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Pioneering Precision in Magnetic Resonance Imaging Training: The Introduction of the MRI Interpretation Competency Scale

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ABSTRACT

Despite the central role of magnetic resonance imaging (MRI) in clinical diagnosis and medical education, there is a notable absence of standardized, validated tools specifically designed to assess MRI interpretation competencies. Existing assessment methods often evaluate general diagnostic reasoning but fail to address the unique cognitive demands of MRI interpretation, such as spatial orientation, recognition of sectional anatomy, and differentiation of normal and pathological structures. In response to these challenges, this study aimed to develop the MRI Interpretation Competency Scale (MRI-ICS), a tool specifically targeting the skills required for accurate MRI interpretation. A sequential exploratory mixed methods approach was employed. Semi-structured interviews with experienced MRI interpreter students (selected via snowball sampling) informed item development. Exploratory factor analysis (EFA) was conducted to establish construct validity, supported by the Kaiser–Meyer–Olkin measure (KMO) and Bartlett's Test of Sphericity (BTS). Reliability was assessed using Cronbach's alpha (α). The MRI-ICS identified three factors: (1) ability to discern structures in MRI images (eight items, explained variance 27.46%, Cronbach's $\alpha = 0.89$); (2) necessity for professional development (seven items, explained variance 20.25%, Cronbach's $\alpha = 0.80$); and (3) utilization in the diagnostic process (six items, explained variance 14.01%, Cronbach's $\alpha = 0.84$). The total explained variance was 61.72%, with an overall Cronbach's α of 0.89. The MRI-ICS offers a reliable, validated framework to enhance MRI interpretation training globally, filling a critical gap in medical education assessment.

1 | Introduction

The integration of advanced technologies in healthcare education, particularly in magnetic resonance imaging (MRI) interpretation, is critical for modern medical training and healthcare delivery [1–3]. As healthcare evolves, there is a growing demand for medical professionals proficient in MRI interpretation, which plays a pivotal role in enabling accurate diagnoses and enhancing our understanding of human anatomy and diseases [4, 5]. This need aligns with the 2023 education strategy in Turkey, which emphasizes a multidisciplinary approach to medical education that integrates technology and education to improve health and educational outcomes globally [4, 5].

Understanding anatomy is central to medical education, and MRI provides high-resolution, non-invasive imagery that bridges the gap between theory and practice, bolstering students' confidence [6–8]. However, a significant gap remains in students' understanding of MRI safety protocols, highlighting the need for improved educational programs in this area [9]. MRI's ability to offer precise anatomical visualizations, detect pathologies, and support interactive learning makes it invaluable for anatomy education [1, 10–15]. These capabilities are essential for developing diagnostic skills and understanding human anatomy in a clinical context.

Researchers have explored the implications of MRI technology on medical education, particularly in terms of its influence on students' acquisition of anatomical knowledge [16, 17]. This paper introduces a framework for assessing medical students' proficiency in MRI interpretation, proposing the MRI Interpretation Competency Scale (MRI-ICS), a five-item tool designed to evaluate students' abilities in interpreting MRI images.

Despite technological advancements and growing interest in integrating MRI into health professions education, a significant gap remains in the availability of validated, standardized tools to assess students' MRI interpretation skills. Current educational practices and diagnostic reasoning tools fall short in addressing the unique cognitive and spatial competencies required for interpreting MRI images in anatomical and clinical contexts.

The key contributions of this study are as follows:

- Identification of a pedagogical gap in medical education concerning the assessment of MRI interpretation skills.
- Development of the MRI-ICS, a five-item instrument grounded in qualitative and quantitative findings.
- Application of a sequential exploratory mixed-methods design to ensure the scale's validity and educational relevance.
- Integration of insights from technological tools (e.g., artificial intelligence (AI) and virtual reality) to inform the scale's practical use in medical training.
- Empirical validation of the MRI-ICS to support its adoption in curriculum development and competency-based assessments.

1.1 | The Role of MRI in Medical Education

MRI has revolutionized anatomy teaching, which traditionally relied on cadaver dissection and textbook images, which provided a static understanding of human structures [18–22]. The introduction of MRI in the late 20th century offered high-resolution, dynamic images of the human body in vivo, transforming this traditional approach [6]. Initially used solely for clinical diagnostics, MRI's educational potential was recognized by the 1980s, with early adopters incorporating MRI into medical curricula to allow students to observe anatomy in its natural state [23, 24]. This pedagogical shift led to the development of digital image libraries to a diverse range of MRI scans for studying anatomical variations and pathologies [25].

Advancements in MRI technology have further expanded its use in education, particularly through the integration of 3D reconstructed MRI images and interactive software, which enable virtual dissection and manipulation of images [26–31]. These technological innovations have enhanced students' understanding of spatial relationships and human anatomy in ways that traditional methods could not. Additionally, augmented reality and virtual reality technologies are being integrated into curricula, offering immersive learning experiences [32, 33]. These technologies provide opportunities for self-directed learning, which is particularly beneficial in remote or resource-limited settings.

Collaborations between medical schools and tech companies have driven the development of specialized educational tools, such as MRI-based simulations that enhance student learning [34]. Research into the effectiveness of MRI-based teaching methods continues to shape curricula, ensuring the integration of MRI technology aligns with educational goals and enhances students' diagnostic skills [35, 36].

1.2 | The Importance of MRI Interpretation in Medical Education

Proficiency in MRI interpretation is becoming an indispensable skill across numerous medical specialties, including radiology, neurology, orthopedics, and oncology, given its central role in diagnosis, treatment planning, and disease monitoring [37, 38]. Understanding MRI enhances diagnostic accuracy and fosters a multidisciplinary approach to patient care, improving collaboration among specialists and patient outcomes [39]. As imaging technology continues to evolve, early exposure to MRI interpretation in medical education prepares students for the complexities of modern diagnostic tools [40, 41].

However, teaching MRI interpretation presents challenges. The detailed and complex nature of MRI images, coupled with the high level of detail required for analysis, makes it difficult to standardize educational content across medical schools, resulting in variations in students' interpretative skills [42, 43]. Access to high-quality MRI images and advanced imaging software may also be limited due to cost or institutional constraints [44, 45]. These challenges, however, present opportunities for innovation. Digital resources, such as online MRI image databases and VR simulations, are emerging as resources that enhance learning experiences by providing access to rare cases and complex pathologies [46, 47]. Furthermore, AI and machine learning are becoming integral to MRI education. AI can assist in detecting abnormalities in MRI scans, helping students recognize key features and patterns, while also preparing them for future technological shifts in healthcare [48–50].

1.3 | Development of MRI Interpretation Competency Tools

As the landscape of medical education evolves, the focus has shifted from merely assessing theoretical knowledge to evaluating clinical skills, decision-making, and professionalism [49–52]. This pedagogical shift prompted the development of Objective Structured Clinical Examinations (OSCEs), which evaluate clinical competencies in standardized, simulated environments [53–55]. The rise of digital assessment tools has further advanced these efforts, enabling adaptive testing and virtual patient scenarios that reflect the complexity of real-world clinical practice [56–60].

Within the domain of MRI interpretation, however, existing assessment instruments fail to adequately capture the specific cognitive and interpretive skills required for image analysis. While tools such as the Clinical Skills Assessment [18] and the Diagnostic Reasoning Scale [20] assess clinical reasoning more broadly, they do not address the distinct demands of MRI interpretation. This gap underscores the need for specialized tools to evaluate MRI-specific competencies.

As shown in Table 1, a critical comparison of traditional educational methods, emerging imaging technologies, and assessment tools highlights both their contributions and their limitations in MRI education. The MRI-ICS addresses these gaps by providing a structured, competency-based tool specifically focused on MRI interpretation skills.

In response to this need, the present study introduces the MRI-ICS, a five-item instrument developed to assess medical students' proficiency in MRI interpretation. By focusing on students' ability to recognize anatomical structures and understand spatial relationships in MRI images, the MRI-ICS identifies key learning needs and informs targeted educational interventions. This scale is intended to provide valuable feedback for refining instructional approaches and enhancing the quality of anatomy education. In the context of MRI training, the adaptation and validation of such focused instruments are essential for accurately measuring learners' interpretive competence [61, 62].

2 | Materials and Methods

This study is methodological in nature, focused on developing and validating a competency scale for MRI image interpretation. Given the lack of existing scales for assessing MRI interpretation competency, this research addresses this gap.

2.1 | Research Design

A sequential exploratory mixed-methods design was adopted, beginning with qualitative data collection and followed by quantitative analysis—an approach frequently employed in scale development studies [63]. In the qualitative phase, semi-structured interviews were conducted with medical and dentistry students who had experience in MRI interpretation. These interviews, together with a review of relevant literature and documents, informed the creation of preliminary competency items for the MRI interpretation scale.

The subsequent quantitative phase involved establishing the scale's validity and reliability through statistical analyses, including factor analysis, to finalize the instrument [64]. This design allowed the initial qualitative findings to inform the structure and content of the quantitative measures. The overall research process is summarized in Figure 1.

2.2 | Qualitative Research Phase

The qualitative phase involved semi-structured interviews with students experienced in MRI interpretation. A non-probability snowball sampling technique was used, enabling participants to refer additional experts. Nine students identified as experts in MRI interpretation were interviewed. Data collection continued until saturation was reached, as subsequent interviews yielded redundant information [65, 66]. The interviews were audio-recorded with consent and later transcribed for analysis. The transcriptions were subsequently reviewed for accuracy and verified with the participants.

Data analysis followed thematic analysis procedures [67], where audio recordings and transcripts were reviewed to create codes, which were then grouped into themes. Two researchers independently reviewed the transcripts and developed a code guide. After comparing the codes, inter-coder agreement was tested. The themes formed the basis for the competency scale items. These draft items were then presented to six experts, including five field experts and one language expert. Expert feedback led to the calculation of the content validity ratio (CVR) and content validity index (CVI), which resulted in the removal of some items.

2.3 | Quantitative Research Phase

The quantitative phase aimed to assess the structural validity of the MRI-ICS, based on the three dimensions identified in the qualitative phase. Gorsuch's [68] recommendation for a sample size of at least 100 participants or five participants per variable guided the selection of 271 participants for this phase. Convenience sampling was used, and participants included medical and dentistry students from a state university, with ethics approval obtained.

A five-point Likert scale was used for the MRI-ICS items, ranging from "Never" to "Always." The survey was administered online to ensure environmental sustainability and avoid paper waste, with voluntary participation.

Data analysis included exploratory factor analysis (EFA) to examine the scale's structural validity and determine how well the quantitative findings aligned with the qualitative phase. EFA is particularly recommended for validating new scales [69, 70]. The suitability of the data for factor analysis was assessed through the Kaiser–Meyer–Olkin (KMO) measure and Bartlett's Test of Sphericity (BTS). The principal components method with Varimax rotation was used for factorization. Eigenvalues greater than one determined the number of factors. A reliability analysis was conducted to assess the final scale's internal consistency based on the factor analysis results.

These analyses allowed for the identification of key dimensions and ensured the scale's reliability and validity.

3 | Results

3.1 | Qualitative Research Findings

In this section, the codes, categories, and themes generated through content analysis of the student interviews are presented in tabulated form. The results of the content analyses related to students' views on gaining MRI interpretation competencies and applying their knowledge are provided in Table 2.

TABLE 1 | Critical evaluation of existing methods and positioning of MRI-ICS in MRI education.

Focus area	Description of current approaches	Strengths	Weaknesses/gaps	Position of MRI-ICS
Traditional anatomy education	Cadaver dissection and textbook-based instruction [18, 20–22]	Offers foundational understanding of human anatomy	Static representations; limited interactivity; lacks real-time or in vivo imaging	Addresses these gaps by incorporating dynamic MRI-based visualization
MRI in medical education	Used as a visual tool to teach anatomy and pathology [6, 23–25]	High-resolution, in vivo imaging enhances realism and spatial awareness	Limited standardization in educational integration; lacks structured evaluation tools	MRI-ICS builds a standardized framework for assessing MRI interpretive skills
3D, AR/VR, and simulated learning tools	Immersive technologies (e.g., virtual dissection, VR platforms) increasingly used in curricula [26–33]	Promotes student engagement, enhances spatial learning, supports self-directed learning	Often lack formal assessment models to measure learning outcomes or interpretative ability	MRI-ICS provides a measurable outcome for learning achieved through these tools
AI-assisted image interpretation	AI and machine learning tools support image recognition and diagnostic assistance [48–50]	Improves accuracy, identifies patterns; introduces future-facing technology	Focused on clinical performance, not learner competency; minimal role in formative assessment	MRI-ICS focuses on student understanding, complementing AI-based instruction
Existing assessment tools (CSA, DRS)	General clinical reasoning and diagnostic scales applied in education [18, 20]	Valid and reliable for general diagnostic skill assessment	Do not capture MRI-specific cognitive and spatial interpretive competencies	MRI-ICS fills this assessment gap by focusing exclusively on MRI interpretation
Digital repositories and online resources	Databases of MRI cases and visual learning modules [46, 47]	Expands access to rare or complex pathologies	Often lack integration with curriculum or outcomes-based assessments	MRI-ICS serves as a feedback tool to evaluate student learning from these resources

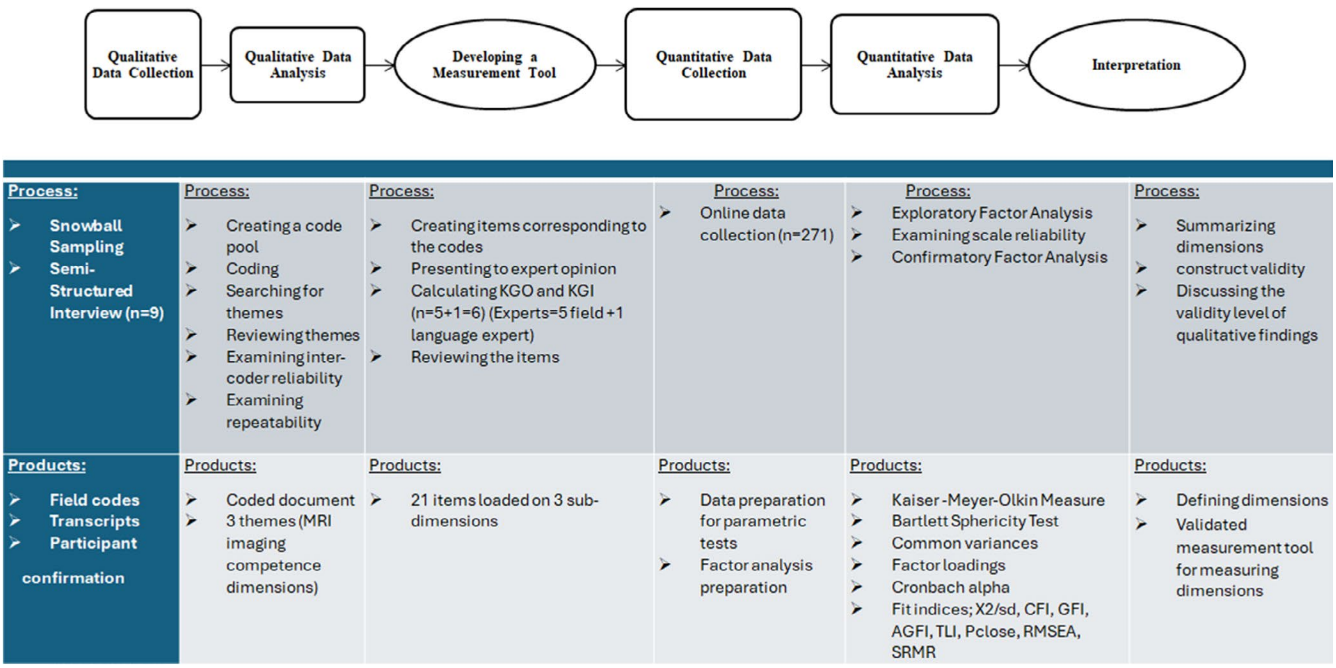

FIGURE 1 | MRI Interpretation Competency Scale (MRI-ICS)—exploratory sequential mixed methods diagram.

3.1.1 | Interview Questions

1. Should physicians be competent in interpreting MRI images? What are your thoughts on this? Please explain with your reasons.
2. When you recall your first experiences as a student with interpreting MRI images, what images come to mind? When and in which courses do you think MRI image interpretation should be taught? What parts of this process did you find challenging and needed support with? How would you teach this to students if you were in charge?
3. Are there any advantages to being competent in MRI interpretation? If so, what are they? What criticisms and suggestions do you have about this process?

TABLE 2 | Student views on competency in interpreting MRI images.

Theme	Category	Code	Sample participant statements
Necessity	Learning-oriented	Sustainable learning (20)	S4:*"I remember in my early years of being a student, I had difficulty aligning structures I saw in books and visuals with the actual human body. When we started using visuals like MRI images, sustainable learning occurred, and my perspective on the profession changed. These are indispensable for our profession.*
		Useful (14)	
		Research skill (17)	
		Thinking skill (13)	
		Makes classes enjoyable (7)	
		Problem-solving (11)	
	Diagnostic-oriented	Provides perspective (10)	
		Facilitates diagnosis (25)	
Criticism	Content-oriented	Not educational (7)	S7: *"Topics are dense, time is short, therefore the skill of interpreting MRI images keeps getting postponed."* S5: *It can also be learned at the beginning of the profession.* S2: *"It's very beneficial to be shown in class, but a student can also gain competency through their own efforts"* S1: *"Transferring theory into practice through this method is quite cost-effective. It must be emphasized."*
		Not useful (8)	
	Learning environment-oriented	Boring (3)	
		Time constraint (3)	
		Overloaded curriculum (8)	
		Irrelevant images (3)	
		Complex (4)	
		Does not meet expectations (6)	
		Limited (4)	
		Unnecessary (5)	
	Desire	Class level (9)	
		Should be given more attention (24)	
		More digital options (24)	
Change	Emotional change	Boring ➔ enjoyable (8)	S1: *"I remember warming up to the subject during my early years as a student when we started using materials like MRIs."* S6: *"Theoretical knowledge is indispensable for transferring into practice. Even if it seems like a waste of time in class, I have personally experienced its facilitation in the field."* S4: *"While I was underestimating the classes and only focusing on passing the exams, analyzing MRI images made me take the subjects more seriously."*
		Monotonous ➔ exciting (2)	
		Disliking the department ➔ liking it (2)	
		Underestimating ➔ taking seriously	
	Thought change	Meaningless ➔ logical (13)	
		Abstract ➔ concrete (12)	
		Waste of time➔ educational (11)	
		Theoretical ➔ practical (30)	
Suggestion	Individual	Education (22)	S8: *"Program developers should reduce theoretical content and increase practical applications."* S3: *"Imaging techniques are advancing in tandem with technology. In this context, medical students should be provided with education to become technologically literate."*
		Following technological advancements (16)	
	Institutional	Content should be enriched (9)	

In Table 2, student views on the interpretation of MRI images are presented. The students' statements suggesting that MRI images should be used as teaching aids in classes were developed into codes, which were then grouped into nine categories. These categories were further organized into four themes: "necessity, criticism, change, and suggestion."

The discussion in classes about MRI images will contribute to the interns' sustainable learning (20), comprehension of the subject (14), enhancement of research (17) and thinking skills (13), making the classes more enjoyable (7), and contributing to problem-solving abilities (11). These codes have been grouped under the "learning-oriented" category. Codes such as Facilitates Diagnosis (25) and Provides Perspective (10) fall under the "diagnostic-oriented" category. These two categories together have formed the theme of "necessity." Students have expressed the necessity of using MRI images in classes with a total of 117 codes, two categories, and one theme.

Responses to the question "Did using MRI images in classes during your early years as a student create any professional or personal change? If so, how?" led to the identification of the following: classes turning from boring to enjoyable (8), monotonous classes becoming exciting (2), beginning to like the department/profession (from a department or profession they initially disliked), and from not taking the subject seriously to recognizing its significance (2). These codes form the "emotional change" category. Furthermore, they have described transforming their perception of topics from meaningless to logical (13), abstract concepts to tangible (12), perceived time-wasting details to useful tools for learning (11), and theoretical knowledge into practical skills (30), creating the "thought change" category. Additionally, students have suggested the need for updated educational methods in line with technological advancements in health technologies like MRI (16) and advocated for enriching the practical content in medical education (9). These recommendations form the individual and institutional suggestion categories.

3.2 | Validity and Reliability Analysis

To develop a valid and reliable measurement tool, several steps were followed in this study [71, 72]:

Determining the Need for Testing: MRI image interpretation is a key skill in anatomy courses, but no existing tools assess student readiness. This gap highlighted the need for a new scale.

Literature Review and Question Pool Creation: A review of existing studies revealed no specific scales for MRI interpretation, guiding the creation of a new tool.

Item Writing: Items were generated to assess key competencies related to MRI interpretation. Creation of a Specification Table: A table was constructed to ensure that all relevant competencies were covered. Additional items were created where gaps were found.

Expert Opinion: Items were reviewed by five experts from medicine and dentistry. The CVR was calculated, and items with low CVR were removed. The CVI was also computed for the remaining items. Linguistic validity was ensured through consultation with a linguist.

Development of the First Draft Form: Based on expert feedback, the first draft was created, incorporating a five-point Likert scale (1–5).

Test Administration: Approval was obtained to administer the test to medical and dentistry students.

Factor Analysis: EFA was performed to assess the scale's structure.

Validity and Reliability Study: Cronbach's alpha (α) was calculated to measure the reliability of the scale and its sub-factors.

Finalizing the Test: Items with low factor loadings or reliability were removed, and the remaining items were organized into factors.

Instructions: Guidelines for completing the scale were added, and it was presented as a five-point Likert scale.

This structured approach ensured the development of a valid and reliable scale for MRI interpretation competency.

3.3 | Validity Analysis

Validity refers to the ability of a measurement instrument to accurately and fully measure the intended attribute without confounding with other characteristics. It concerns the degree to which an instrument measures what it is supposed to measure. Validity exists when the measurements of a particular phenomenon accurately reflect, define, or theoretically explain the phenomenon [73]. Validity reveals the measurability of the variable in question [74–80].

3.4 | "CVRs," Developed by Lawshe (1975) [81], Consist of a Six-Step Approach Known as the Lawshe Technique

a. Formation of an "expert panel."
b. Preparation of candidate scale forms.
c. Acquisition of expert opinions.
d. Derivation of CVRs for items.
e. Calculation of CVIs for the scale.
f. Creation of the final form based on CVR/CVI criteria

The Lawshe technique requires a minimum of 5 and a maximum of 40 expert opinions. Each item is rated by experts as "measuring the targeted construct," "related but unnecessary," or "not measuring the targeted construct." In addition to content validity, expert ratings can also assess item comprehensibility, appropriateness for the target audience, etc. Based on the experts' opinions on each item, CVRs are obtained (see Table 3).

TABLE 3 | CVR values following expert opinions.

Items	Necessary	Necessary/ insufficient	Unnecessary	CVR	Items	Necessary	Necessary/ insufficient	Unnecessary	CVR
Item 1	5			1.00	Item 16	5			1.00
Item 2	5			1.00	Item 17	5			1.00
Item 3	5			1.00	Item 18	5			1.00
Item 4	5			1.00	Item 19	5			1.00
Item 5	5			1.00	Item 20	5			1.00
Item 6	5			1.00	Item 21	5			1.00
Item 7	5			1.00	Item 22	3	1	1	−0.20
Item 8	5			1.00	Item 23	2	2	1	0.20
Item 9	1	0	4	−0.60	Item 24	5			1.00
Item 10	5			1.00	Item 25	5			1.00
Item 11	5			1.00	Item 26	3	0	2	0.20
Item 12	5			1.00	Item 27	5			1.00
Item 13	2	0	3	−0.20	Item 28	5			1.00
Item 14	5			1.00	Item 29	5			1.00
Item 15	5			1.00	Item 30	5			1.00

Note: Number of expert panelists = 5. Content validity ratio (CVR) = 0.993. Content validity index (CVI) = 0.986.

The CVRCVR is calculated by subtracting one from the ratio of the number of experts deeming an item "essential" to the total number of experts who provided an opinion on the item.

$$CVR = \frac{NG}{N/2} - 1 \quad (1)$$

While the Lawshe technique is the most common method for content validity, other techniques have been developed. Davis' (1992) [78] technique categorizes expert opinions into four levels:

(a) "Suitable," (b) "Item should be slightly revised," (c) "Item needs serious revision," and (d) "Item is not suitable." In this technique, the number of experts who choose options (a) and (b) is divided by the total number of experts to obtain the "CVI" for the item. This index does not compare to a statistical measure but uses 0.80 as the criterion value. The CVI is then found by averaging the CVR values of the remaining items [79].

$$CVI = \frac{NG + NGY}{N} \quad (2)$$

Following expert opinions, proposed structural as well as language and spelling corrections were made, and the CVR was calculated. The calculation results are presented in Table 3.

Following expert reviews, items 9, 13, 18, 22, and 26 were removed from the study; items 6 and 17 were transformed into different items. Moreover, item 5 was divided into two separate questions, and four additional items were included based on expert recommendations. The draft scale's CVR was calculated at 0.993 and CVI at 0.986.

3.5 | Reliability Analysis

Preliminary analyses focused on verifying the suitability of data for EFA on the MRI-ICS. This involved assessing missing data, reversed items, outlier data, data normality, inter-item correlations, sample size, and sample adequacy (KMO and BTS) [80–85]. Additionally, negatively phrased items such as 9, 10, 11, 12, 13, 14, 27, and 28 were reversed. The dataset's normality tests included the Kolmogorov–Smirnov test ($p > 0.05$), histogram plots, and skewness and kurtosis values within the range of –2 to +2 [86].

3.6 | Parametric Test Assumptions

Before factor analysis, the data distribution was tested against parametric test assumptions, including sample size, normality, and homogeneity of variances. According to Yazıcıoğlu and Erdoğan (2004), the required sample size was determined to be at least 254 participants for a 0.05 sampling error at a 95% confidence level, based on a population of 750. The actual participant count of 272 exceeded the necessary sample size, fulfilling the parametric test assumption for sample size (N1 = 272 > 254). Normality analysis was conducted to determine if the data distribution was normal. The results of these analyses are presented in Table 4.

In the literature, it is suggested to use Shapiro–Wilk for sample sizes less than 30 and Kolmogorov–Smirnov for larger sample sizes [81]. This study used Kolmogorov–Smirnov due to the sample size exceeding 30, and the results confirmed the normal distribution of the data [82]. For a distribution to be considered normal, skewness, and kurtosis values should ideally lie between –1.50 and +1.50 [83]. Before conducting factor analysis, the distribution's suitability for parametric tests was assessed (see Table 5).

TABLE 4 | Normality test.

	Kolmogorov–Smirnov $n > 30$				
	Statistic	**df**	**Sig.**	**Skewnes**	**Kurtosis**
MR-ICS	0.033	271	0.200	−0.816 and 0.148	1.468 and 0.295

TABLE 5 | KMO and Bartlett's test values.

KMO and Bartlett's test		
Kaiser–Meyer–Olkin measure of sampling adequacy		0.877
Bartlett's test of sphericity	Approx. Chi-square	2879.471
	df	210
	Sig.	0.000*

*$p < 0.05$.

The adequacy of the sample used in the study was evaluated using the KMO measure and BTS to determine if the scale was suitable for factor analysis. The KMO statistic varies between 0.00 and 1.00. A value close to 1.00 indicates compactness in the correlation patterns, which is conducive for reliable and discriminative factor analysis. KMO values are classified as follows [84]:

- 0.50–0.70: mediocre.
- 0.70–0.80: good.
- 0.80–0.90: very good.
- Above 0.90: excellent.

The KMO test result for this measuring instrument was calculated to be 0.877, which is considered "very good." This suggests that the factor analysis based on these data is likely to be reliable. The BTS examines whether the population correlation matrix resembles an identity matrix, essentially testing if the correlation matrix's off-diagonal elements are all zero, which would make it unsuitable for factor analysis. A significant BTS value indicates that the data are appropriate for factor analysis. In this study, the BTS was highly significant ($B = 2879.471$, $p < 0.01$), confirming that the data are suitable for factor analysis.

3.7 | Exploratory Factor Analysis

EFA was conducted to explore the relationships among items in MRI-ICS based on a correlation matrix. The unrotated principal component analysis suggested a three-factor structure, with eigenvalues above 2.00, explaining a significant portion of the variance. The communalities ranged from 14.00 to 27.45, indicating strong contributions to the variance.

Showed that there was a clear break after the third factor, which suggests that the scale could be structured around three factors [84–86]. However, reliance solely on the plot for factor selection is not advisable. Thus, further analysis was performed using Maximum Likelihood and Varimax rotation with Kaiser Normalization. A threshold of 0.40 for factor loadings was used, ensuring only significant items were retained. The rotated component matrix showed some items loading on multiple factors, necessitating further refinement and reducing the item count to 21 (Table 6).

The factor loadings ranged from 0.32 to 0.70, with 9 items rated as "excellent" (0.70+), 6 as "very good" (0.63–0.69), and 6 as "good" (0.55–0.62) [87–91]. This confirmed that the MRI-ICS could be used both multifactorially and unidimensionally. Reliability analysis indicated that no item decreased the overall scale's reliability, resulting in the final scale of 21 items, using a five-point Likert scale ranging from "Never" to "Always."

The MRI-ICS scores range from 21 to 101, with higher scores indicating greater competency in MRI interpretation. To assess the discriminative power of the items, the sample was divided into two groups (upper and lower 27% based on scores). An independent samples t-test revealed significant differences between the groups, confirming the scale's effectiveness in distinguishing competency levels ($p < 0.05$) (Table 7).

TABLE 6 | Factor and item loadings according to rotated component matrix.

Items	Factor 1	Factor 2	Factor 3	Cronbach's alpha if item deleted
I7	0.846			0.871
I 6	0.817			0.872
I 4	0.685			0.869
I 2	0.634			0.871
I 23	0.657			0.875
I 3	0.595			0.871
I 22	0.612			0.871
I 1	0.589			0.873
I 15		0.821		0.874
I 17		0.812		0.877
I 20		0.779		0.876
I 21		0.722		0.879
I 11		0.691		0.878
I 8		0.676		0.878
I 24		0.605		0.878
I 5			0.760	0.872
I 28			0.736	0.878
I 26			0.721	0.873
I 25			0.631	0.870
I 30			0.587	0.879
I 18			0.580	0.873
Explained variance	27.45	20.25	14.00	

3.8 | Reliability and Validity of the MRI-ICS

Descriptive statistics for the sub-factors of MRI-ICS are detailed in Table 8. The three factors, along with their explained variance and Cronbach's α coefficients, are as follows:

- Factor 1 (ability to discern structures in MRI images): eight items, 27.46% explained variance, Cronbach's $\alpha = 0.89$
- Factor 2 (necessity for professional development): seven items, 20.25% explained variance, Cronbach's $\alpha = 0.80$
- Factor 3 (utilization in the diagnostic process): six items, 14.01% explained variance, Cronbach's $\alpha = 0.84$

The total explained variance by the MRI-ICS is 61.72%, with an overall Cronbach's α of 0.89, indicating high internal consistency across the constructs.

3.9 | Correlations Between Sub-Dimensions

Table 9 presents the correlation between the factors and total scale scores. Significant positive correlations were found between the total scale score and Factor 1 ($r = 0.830$; $p < 0.01$), Factor 2 ($r = 0.842$; $p < 0.01$), and Factor 3 ($r = 0.619$; $p < 0.01$). The correlations between factors also revealed positive relationships, with moderate correlations between Factor 1 and Factor 3 ($r = 0.740$; $p < 0.01$), and between Factor 2 and Factor 3 ($r = 0.242$; $p < 0.01$). These results indicate that the scale is valid both as a whole and in its individual factors.

This exploratory analysis supports the MRI-ICS as a valid, reliable tool for assessing MRI interpretation competency, with significant factor structures and internal consistency, making it applicable for use in educational settings.

4 | Discussion

The need to assess and improve medical professionals' MRI interpretation skills has led to the development of the MRI-ICS [1, 5, 87, 88]. Initially, a 30-item version was implemented, but it was refined into a 21-item scale focusing on the cognitive aspects essential for accurate MRI interpretation. This revised version underwent rigorous validation under diverse conditions to ensure its broad applicability, regardless of healthcare system maturity or curriculum specifics. Validation results demonstrated that the MRI-ICS effectively measures competency in MRI interpretation, showing strong fit statistics across educational phases. Its construct validity was confirmed by the consistent impact on learners' proficiency, suggesting its potential to significantly improve MRI competency, enhance diagnostic accuracy, and, ultimately, boost patient care quality.

4.1 | Theoretical and Practical Implications

Comparative analysis with prior studies underscores the contribution of the MRI-ICS to this field. For example, earlier research by Hyde et al. [89] highlighted the need for a structured approach to assessing eHealth literacy among imaging outpatients—a need addressed by the MRI-ICS through its robust methodological framework. Additionally, the variability in experiential learning implementation across medical programs, as reported in studies [90–92], supports the necessity of the MRI-ICS's standardized approach to embedding practical skills within educational curricula. The MRI-ICS represents a significant theoretical advancement in medical education, bridging the divide between theoretical knowledge and clinical application.

It reflects a shift toward competency-based evaluation and practical skills integration, moving away from traditional models reliant on rote memorization. This shift aligns with evolving educational frameworks that emphasize experiential learning [92–95], and is further supported by studies such as those by Van Reeth et al. [6] and Wade et al. [23], which call for competency-focused curricula. The MRI-ICS advances this pedagogical direction by integrating practical skill development into medical

TABLE 7 | Results regarding the comparison of the discrimination levels of the items.

Items	Group	N	M	SD	*t*	df	*p*
I 1	Upper group	73	3.75	0.78	9.210	144	0.000*
	Lower group	73	2.42	0.96			
I 2	Upper group	73	2.88	1.13	10.828	144	0.000*
	Lower group	73	1.30	0.52			
I 3	Upper group	73	3.59	0.74	12.892	144	0.000*
	Lower group	73	1.95	0.80			
I 4	Upper group	73	3.04	0.99	13.412	144	0.000*
	Lower group	73	1.29	0.51			
I 5	Upper group	73	2.79	1.12	9.865	144	0.000*
	Lower group	73	1.33	0.60			
I 6	Upper group	73	2.77	0.86	11.872	144	0.000*
	Lower group	73	1.33	0.58			
I 7	Upper group	73	2.63	0.86	12.804	144	0.000*
	Lower group	73	1.19	0.43			
I 8	Upper group	73	4.41	0.88	6.956	144	0.000*
	Lower group	73	3.14	1.29			
I 11	Upper group	73	3.93	0.99	6.505	144	0.000*
	Lower group	73	2.79	1.12			
I 15	Upper group	73	4.45	0.69	6.557	144	0.000*
	Lower group	73	3.34	1.27			
I 17	Upper group	73	4.49	0.73	6.795	144	0.000*
	Lower group	73	3.33	1.27			
I 18	Upper group	73	3.55	0.83	11.245	144	0.000*
	Lower group	73	1.96	0.87			
I 20	Upper group	73	4.49	0.65	6.537	144	0.000*
	Lower group	73	3.36	1.34			
I 21	Upper group	73	4.25	0.72	4.946	144	0.000*
	Lower group	73	3.45	1.17			
I 22	Upper group	73	2.85	1.08	11.948	144	0.000*
	Lower group	73	1.22	0.45			
I 23	Upper group	73	2.41	1.08	8.152	144	0.000*
	Lower group	73	1.25	0.57			
I 24	Upper group	73	4.16	0.78	5.935	144	0.000*
	Lower group	73	3.10	1.32			
I 25	Upper group	73	3.64	0.86	15.774	144	0.000*
	Lower group	73	1.48	0.80			
I 26	Upper group	73	3.11	1.11	10.515	144	0.000*
	Lower group	73	1.42	0.80			
I 28	Upper group	73	2.92	1.08	6.733	144	0.000*
	Lower group	73	1.71	1.09			
I 30	Upper group	73	4.63	0.59	5.328	144	0.000*
	Lower group	73	3.62	1.52			

*$p < 0.05$.

training, in line with the curriculum restructuring advocated by researchers like Dent et al. [96].

Furthermore, comparisons with earlier studies, such as Hyde et al. [89], reveal how MRI-ICS addresses gaps in previous

TABLE 8 | Number of items, explained variance, and internal consistency coefficients for the sub-dimensions of the scale.

Faktörler	Item numbers	Number of items	Explained variance values	Cronbach's alpha (α)
Factor 1: ability to discern structures in MRI images	1, 2, 3, 4, 6, 7, 22, 23	8	27.46	0.89
Factor 2: necessity for professional development	15, 17, 20, 21, 11, 8, 24	7	20.25	0.80
Factor 3: utilization in the diagnostic process of MRI images	5, 28, 26, 25, 30, 18	6	14.01	0.84
Total		21	61.717	0.89

TABLE 9 | Correlations analysis results.

		Factor 1	Factor 2	Factor 3	Total score
Factor 1	Pearson correlation	1			
	p				
	N	271			
Factor 2	Pearson correlation	0.148*	1		
	p	0.015			
	N	271	271		
Factor 3	Pearson correlation	0.740**	0.242**	1	
	p	0.000	0.000		
	N	271	271	271	
Toplam Puan	Pearson correlation	0.830**	0.619**	0.842**	1
	p	0.000	0.000	0.000	
	N	271	271	271	271

*Correlation is significant at the 0.05 level (two-tailed).
**Correlation is significant at the 0.01 level (two-tailed).

educational frameworks, particularly regarding the assessment of eHealth literacy in imaging contexts. Its standardized approach contributes to a more structured, real-world-aligned medical curriculum. Additionally, MRI-ICS could catalyze academic discussions about balancing theoretical knowledge and practical skills training in medical education, which is increasingly necessary to address the complexities of modern healthcare environments [97].

The MRI-ICS has practical benefits across various educational sectors. For medical institutions, it offers a tested framework to assess and refine MRI interpretation skills. By identifying skill gaps, the MRI-ICS enables curriculum adjustments that directly align with both academic goals and clinical demands. It informs curriculum development by embedding a competency-based approach that prepares students for the clinical challenges they will face. For policymakers, the MRI-ICS serves as a benchmark for standardizing MRI competency assessments, potentially influencing national accreditation standards. This standardization can enhance the overall quality of medical training globally.

For learners, MRI-ICS provides a clear pathway to mastering MRI interpretation, offering structured feedback and progress tracking. It enhances learning experiences by focusing on practical skills directly applicable to clinical settings. Moreover, the MRI-ICS can drive further research into optimizing competency-based assessments in medical education, potentially leading to new insights into effective teaching strategies.

4.2 | Conclusion

The MRI-ICS represents a significant advancement in medical education, particularly in radiology and anatomy, by providing a competency-based framework for assessing MRI interpretation skills. In this study, the MRI-ICS was developed through a sequential exploratory mixed methods design and validated through EFA. The final scale consists of 21 items across three factors: (1) ability to discern structures in MRI images, (2) necessity for professional development, and (3) utilization in the diagnostic process. The MRI-ICS demonstrated high construct validity (total explained variance = 61.72%) and excellent internal consistency (overall Cronbach's $\alpha = 0.89$). These findings confirm the scale's robustness and educational relevance. By addressing the previously unmet need for standardized, MRI-specific competency assessments, the MRI-ICS bridges the gap between theoretical knowledge and clinical application. It enhances both the precision of student evaluations and the alignment of educational outcomes with real-world diagnostic demands. As the MRI-ICS continues to inform curriculum development and competency-based assessment strategies, it will contribute to the training of highly skilled medical professionals equipped to meet the evolving challenges of modern healthcare. Furthermore, it underscores the necessity of continuous adaptation and refinement of educational tools in response to technological and clinical advancements.

4.3 | Limitations and Future Research

Despite its promise, the MRI-ICS has limitations. Its reliance on self-reported measures may not fully capture students' practical abilities in real-world settings. Future studies could incorporate direct observational techniques or simulation-based assessments to provide a more accurate measure of competency. Additionally, while the MRI-ICS is currently tailored for specific medical education settings, its adaptability to other disciplines, such as neurology or cardiology, remains untested. Future research could explore its use in these areas to broaden its applicability.

Cross-cultural validity is another important consideration. The scale's effectiveness may vary across different international educational environments with diverse teaching methodologies and clinical practices. Exploring these variations will help customize the MRI-ICS for different educational norms and clinical expectations. Longitudinal studies are also needed to assess the long-term predictive validity of the MRI-ICS, tracking students' clinical performance over time to gauge the enduring impact of competency-based education on clinical proficiency.

Integrating advanced technologies like AI and machine learning could revolutionize the MRI-ICS's application. These technologies could automate the assessment process, provide real-time feedback, and enhance the scale's accuracy and efficiency, making it even more dynamic and responsive to students' learning patterns.

Ethics Statement

The study was submitted to the Non-Interventional Clinical Researches Publication Ethics Committee of Ordu University, and the decision of the Ethics Committee, dated 29.09.2023 and numbered 2023/243, was obtained (Appendix 1).

Conflicts of Interest

The authors declare no conflicts of interest.

Data Availability Statement

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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Appendix 1

The MRI Interpretation Competency Scale (MRI-ICS)

Factor and item	Never	Rarely	Sometimes	Often	Always
Factor 1: Ability to discern structures in MRI images					
1. I can distinguish organs in an MRI image.					
2. I can identify the level of the MRI image.					
3. I can differentiate between various structures in the MRI image.					
4. I can detect major anomalies in the MRI image.					
5. I can recognize variations in the MRI image.					
6. I can distinguish between variations and pathological anomalies in the MRI image.					
7. I can detect hematomas in the MRI image.					
8. I can grade hematomas in the MRI image.					
Factor 2: Necessity for professional development					
9. I believe that improving my ability to interpret MRI images will contribute to my profession.					
10. I feel a need for more attention to MRI images in lessons.*					
11. I think my ability to interpret MRI images will improve as I study them.					
12. As my knowledge of MRI imaging increases, so does my confidence in my professional competence.					
13. I believe it is necessary to utilize MRI images in modern anatomy education.					
14. I think MRI images serve as a bridge between basic and clinical medicine.					
15. I believe that interpreting MRI images in emergencies increases survival rates.					
Factor 3: Utilization in the diagnostic process of MRI images					
16. I can critique a report related to an MRI image.					
17. I can estimate when an MRI image should be requested.					
18. I can communicate the results of MRI images to patients in a way they understand.					
19. I know what to do when I encounter a pathology in an MRI image.					
20. I am not hesitant to interpret an MRI image in an unprepared situation.					
21. I do not hesitate to seek my colleagues' opinions when I find it difficult to interpret MRI images.					
*Reverse-scored item					