point scale ranging from 1 = completely irrelevant to 5 = extremely relevant (Abdalla et al., 2011). Items rated "1" were discarded, and those with mean ratings below "4" were re-distributed for re-evaluation in the next round. Experts also revised item wording for clarity when needed.

To quantify content validity, both the Content Validity Index (CVI) and the Content Validity Ratio (CVR) were computed. The item-level CVI (I-CVI) values ranged from 0.83 to 1.00, indicating strong agreement among the experts on item relevance, while

the scale-level CVI (S-CVI/Ave) was 0.92, reflecting excellent overall content validity (Polit & Beck, 2006). For CVR, experts classified each item as "essential," "useful, but not essential," or "not necessary." The CVR values ranged from 0.67 to 1.00, exceeding Lawshe's (1975) (Romero Jeldres et al., 2023) critical value of 0.62 for six experts, confirming that all retained items were judged essential for measuring intramuscular-injection knowledge.

The final MCQ draft was then administered to 150 nursing students for face validity. Students commented on the clarity, wording, and time needed to complete the test. Minor revisions were made accordingly. Regarding reliability, Kuder–Richardson 20 (KR-20) was applied to assess internal consistency (Kuder & Richardson, 1937; Sabri & Idris, 2013; Savran et al., 2014). The KR-20 coefficient was 0.776, indicating acceptable reliability of the MCQ tool. Overall, the combination of expert evaluation (Delphi method), quantitative content validity indices (CVI, CVR), and internal consistency evidence (KR-20) supports the robustness and psychometric soundness of the developed MCQ instrument.

Phase 3. Application of the Test

The MCQs were applied to the pilot group to check face validity and collect information about students' comprehension. The multiple-choice question (MCQ) score refers to the sum of a 15-item self-administered examination sheet that assesses the various components of theoretical IMI knowledge of the nursing students before and after undertaking one IMI teaching method. Each MCQ contains five responses, and only one response is correct. Each correct response for an MCQ is given one score, and the maximum score will be 15 for the 15 MCQs. The sum of correct responses to the MCQs is referred to as the MCQ score. The MCQs were developed with four domains under 1) Location of the IMI (three items), 2) Responsibility of the nurse (six items),3) Complications of the IMI (two items), and 4) Method of IMI (four items).

Participants

Participants of this study consisted of six senior nurse educators involved in teaching and supervising intramuscular injection to the diploma and undergraduate nursing students in the School of Health Sciences, Universiti Sains Malaysia. They were selected using purposive sampling with criteria, such as having experience in teaching and supervising nursing students on intramuscular injection. All the participants were between 30 years and 60 years old. About 80% of the participants had from 10 years to 20 years of nursing education experience, and the other 20% had more than 20 years of nursing education experience. For clinical nursing experiences, 60% of the participants had from 10 years to 20 years, and the remaining 40% had more than 21 years. This shows that the participants were experts both in content and clinical nursing.

Other 150 nursing students were selected for face validity and IRT analysis. All second-year students met the inclusion criteria, such as knowing the muscles' anatomy and physiology, but did not undergo the IMI course yet.

Data Collection and Analysis

Firstly, the content specialist group discussions and the literature review carried out to check the research gap were conducted by the note taker. All notes or data obtained from the discussions were presented to all participants. All agreed MCQ items and suggestions were written and finalized. Secondly, data collection was carried out to verify face validity and IRT (Item analysis) and reliability. Then, the final MCQs were applied to the sample students in both groups.

Statistical Analysis

The MCQ questionnaire's psychometric properties for knowledge were assessed using the two-parameter logistic item response theory (2PL IRT) analysis, utilizing the LTM package, version 1.1-1. The MCQs have a dichotomous response as either a right or a wrong answer. For this study, the difficulty of -3 to +3 and discrimination of 0.25 to infinity were used as acceptable cut-off values to establish the items' psychometric properties for each domain (Arifin & Yusoff, 2017). The items' fit was evaluated using the chi-square goodness-of-fit per item and the uni-dimensionality using modified parallel analysis.

Ethical Clearance

The development and validation of the MCQs were conducted as part of a study under the Research University Individual (RUI) Grant of Universiti Sains Malaysia (USM). Ethical approval for this study was obtained from the institution's Human Ethical

Committee with the assigned code USM/JEPeM/ 17020139.

Results

Item Response Theory

The IRT analysis illustrated the psychometric properties of the MCQ domains. As displayed in Table 1, the developed tool identified four distinct constructs (domains): location of intramuscular injection, responsibility of the nurse, complications of intramuscular injection, and methods of intramuscular injection. The sub-domains are location (Q1, Q3, Q15), responsibility (Q2, Q6, Q11, Q12, Q13, Q14), complications (Q4, Q5), and methods (Q7, Q8, Q9, Q10). The difficulty parameter revealed that all the items were within the desired cut-off values of -3 to +3. For discrimination, all the items were above the recommended cut-off value of 0.25. All the results are displayed in Table 1. The items' fit based on the chi-square goodness-of-fit showed that only Q2, Q8, Q11, and Q15 had an adequate fit (*P*-value > 0.05). However, all the items were retained, because they have desired difficulty and discrimination values, based on expert advice, due to their relevance and importance to the study. The total amount of information obtained from the items between -3 to +3 across the four sub-domains of the MCQ questionnaire ranged between 97% and 99.8%. The uni-dimensionality assumption assessed using the modified parallel analysis was met for all the sub-domains: location (*P*-value = 0.2772), responsibility (*P*-value = 0.0594), complications (*P*-value = 0.2376), and methods (*P*-value = 0.2673). Thus, the data is uni-dimensional. This indicates that each sub-domain explains the relationship between its corresponding items.

Table 1. Results of the IRT analysis in the MCQ questionnaire (n = 150)

Items	b	a	X^2 (df = 8)	*P*-value
Location of IMI				
Q1	-1.80	0.83	132.05	< 0.001
Q3	-0.48	1.86	92.42	< 0.001
Q15	-0.11	4.50	2.85	0.827
Responsibility of the nurse				
Q2	-2.14	1.02	8.92	0.349
Q6	0.13	0.94	46.12	< 0.001
Q11	-1.10	5.20	8.11	0.423
Q12	0.45	0.81	33.92	< 0.001
Q13	0.13	0.93	46.41	< 0.001
Q14	0.50	0.17	38.45	< 0.001
Complications of IMI				
Q4	-0.31	4.61	19.35	< 0.001
Q5	-1.01	2.66	58.39	< 0.001
Methods of IMI				
Q7	-0.18	3.48	26.39	< 0.001
Q8	-1.30	4.80	1.91	0.984
Q9	-0.05	0.52	142.50	< 0.001
Q10	-1.62	1.96	81.03	< 0.001

Note: a = discrimination, b = difficulty, df = degree of freedom, IRT = item response theory, X^2 = chi-square.

Item Characteristic Curves (ICCs), Item Information Curves (IICs), and Test Information Function (TIF)

The psychometric properties across all four domains were evaluated using Item Response Theory. For the "Location of the Intramuscular Injection" domain, the ICCs for items Q1, Q3, and Q15 demonstrated strong discrimination and a wide range of difficulties. This was reflected in their IICs, which showed that the items provided precise information across the ability spectrum, from low (Q1) to high (Q15) levels. The TIF confirmed the domain's high reliability, with a peak information of approximately 5.0 at an average ability level ($\theta = 0$), maintaining strong precision across a broad range of test-takers.

The "Responsibility of the Nurse" domain, comprising six items (Q2, Q6, Q11, Q12, Q13, and Q14), exhibited excellent measurement characteristics. The ICCs for all items showed steep slopes, indicating very high discrimination. The IICs revealed that these

items were exceptionally informative, with high peak values, collectively providing substantial information across a wide ability range. Consequently, the TIF for this domain displayed a high, wide plateau, signifying superb and consistent reliability for the vast majority of respondents.

For the "Complications of the IM Injection" domain, the two items (Q4 and Q5) showed strong discriminatory power in their ICCs, with difficulties cantered near the average ability level. Their IICs confirmed that both items are highly informative for individuals around this average proficiency. The resulting TIF showed a strong, well-defined peak with maximum information of approximately 5.0 at $\theta = 0$, indicating that this domain is a very reliable measure, though its precision is most concentrated for test-takers of average ability.

Finally, regarding domain four (Methods of IMI), the Item Characteristic Curves (ICCs) for items Q7, Q8, Q9, and Q10 showed varied psychometric properties: Q7 and Q10 demonstrate good discrimination and moderate difficulty, Q8 is highly difficult, but discriminating, and Q9 shows low discrimination. The Item Information Curves (IICs) reveal that Q8 provides high information at a specific high-ability range, Q7 offers moderate information around average ability, while Q9 and Q10 contribute minimal information. The Test Information Function (TIF) shows a peak information of approximately 6.0 at $\theta = 0$, confirming the domain's strong reliability for assessing average-ability respondents while maintaining good precision across a broad ability range. The figures for item characteristic curves (ICCs), item information curves (IICs), and test information function (TIF) are presented below for each sub-domain.

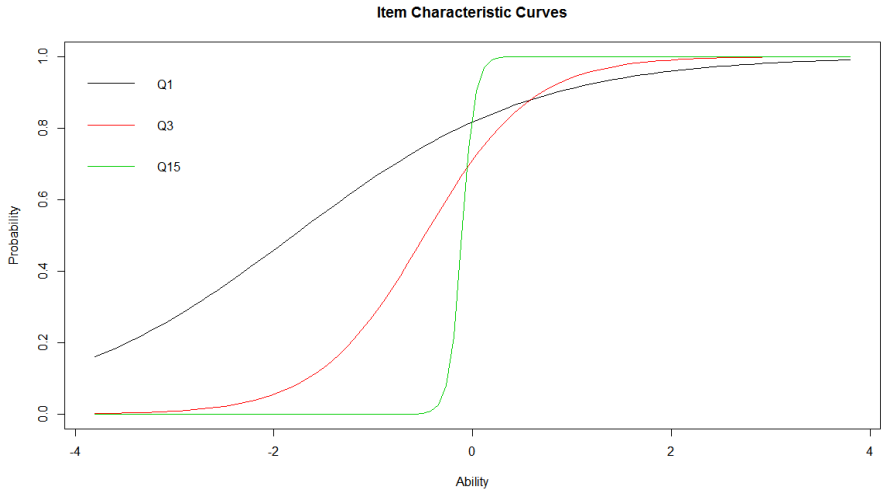

Figure 1. Item characteristic curves for the (location of IMI) domain

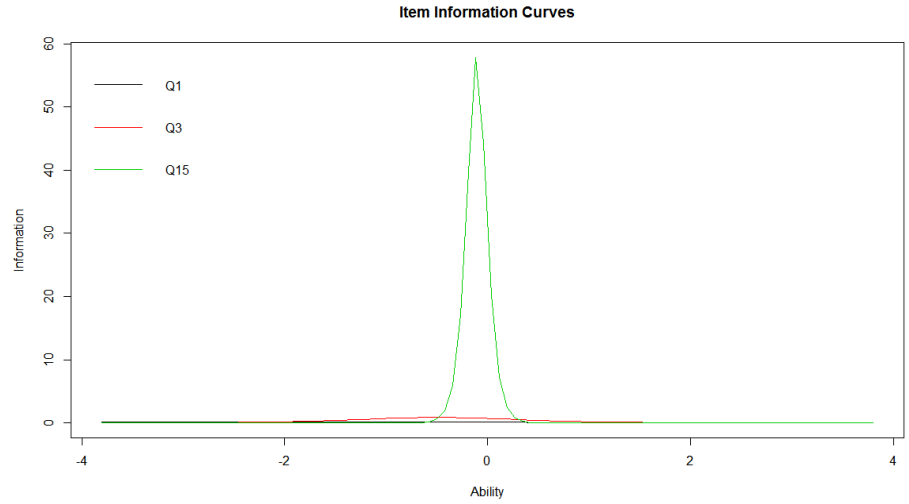

Figure 2. Item information curves for the (location of IMI) domain

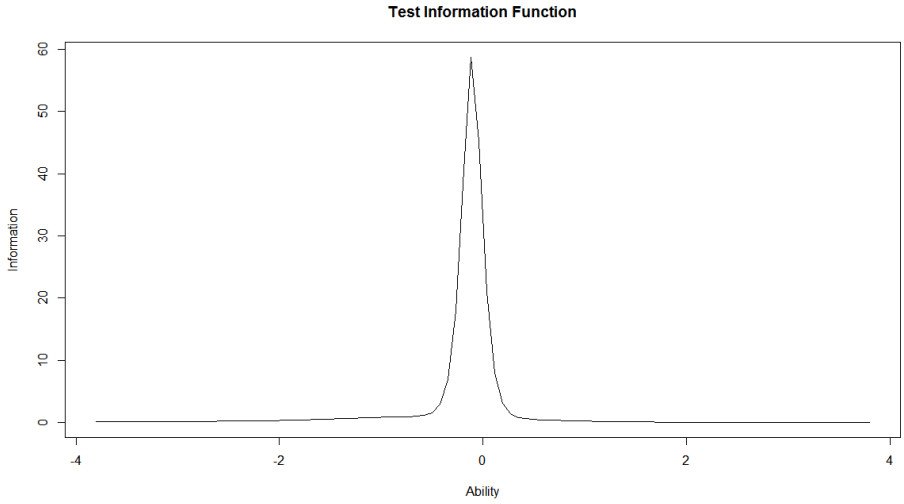

Figure 3. Test information function for the (location of IMI) domain

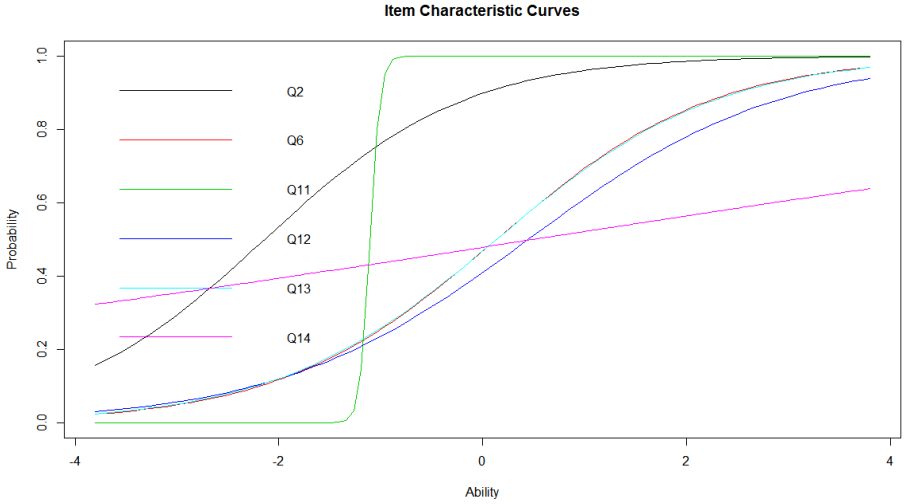

Figure 4. Item characteristic curves for the (responsibility of the nurse) domain

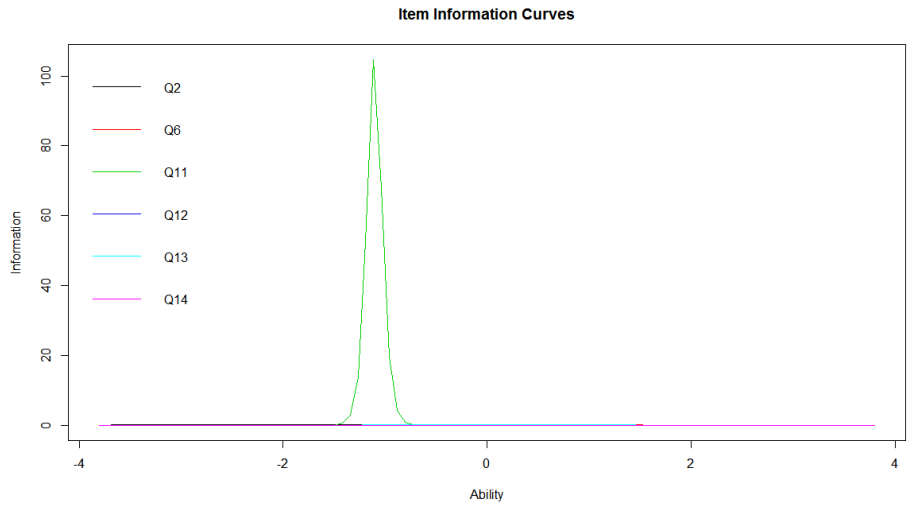

Figure 5. Item information curves for the (responsibility of the nurse) domain

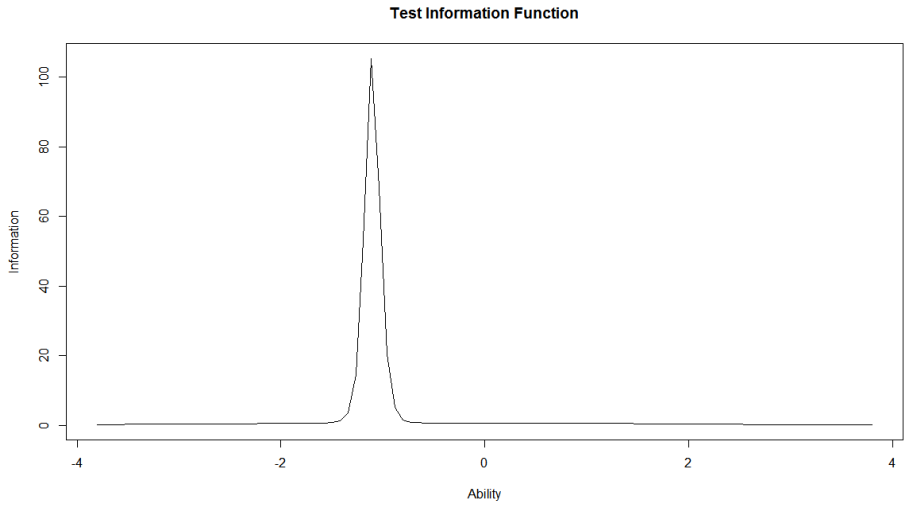

Figure 6. Test information function for the (responsibility of the nurse) domain

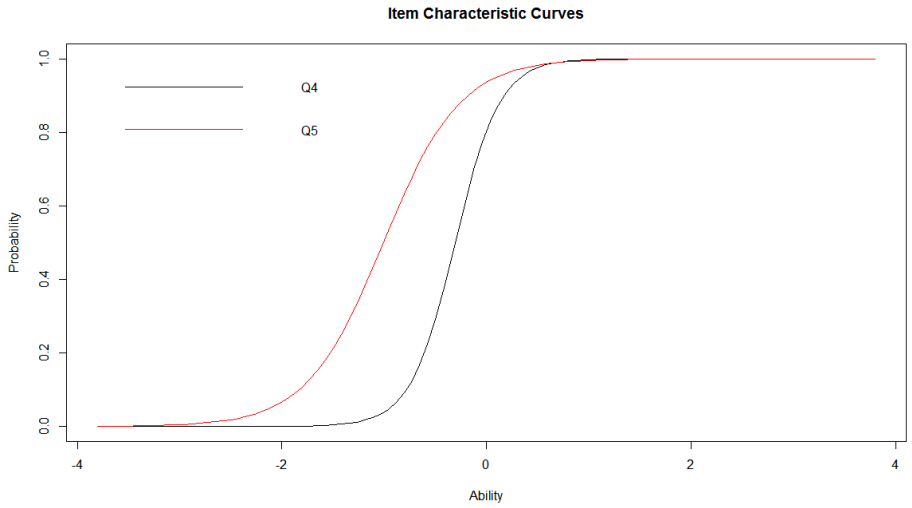

Figure 7. Item characteristic curves for the (complications of IMI) domain

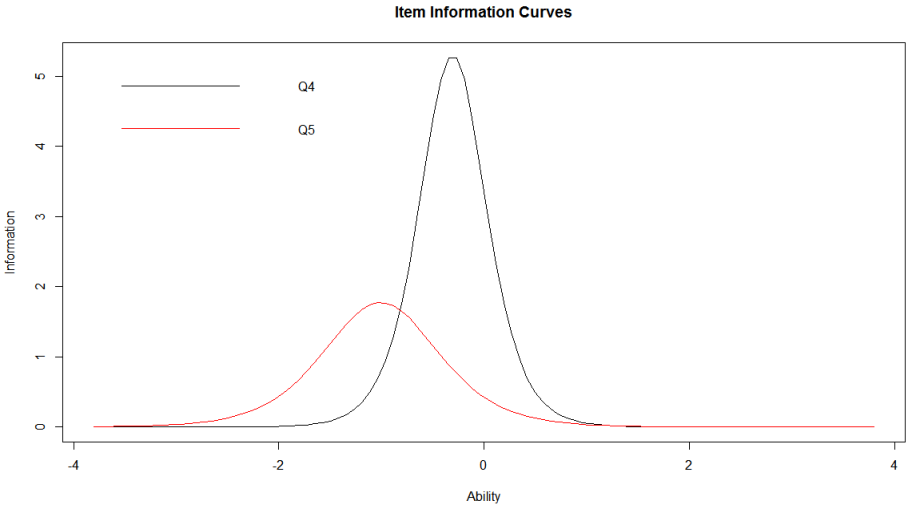

Figure 8. Item information curves for the (complications of IMI) domain

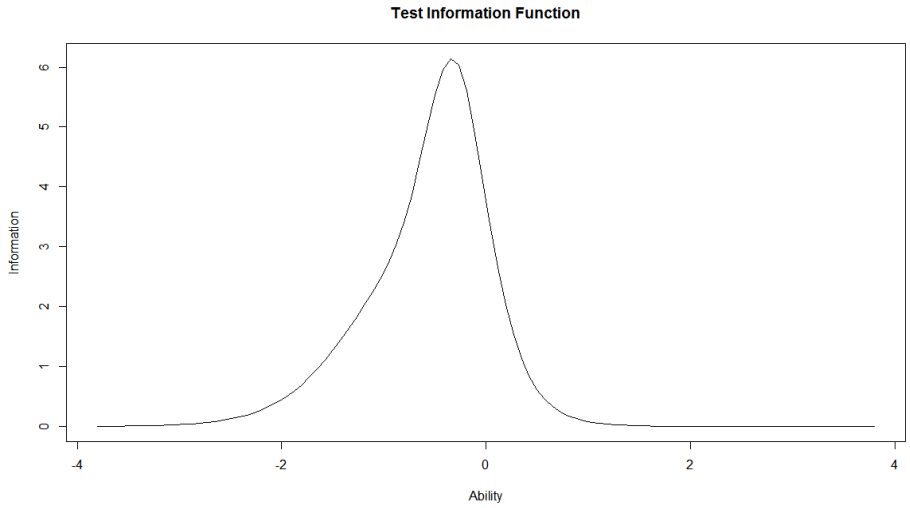

Figure 9. Test information function for the (complications of IMI) domain

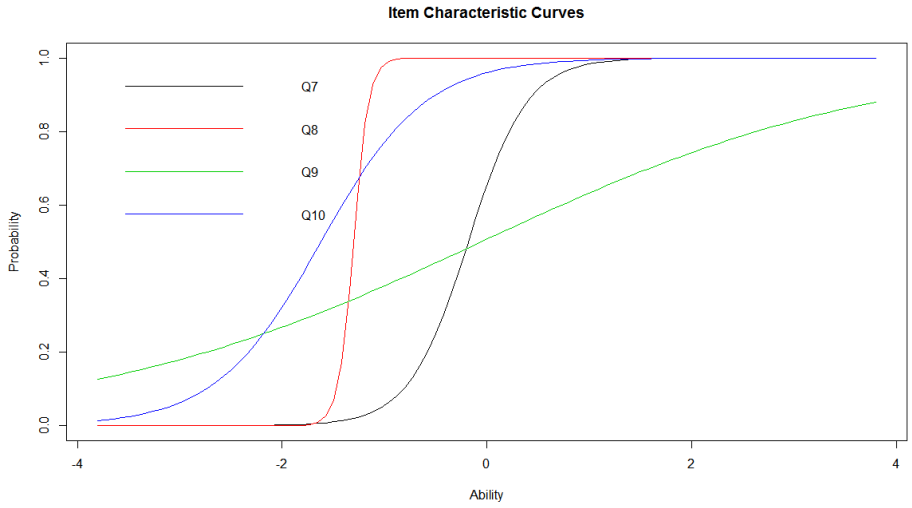

Figure 10. Item characteristic curves for the (methods of IMI) domain

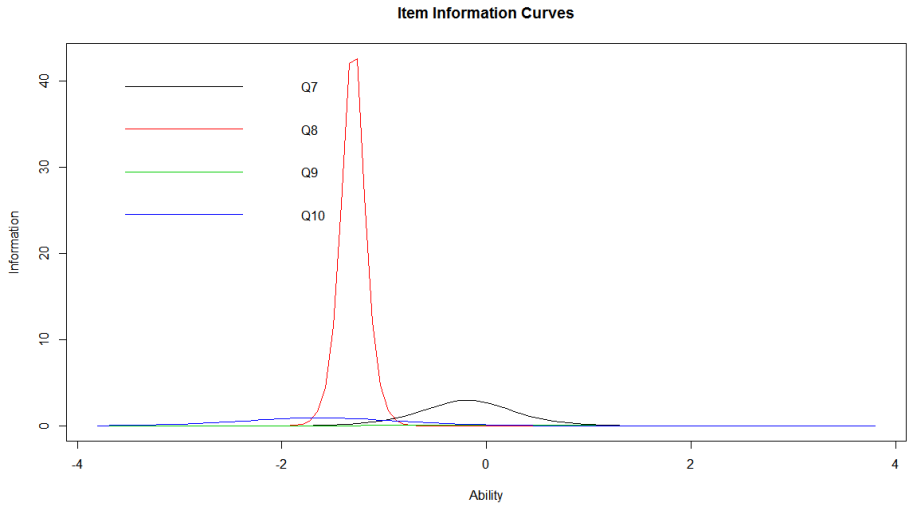

Figure 11. Item information curves for the (methods of IMI) domain

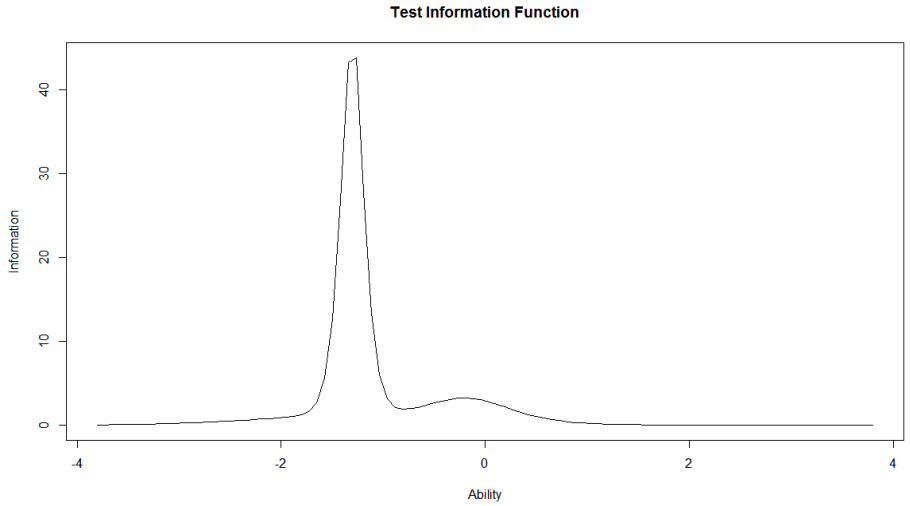

Figure 12. Test information function for the (methods of IMI) domain

Discussion

The assessment criteria established in the literature on educational measurement are used to determine whether or not the construction of the MCQs in this study was effective. While many sources guide developing MCQs, there is little actual groundwork and research on the creation of effective MCQ tests. The construction quality of MCQs and their violations are also the subjects of several inquiries. Recently, the creation of teaching resources to guide academics in creating MCQ tests, especially in the field of nursing education, is a must for educational goals (D'Sa & Visbal-Dionaldo, 2017). In this study, Item Response Theory (IRT) was employed to test the developed MSCQ, since IRT is built on the following two main precepts (Hambleton et al., 1991): (1) The results of an examinee in a test may be predicted or explained by a collection of traits known as hidden features; and (2) The question characteristic function, also known as the item characteristic curve, is an increasing monotonous function that describes the relationship between the examinee's performance and the collection of qualities of a question that underlie its performance (Item Characteristic Curve, ICC).

The MCQ development came as an actual need to measure IMI knowledge gain by nursing students after undergoing an educational method. Since teaching IMI involves the nursing students' cognitive actions for comprehension of the IMI procedure, the MCQ results showed increased cognitive abilities and personal competence (Hambleton et al., 1991). For example, MCQs have various benefits, enabling reviewers to cover a wide range of content and determine the right answer, among other distractors. MCQs evaluate a wide intelligence field, including higher cognitive abilities in Kirkpatrick models, such as interaction, learning, behavioral change, and the result of the training or an educational program (Kirkpatrick & Kirkpatrick, 2006).

A scientific approach to creating and evaluating MCQs is essential for evaluating the students' expertise and experience (Oc & Hassen, 2025). A study by Ho (2021), which developed MCQs to assess critical care nurses' knowledge of delirium care, followed a similar development process to that used in the present study. The significance of the discriminating power also may be affected by face validity and construct validity. MCQs with very flower stalks, poorly developed keys or distractors, and ambiguous thematic build can fail to recognize another high scorer. Distractors were examined to assess how useful they are when assessing an examinee who has the expertise to answer the query.

The created MCQs intended to measure overall IMI knowledge gain by year-2 nursing students after undergoing the anatomy and physiology modules in their study, but still did not study IMI as a separate course (within the fundamentals of nursing module). The four domains of the MCQ examination tried to cover all aspects of IMI knowledge. The first domain was the location of the IMI, consisting of three items Q1, Q3, and Q15. The second domain was the nurse's responsibility, consisting of six items Q2, Q6, Q11, Q12, Q13, and Q14. The third domain was the complications of IMI, consisting of two items, Q4 and Q5. Finally, the fourth domain was the methods of IMI, consisting of four items, Q7, Q8, Q9, and Q10.

Implications for Nursing

This validated 15-item MCQ tool offers nurse educators a reliable, standardized method to assess intramuscular injection (IMI) knowledge across four essential domains. By identifying specific theoretical gaps, it enables targeted curriculum improvements and evidence-based teaching refinements. The tool ensures that students acquire essential theoretical knowledge before clinical practice, directly enhancing patient safety and care quality through better prepared nursing graduates. Its practical 30-minute format supports regular implementation for ongoing competency assessment in nursing education programs.

Limitations

This study has a few limitations. The IRT analysis was conducted with 150 participants, slightly below the recommended sample size for highly stable parameter estimation, which may have contributed to extreme discrimination values for a few items. Participants were drawn from only two Malaysian universities, which limits generalizability to other programs or regions. Construct validity was examined using IRT and uni-dimensionality tests; future studies could expand this with confirmatory factor analysis or known-group validation. Despite these constraints, the study provides a carefully developed, psychometrically sound instrument that can be refined and tested further in larger, more diverse samples.

Conclusion

This tool can be utilized for future measurement of nursing students' cognitive dimension of KNOW and KNOW HOW according to the Miller pyramid of learning assessment (Tangpaisarn et al., 2025), and to check their understanding of the theory part of IMI lessons. The created MCQ examination is considered a valid and reliable tool to measure Intramuscular Injection (IMI) knowledge gain for year-2 nursing students.

Authors' Contributions

Study Design: **AK, NA**. Data Collection: **AK**. Data Analysis: **AK, NA**. Study Supervision: **NA**. Manuscript Writing: **AK, KM, NA**. Critical Revision for Important Intellectual Content: **AK, KM, NA**.

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