DEVELOPMENT OF A MULTICRITERIA DIAGNOSTIC INSTRUMENT FOR EVALUATING THE QUALITY OF TEACHING RADIATION SAFETY TOPICS BASED ON PROBLEM-BASED LEARNING

Olimboyeva Donakhon
Acting Associate Professor
Department of Internal Diseases, Faculty of General Medicine and Pediatrics
Alfraganus University, NOTT

DOI: 10.67620/sai.58b0009

ABSTRACT

This study developed a multicriteria diagnostic questionnaire for evaluating problem-based teaching of radiation safety topics in higher medical education, using dosimetry as the instructional context. The instrument provides a multidimensional assessment of student learning beyond conventional grade-based indicators. It includes five criteria—cognitive, motivation, readiness, practice orientation, and methodological competence—represented by 31 items. Cognitive performance is assessed through multiple-choice items, whereas the remaining criteria use a five-point Likert scale. Content validity was evaluated by five experts in pedagogy and medicine, and internal consistency was considered using Cronbach's alpha. The instrument was piloted at Samarkand State Medical University during instruction on "The Importance of Dosimetry in Medicine." Participants comprised a control group taught using a traditional method (n = 25) and an experimental group taught through problem-based learning (n = 26). Across all five criteria, the experimental group achieved higher results, with an average difference of 15.8 percentage points. The consistent criterion-level separation supports the argument that multidimensional assessment can reveal differences in motivation, readiness, practical application, and methodological competence that may be obscured by a single aggregate grade, strengthening the instrument's practical value for evaluating pedagogical approaches in higher medical education.

ACCEPTED

07.09.26

Keywords: *diagnostic tool, questionnaire, system of criteria and indicators, problem-based learning, radiation safety, dosimetry, reliability, higher medical education, testing.*

CC BY

Introduction

In pedagogical research, evaluating teaching quality only through an average score or the proportion of high grades is convenient but conceptually narrow. Such indicators summarize performance, yet they do not show whether students are motivated to use what they know, ready to act in non-standard situations, able to transfer knowledge to practice, or capable of regulating their own learning. This limitation is especially important in radiation safety, where competent medical practice depends not only on recalling dose units and protection rules but also on applying them appropriately in clinical decisions. International guidance explicitly emphasizes theoretical and practical radiation-protection education for medical professionals, while consensus work has identified radiation-protection competencies that medical students should possess at graduation (European Commission, Directorate-General for Energy, 2014;

ISSN: 2181-3337 | SCIENTISTS.UZ

Singh et al., 2008). Therefore, a diagnostic instrument for this field should measure several educational dimensions rather than reduce teaching quality to a single grade. This position is consistent with contemporary testing standards and scale-development guidance, which emphasize that score interpretations should be supported by evidence relevant to the intended constructs and uses (American Educational Research Association et al., 2014; Boateng et al., 2018; DeVellis, 2017).

The purpose of this study is to develop a multicriteria diagnostic questionnaire instrument that enables a comprehensive assessment of the quality of teaching radiation safety, specifically dosimetry, in higher medical education using problem-based learning (PBL); to present the theoretical basis for its five criteria; and to examine its practical sensitivity through a pedagogical pilot conducted at Samarkand State Medical University. The central argument is that a multidimensional instrument can provide more educationally actionable information than a single aggregate score because it shows not only whether groups differ, but also in which dimensions those differences are most pronounced.

Theoretical Foundations

The instrument's criteria are based on the following theoretical foundations:

The cognitive criterion is based on Bloom's taxonomy of educational objectives: this criterion measures how well a student has mastered theoretical knowledge of dosimetry—units, instruments, principles, and standards (Bloom, 1956).

The motivation criterion is based on Deci and Ryan's self-determination theory: according to this theory, a person's intrinsic interest and the value they attach to a subject determine their learning engagement, so this criterion assesses the student's interest in the topic and their awareness of its professional significance (Deci & Ryan, 1985).

The readiness criterion measures the student's inner confidence in applying acquired knowledge to practical situations—calculating radiation dose and making decisions in non-standard situations—and represents one of the primary goals of problem-based learning technology (Trullàs et al., 2022).

The practice-orientation criterion reflects the student's ability to connect theoretical knowledge with real clinical situations and to make evidence-based decisions.

The methodological competence criterion assesses the student's ability to manage their own learning activity—planning, reflection, analyzing sources, and explaining material to others—a skill essential for independent, lifelong learning in the future.

The overall methodology for designing the questionnaire structure and measurement instruments was organized in accordance with DeVellis's scale development theory (DeVellis, 2017).

Research Methodology

The research topic—"The Importance of Dosimetry in Medicine"—is a core component of preparation for clinical fields such as radiology, radiation therapy, and nuclear medicine. It includes knowledge and skills related to ionizing-radiation dose, dosimetric instruments, and protection of patients and medical personnel. Radiation-protection guidance emphasizes that medical education should include both theoretical knowledge and practical competence, and prior consensus research has identified a broad set of radiation-protection competencies relevant to graduating medical students (European Commission, Directorate-General for Energy, 2014; Singh et al., 2008). The technical and applied nature of dosimetry therefore makes it particularly suitable for teaching approaches that require students to connect concepts with realistic decisions rather than rely on verbal explanation alone.

For this reason, the study applied problem-based learning (PBL). Students were presented with realistic dosimetry problems—for example, calculating a patient's radiation dose or analyzing a case in which a radiation-safety rule had been violated—and worked in small groups to identify what they knew, determine what additional information was needed, and justify a solution before collective discussion and conclusion. This choice is theoretically and empirically grounded. PBL can activate prior knowledge, promote elaboration, stimulate situational interest, and organize learning around meaningful problems

ISSN: 2181-3337 | SCIENTISTS.UZ

(Schmidt et al., 2011). Meta-analytic and systematic-review evidence indicates that PBL is particularly relevant to application, skills, and competency-oriented outcomes, even when effects on factual knowledge are more variable (Dochy et al., 2003; Koh et al., 2008; Trullàs et al., 2022). Accordingly, an evaluation of PBL in radiation safety should assess more than knowledge alone; it should also examine motivation, readiness, practical application, and methodological competence.

The diagnostic instrument was designed with five criteria: cognitive (5 items), motivation (4 items), readiness (7 items), practice orientation (8 items), and methodological competence (7 items)—31 items in total. The cognitive criterion is assessed through multiple-choice test items (with a single correct answer), while the remaining four criteria are assessed using a 5-point Likert scale ("fully agree"—4 points, to "fully disagree"—0 points). Each item is worth 3.23 points, so the overall maximum score is 100. Based on the score obtained, four levels (high, medium, low, lowest) are defined for each criterion and for the overall result; these level zones and the groups' positions relative to them are presented in Figure 1.

The content of the instrument was reviewed by five experts in pedagogy and medicine as an initial source of content-validity evidence. This step is consistent with established scale-development practice, in which expert review is used to examine whether items adequately represent the intended constructs (Boateng et al., 2018; DeVellis, 2017). Internal consistency was considered using Cronbach's alpha (Cronbach, 1951). In accordance with contemporary testing standards, these forms of evidence should be viewed as part of an ongoing validation process rather than as a single definitive test of validity (American Educational Research Association et al., 2014). The pilot results indicated a satisfactory level of reliability; future studies should report the numerical reliability coefficient and extend validation using larger samples and additional evidence of dimensional structure and score interpretation.

To pilot the instrument, a pedagogical experiment was conducted at Samarkand State Medical University during the teaching of the topic "The Importance of Dosimetry in Medicine." The study involved a control group (25 students, taught the topic using the traditional method) and an experimental group (26 students, taught the topic based on problem-based learning technology). The questionnaire was administered individually to both groups at the end of the lesson.

Research Results and Analysis

Based on the questionnaire results, the average scores and percentage indicators of the control and experimental groups across the criteria are presented in Table 1.

Table 1

Diagnostic Results of the Control and Experimental Groups by Criterion

Criterion	Control (n = 25), points	Control, %	Experimental (n = 26), points	Experimental, %	Difference, p.p.
Cognitive	11.8	73.3	14.3	88.8	15.5
Motivation	9.6	74.4	11.8	91.5	17.1
Readiness	16.9	74.8	20.5	90.7	15.9
Practice orientation	19.2	74.4	23.4	90.7	16.3
Methodological competence	16.5	73.0	19.8	87.6	14.6
Overall score (out of 100)	**74.0**	**74.0**	**89.8**	**89.8**	**15.8**

Note. p.p. = percentage points.

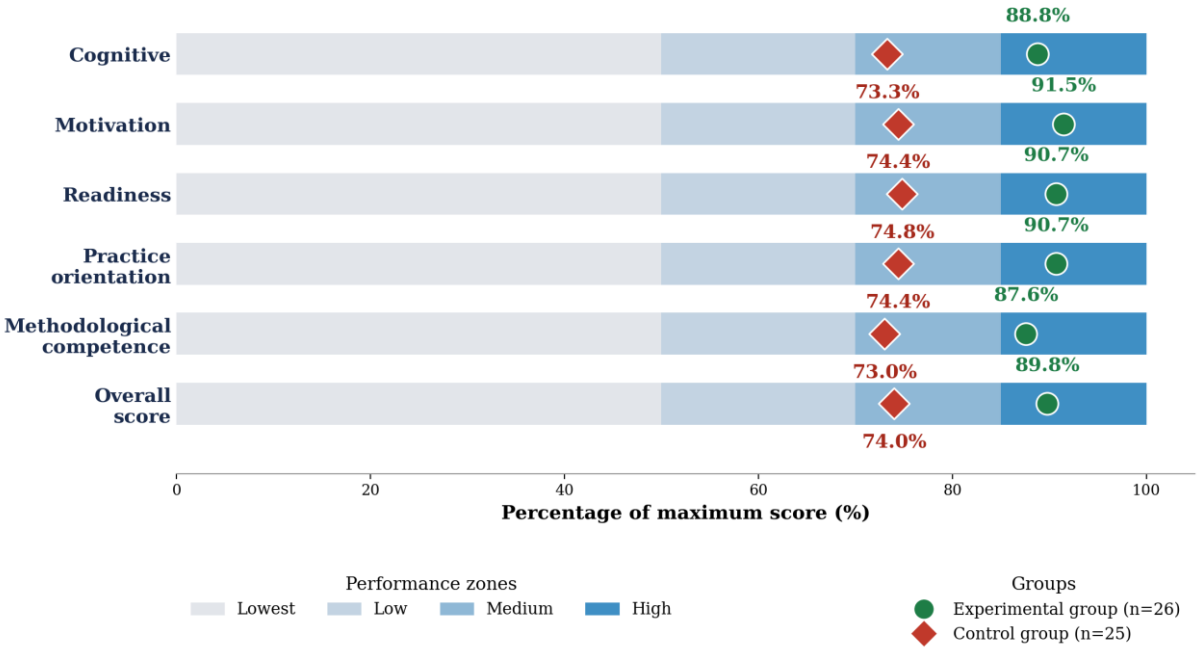
The table data show that the experimental group's results across all five criteria fall into the "high level" (close to the 86.0–90.0-point range), while the control group's results fall into the "medium level" (71.0–85.0 points). The difference in the overall score amounted to 15.8 percentage points.

Figure 1 shows, in a single combined view, the four level zones defined for each criterion (lowest, low, medium, high) as the background, with the average results of the control and experimental groups shown as markers.

ISSN: 2181-3337 | SCIENTISTS.UZ

Figure 1

Performance Zones by Criterion and Comparative Average Results of the Groups



The figure shows that all of the control group's indicators lie within the "medium level" zone, while the experimental group's indicators lie within the "high level" zone across all criteria. This confirms the instrument's ability to clearly and visually demonstrate the difference between the groups.

Figure 2 presents the comparative indicators of both groups across the five criteria.

Figure 2

Comparative Indicators of the Control and Experimental Groups Across Five Criteria

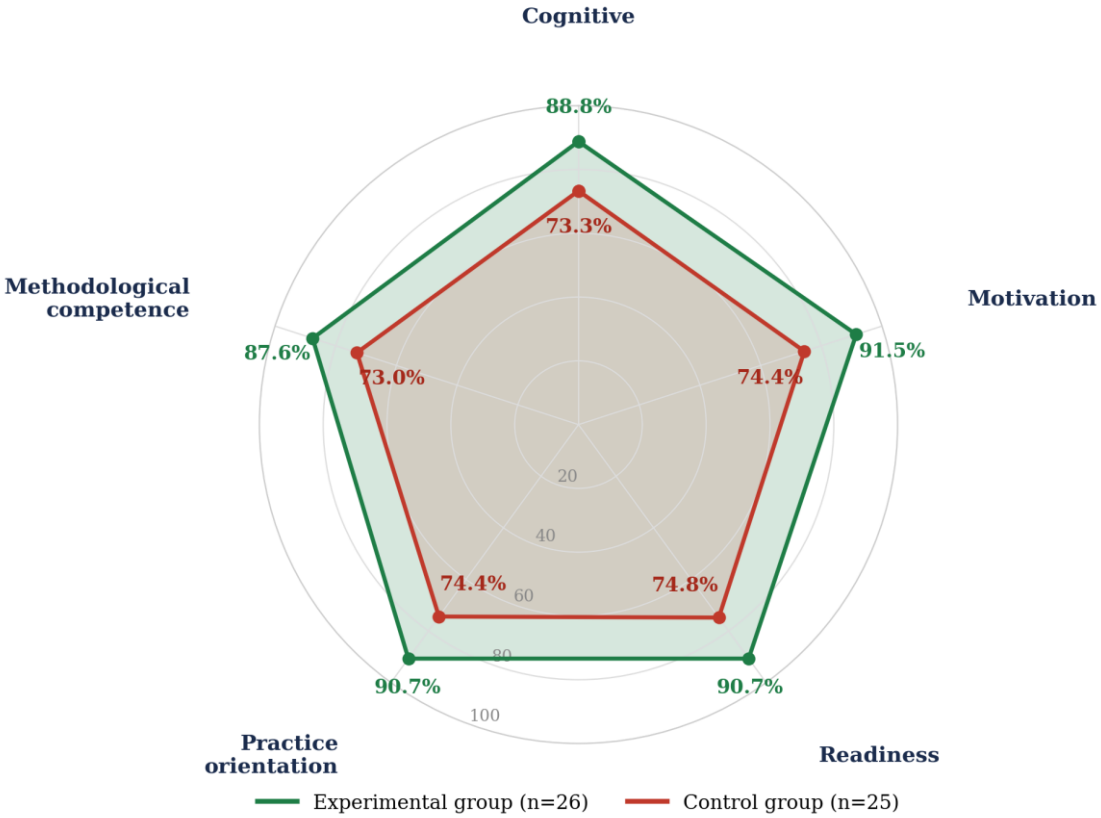


Figure 2 shows that the experimental group's line lies outside the control group's line for every criterion. The largest difference was recorded for the motivation (17.1%) and practice-orientation (16.3%)

ISSN: 2181-3337 | SCIENTISTS.UZ

criteria, and the smallest for the methodological competence criterion (14.6%). This demonstrates that the instrument has discriminant power across different criteria—that is, it can distinguish not just an overall score but also which aspects of the teaching technology it affects more strongly.

Discussion

The central argument of this study is that teaching quality in radiation safety is not adequately represented by a single final grade. Safe practice requires a combination of knowledge, motivation to apply protection principles, readiness to respond to non-standard situations, translation of theory into clinical decisions, and the capacity for independent learning. This multidimensional view is consistent with competency-oriented radiation-protection guidance and with consensus work on what graduating medical students should know and be able to do (European Commission, Directorate-General for Energy, 2014; Singh et al., 2008). From a measurement perspective, it also aligns with the principle that an assessment should provide evidence relevant to the distinct constructs it is intended to represent rather than collapse them into one undifferentiated outcome (American Educational Research Association et al., 2014; Boateng et al., 2018).

The observed criterion-level separation provides a practical argument for the usefulness of the instrument. PBL is designed to engage learners with authentic problems, activate prior knowledge, and require elaboration and collaborative reasoning (Schmidt et al., 2011). Broader evidence from meta-analysis and systematic review suggests that PBL can be especially beneficial for applied, skills-based, and professional competency outcomes (Dochy et al., 2003; Koh et al., 2008; Trullàs et al., 2022). In the present pilot, the largest descriptive differences occurred in motivation and practice orientation, which is theoretically coherent with a learning approach built around meaningful clinical problems and active decision-making. The value of the multicriteria instrument is therefore not merely that it produces a higher or lower total score; it makes visible which dimensions of learning show the greatest separation between instructional conditions, information that an aggregate grade may conceal.

At the same time, the findings should be interpreted as preliminary evidence of practical sensitivity rather than definitive proof of construct validity or causal superiority. The pilot included a small sample and relied on descriptive comparisons between groups, and the manuscript does not report the numerical Cronbach's alpha coefficient or inferential tests of group differences. Future validation should report reliability coefficients, quantify and document content-validity evidence, examine the instrument's dimensional structure, and test score interpretations in larger independent samples (American Educational Research Association et al., 2014; Boateng et al., 2018). Stating these limits strengthens rather than weakens the study's argument: the present results show why a multicriteria approach is educationally informative, while further psychometric work can establish how consistently and generalizably the instrument performs.

Conclusion

The five-criteria diagnostic questionnaire—cognitive, motivation, readiness, practice orientation, and methodological competence—offers a more informative framework for evaluating radiation-safety teaching than a single grade-based quality indicator. In this pilot, the experimental group taught through PBL scored higher than the control group across every criterion, with an average descriptive difference of 15.8 percentage points. The consistency of the criterion-level pattern, together with broader evidence that PBL supports applied and competency-oriented learning, strengthens the case for using multidimensional assessment when evaluating pedagogical approaches in higher medical education (Dochy et al., 2003; Koh et al., 2008; Trullàs et al., 2022). These results support the instrument's practical utility and justify larger validation studies. Before broad generalization, future research should confirm reliability, dimensional structure, content validity, and criterion-related evidence in larger and independent samples.

ISSN: 2181-3337 | SCIENTISTS.UZ

Funding

This article was prepared within the framework of the innovative project No. AM-П3-2019062031, "Creation of multimedia textbooks for bachelor's and master's students in the disciplines 'Nuclear Power Engineering,' 'Nuclear Medicine and Technologies,' and 'Radiation Medicine and Technologies.'"

REFERENCES

1. American Educational Research Association, American Psychological Association, & National Council on Measurement in Education. (2014). *Standards for educational and psychological testing*. American Educational Research Association.
2. Bloom, B. S. (Ed.). (1956). *Taxonomy of educational objectives: The classification of educational goals. Handbook I: Cognitive domain*. David McKay Company.
3. Boateng, G. O., Neilands, T. B., Frongillo, E. A., Melgar-Quiñonez, H. R., & Young, S. L. (2018). Best practices for developing and validating scales for health, social, and behavioral research: A primer. *Frontiers in Public Health, 6*, Article 149. https://doi.org/10.3389/fpubh.2018.00149
4. Cronbach, L. J. (1951). Coefficient alpha and the internal structure of tests. *Psychometrika, 16*(3), 297–334. https://doi.org/10.1007/BF02310555
5. Deci, E. L., & Ryan, R. M. (1985). *Intrinsic motivation and self-determination in human behavior*. Plenum Press. https://doi.org/10.1007/978-1-4899-2271-7
6. DeVellis, R. F. (2017). *Scale development: Theory and applications* (4th ed.). SAGE Publications.
7. Dochy, F., Segers, M., Van den Bossche, P., & Gijbels, D. (2003). Effects of problem-based learning: A meta-analysis. *Learning and Instruction, 13*(5), 533–568. https://doi.org/10.1016/S0959-4752(02)00025-7
8. European Commission, Directorate-General for Energy. (2014). *Guidelines on radiation protection education and training of medical professionals in the European Union* (Radiation Protection No. 175). Publications Office of the European Union. https://doi.org/10.2833/19786
9. Koh, G. C.-H., Khoo, H. E., Wong, M. L., & Koh, D. (2008). The effects of problem-based learning during medical school on physician competency: A systematic review. *CMAJ, 178*(1), 34–41. https://doi.org/10.1503/cmaj.070565
10. Schmidt, H. G., Rotgans, J. I., & Yew, E. H. J. (2011). The process of problem-based learning: What works and why. *Medical Education, 45*(8), 792–806. https://doi.org/10.1111/j.1365-2923.2011.04035.x
11. Singh, R. K., McCoubrie, P., Burney, K., & Miles, J. A. (2008). Teaching medical students about radiation protection—what do they need to know? *Clinical Radiology, 63*(12), 1344–1349. https://doi.org/10.1016/j.crad.2008.06.010
12. Trullàs, J. C., Blay, C., Sarri, E., & Pujol, R. (2022). Effectiveness of problem-based learning methodology in undergraduate medical education: A scoping review. *BMC Medical Education, 22*, Article 104. https://doi.org/10.1186/s12909-022-03154-8