Research Square

Preprints are preliminary reports that have not undergone peer review.
They should not be considered conclusive, used to inform clinical practice,
or referenced by the media as validated information.

QualiComp: Development and Initial Validation of a Competency Questionnaire for Quality Improvement in Health Services

Eliane Pereira Silva

eliane.pereira@ufrn.br

Federal University of Rio Grande do Norte

Selma Souza Bruno

Federal University of Rio Grande do Norte

Ana Carolina Patrício Albuquerque Sousa

Federal University of Rio Grande do Norte

Paulo José Medeiros

Federal University of Rio Grande do Norte

Marise Reis Freitas

Federal University of Rio Grande do Norte

André Luiz Barbosa Lima

Secretaria Municipal de Saúde

Zenewton André Silva Gama

Federal University of Rio Grande do Norte

Research Article

Keywords: Health Care Quality, Quality Improvement, Professional competence

Posted Date: March 19th, 2026

DOI: https://doi.org/10.21203/rs.3.rs-9016562/v1

License: This work is licensed under a Creative Commons Attribution 4.0 International License.
Read Full License

Additional Declarations: No competing interests reported.

Abstract

Background

Successful quality improvement (QI) projects hinge on professionals' competencies to diagnose, implement, and sustain change.

Objective

To develop and provide initial validation evidence for QualiComp, a competency questionnaire for QI in health services.

Methods

We built a competency model combining widely used approaches in Brazil (diagnostic-oriented cycles) and international QI methods, explicitly integrating attitudes/beliefs, technical-analytical, and behavioral (soft) skills. Content validity was assessed by a two-round Delphi with experts, using item- and scale-level Content Validity Indexes (CVI). Cognitive interviews (n = 10) evaluated comprehensibility and response burden. The 31-item prototype was administered to a convenience sample of healthcare students and professionals (n = 155). Using polychoric correlations and WLSMV estimator with oblique rotation, we conducted exploratory factor analysis (EFA) to assess structural validity; factor retention combined fit indices, explained variance, and interpretability.

Results

Scale-level CVI was high across criteria (relevance 0.96; adequacy 0.97; usefulness 0.97; clarity 0.95). Cognitive interviews indicated good comprehensibility and ~ 7-minute completion time. EFA supported a parsimonious three-factor solution - beliefs/attitudes (4 items), technical-analytical competencies (19 items), and behavioural skills (7 items) - with adequate fit (e.g., RMSEA 0.077; CFI 0.954; TLI 0.943; SRMR 0.075) and improved structure after removing one misfitting item. Although four- and five-factor models yielded slightly better global fit, they produced conceptually weak/sparse factors and higher cross-loadings; therefore, we retained a parsimonious three-factor structure.

Conclusion

QualiComp shows promising evidence of content validity, acceptability, and structural validity, offering an integrated view of QI competencies. proving to be a promising and reliable instrument for assessing attitudes, technical, and It can support formative diagnosis, training design, and competency monitoring

in QI cycles. Further studies should confirm the structure (CFA), test invariance, reliability, and responsiveness.

Introduction

Quality Improvement (QI) in health services is essential to strengthen health systems and deliver safer, person-centered, and resilient care (1–3). In Brazil's Unified Health System (SUS), a public, universal, and equity-oriented system, building institutional and professional capacity for continuous QI is strategic for the effectiveness of public policy and for the right to health.

Preparing services and teams for successful improvement requires more than isolated projects; it depends on professionals' competencies and on supportive organizational contexts. Aligned with recommendations from the National Academy of Science, Engineering and Medicine, health systems should train professionals capable of delivering person-centered care, using evidence-based practice, adopting a continuous improvement stance, and prioritizing equity and safety (4, 5). In this equation, valuable resources (6) include domains such as communication, personal attributes, relationships, alongside the principles and practices. Recently, many studies have demonstrated that patient engagement impacts the healthcare results and is recognized as an improvement of quality of care (7, 8)

The Model for Understanding Success in Quality (MUSIQ) underscores the role of clinical microsystems and the interplay between motivation and competence in achieving results (9). Complementarily, the COM-B model (Capability, Opportunity, Motivation → Behavior) clarifies how capability and motivation shape the behaviors that sustain change (10). Prior work by our group has examined motivational determinants relevant to QI engagement (11).

Several instruments have been proposed to assess QI-related knowledge, skills, and attitudes. The Quality Improvement Knowledge Application Tool (QIKAT) focuses on the ability to formulate aims, measures, and changes aligned with the Institute for Healthcare Improvement (IHI) Model for Improvement (12); the Mayo Evaluation of Reflection on Improvement Tool (MERIT) targets reflective domains (13); and the Beliefs, Attitudes, Skills, and Confidence in Quality Improvement Scale (BASiC-QI) offers a multidimensional self-assessment (14). However, most tools are anchored in North American paradigms and emphasize limited sets of competencies.

In Brazil, QI education and practice have been strongly influenced by diagnostic-oriented cycles rooted in Juran's quality improvement (15–19). This approach foregrounds structured problem diagnosis—process mapping, cause-and-effect analysis, Pareto analysis, and stratification—before setting aims and testing changes (16, 20). By contrast, the IHI framework promotes a rapid approach starting from aims, measures, and changes, tested through Plan-Do-Study-Act (PDSA) cycles (20). Both approaches are widely used; in complex settings such as the SUS, teams frequently need both rigorous diagnostic capability and disciplined testing to achieve reliable change. International models of clinical governance and audit similarly emphasize diagnostic cycles as a core component of quality management (21–23).

Despite this landscape, remains a gap for an instrument that (i) integrates competencies from both the diagnostic-oriented tradition and the rapid approach, and (ii) explicitly assess behavioral (non-technical) skills—such as leadership, communication, and teamwork now recognized as critical to sustaining change (11, 24–26). Addressing this gap may support training, mentoring, and deployment of QI initiatives in resource-constrained, high-turnover environments that are typical of many SUS services.

We therefore aimed to develop QualiComp, a competency questionnaire for QI in health services, and to gather initial evidence of content validity, acceptability, and structural validity in a student/professional sample.

Materials and Methods

Study design and setting

We conducted a multi-step validation study to develop QualiComp and obtain initial evidence of its measurement properties: (1) instrument construction grounded in a competency framework; (2) expert content assessment using a two-round Delphi technique; (3) cognitive pre-testing; and (4) assessment of structural validity by exploratory factor analysis (EFA) alongside estimation of internal consistency.

The study was carried out at the Federal University of Rio Grande do Norte (UFRN), Brazil. The recruitment process was conducted in two distinct phases. The first phase, involving the recruitment of experts for the Delphi technique, took place between August 18, 2023, and October 24, 2023. The second phase, comprising the administration of the questionnaire for assessment of structural validity, was carried out from June 26, 2024, to June 25, 2025.

Step 1. Instrument construction

Drawing on the Institute for Healthcare Improvement (IHI) Model for Improvement (20, 27, 28), the Spanish diagnostic-oriented improvement tradition (15, 16), and evidence on behavioural (non-technical) skills in QI (24, 25), we specified a competency model encompassing three domains:

1. beliefs and attitudes toward QI;
2. technical-analytical skills (eg. problem diagnosis and use of improvement tools), and
3. behavioural skills (leadership, teamwork, communication).

Item generation combined this competency model with the authors' teaching and implementation experience in the Brazilian Unified Health System (SUS), as well as the MUSIQ (9) and COM-B (10) frameworks, in order to explicitly integrate motivation and capability-related dimensions.

The initial pool comprised 37 items across four sections: basic knowledge (4 items), attitudes (5 items), technical skills (21 items), behavioural skills (7 items). After content validation and cognitive testing

(Steps 2 and 3), a 31-item version was retained for psychometric analyses. The English version of the instrument is available as Supplementary File 1.

Step 2. Content validity (Delphi)

Participants. We purposively recruited QI experts according to recommended criteria (29): formal training in QI and more than 5 years of experience in leading improvement projects and/or teaching QI. We invited 20 experts, anticipating non-response rates of 30–50% in the first round and 20–30% in the second round.

Procedures.

In Round 1, experts received: (i) the draft instrument (spreadsheet format), (ii) a summary of the underlying competency model, and (iii) detailed instructions for rating. Each item was rated on 5-point Likert scales for relevance, adequacy, usefulness, and clarity, and experts could provide qualitative comments and suggestions for rewording, deletion, or addition of items.

In Round 2, we re-presented the revised items, highlighting changes (e.g. tracked changes or site-by-side versions) and requested experts to re-rate them using the same four criteria.

Analysis.

For each criterion, we calculated item-level and scale-level Content Validity Indexes (I-CVI, S-CVI) following Waltz, Strickland, and Lenz (30). A priori, items with I-CVI≤ 0.80 were candidates for revision or deletion, whereas an S-CVI ≥ 0.90 was considered evidence of adequate overall content validity. Qualitative comments were analysed thematically and adjudicated by the research team, prioritizing theoretical coherence with the competency model and clarity for the target audience.

Step 3. Cognitive pre-testing

We conducted cognitive interviews with 10 participants who resembled the target population (intentional sampling across students and health professionals). The objective was to assess comprehension of items and instructions, cognitive load, item order and flow, and potential redundancy.

Interviews explored how respondents interpreted each item, how they chose response options, and any difficulties with terminology or format. Based on emerging issues, we planned iterative edits to wording, instructions, and item sequence until no new relevant problems were identified (problem saturation). Completion time for the full instrument was recorded to assess feasibility (31).

Step 4. Structural validity

Participants and data collection

The 31-item QualiComp was administered to 155 respondents from three groups:

1. medical students enrolled in a mandatory course on quality management in health services;
2. students from the Master Degree in Quality Management in Health Services (Qualisaúde/UFRN); and
3. staff from the university hospital.

The questionnaire was administered primarily in digital format (email or application-based link) with paper forms available as backup. All items used a 5-point Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree). All participants provided informed consent prior to participation.

Exploratory Factor Analysis

We conducted an EFA using Mplus (version 7), under a structural equation modeling framework. Given the ordinal nature of the response scale, we used the robust weighted least squares estimator with mean and variance adjustment (WLSMV), which first estimates the polychoric correlation matrix and then minimizes residuals.

We inspected the polychoric correlation matrix to identify potential issues of extreme collinearity ($r > 0.90$) and item redundancy. Items with excessive missingness or zero variance were flagged for further consideration.

We used oblique Geomin rotation, allowing factors to be correlated, in line with the conceptual interdependence among beliefs/attitudes, technical-analytical, and behavioral domains. We tested 1–5 solutions. Factor retention decisions were based on a combination of:

- results of parallel analysis (polychoric correlations),
- global fit indices (Root Mean Square Error of Approximation - RMSEA, Comparative Fit Index - CFI, Tucker-Lewis Index - TLI, Standardized Root Mean Square Residual - SRMR),
- proportion of explained variance, and
- theoretical interpretability and parsimony of the factor structure.

Factor loadings were evaluated for statistical significance at the 5% level ($p < 0.05$). For interpretation, each item was assigned to the factor on which it exhibited the highest statistically significant loading. Cross-loadings and items with low loadings were examined in terms of both statistical performance and conceptual relevance to decide on retention or exclusion.

Ethical considerations

The study was conducted in compliance with the ethical standards of the institutional and national research committees, specifically following Resolutions 466/12 and 510/16 of the Brazilian National Health Council (CNS), which regulate research involving human participants in Brazil. Furthermore, the protocol adhered to the principles of the Declaration of Helsinki (1964) and its subsequent amendments. This study was approved by the Research Ethics Committee of the Federal University of Rio Grande do Norte, Brazil (approval No. 6.099.338), approved on 3 July 2023. Informed consent was obtained from all participants. The study only proceeded after participants had read and signed the consent form, which was provided in either electronic or paper format. As the study did not include minors. Participation was voluntary and had no consequences for academic assessment or employment.

Results

Content Validity

Fourteen experts participated in Round 1 and 12 in Round 2 of the Delphi process. In Round 1, most items met the a priori threshold for relevance (I-CVI ≥ 0.80); three items were slightly below this cut-off (Items 8, 9, and 26: I-CVI = 0.79 each). Based on qualitative feedback, we consolidated Items 13 and 14 due to overlap and refined the wording of several items, including reverse-worded items.

In Round 2, agreement was high across all four criteria. Only Item 9 remained below the relevance threshold (I-CVI = 0.75). Given the overall convergence of ratings, stability of scores between rounds, and the conceptual relevance of Item 9, we decided to close the Delphi after Round 2 and retained Item 9 (with revised wording) for subsequent psychometric testing.

Scale-level CVI values were high: 0.96 for relevance, 0.97 for adequacy 0.97, 0.97 for usefulness, and 0.96 for clarity, indicating strong overall content validity. Table 1 presents the characteristics of the Delphi experts, and Table 2 shows item-level CVI values by criterion and round. Reverse-worded items (Item 8 and 9) were recoded prior to the subsequent analyses.

Table 1
Characterization of Delphi experts (n = 14).

Interviewee profile		n	%
Sex	Female	7	50.0
	Male	7	50.0
Undergraduate background	Medicine	6	42.7
	Nursing	2	14.3
	Physiotherapy	2	14.3
	Computer Science	1	7.1
	Electrical Engineering	1	7.1
	Pharmacy	1	7.1
	Dentistry	1	7.1
Highest degree	Specialist	1	7.1
	Master's	3	21.4
	Doctorate	6	42.9
	Postdoctoral	4	28.6
	Total	**14**	**100.00**

Table 2
Content Validity Indexes (CVI) by item and criteria in rounds 1 and 2.

Item	Relevance		Adequacy		Usefulness		Clarity	
	CVI1	CVI2	CVI1	CVI2	CVI1	CVI2	CVI1	CVI2
1. Strategies for evaluating healthcare in my health service	0.93	0.92	0.79	0.92	0.71	0.92	0.71	0.92
2. The role of healthcare professionals as part of a system that affects patient and family outcomes	0.93	0.92	0.86	0.92	0.93	1.00	0.79	1.00
3. The importance of variation and evaluation of the quality of healthcare	0.93	0.92	0.86	1.00	0.86	1.00	0.64	1.00
4. Approaches to change healthcare processes for the better	1.00	0.92	1.00	1.00	0.93	1.00	0.93	1.00
5. Continuous quality improvement is an essential part of the daily work of all healthcare professionals	1.00	0.92	0.93	1.00	0.93	1.00	1.00	1.00
6. I and others can contribute to improving the results of care in my health service	1.00	0.92	1.00	1.00	0.79	0.92	0.93	0.92
7. Changing healthcare for the better can lead to greater job satisfaction	1.00	1.00	1.00	1.00	0.93	1.00	1.00	1.00
8. Quality improvement projects increase the burden on healthcare professionals	0.79	0.83	1.00	1.00	1.00	1.00	0.86	1.00
9. In my service we always do the right things in health care; the problems are just structural	0.79	0.75	1.00	0.92	1.00	0.2	0.86	0.83
10. Identify opportunities for improvement in healthcare	1.00	1.00	1.00	1.00	0.93	1.00	1.00	1.00
11. Prioritize the most important opportunities for improvement in my local context	1.00	1.00	1.00	1.00	0.86	1.00	1.00	1.00
12. Use a consensus method to prioritize an improvement opportunity with my work team	0.93	1.00	0.93	1.00	0.93	1.00	0.93	1.00
13. Analyze the causes of problems on quality of care with	1.00	1.00	1.00	1.00	0.93	1.00	0.93	1.00

Notes: Item 14 was merged into item 13 after round 1; therefore, it was not re-rated in round 2.

Item	Relevance		Adequacy		Usefulness		Clarity	
	CVI1	CVI2	CVI1	CVI2	CVI1	CVI2	CVI1	CVI2
the aim of improving								
14. Use tools for analyzing causes (e.g. cause-effect diagram, why technique, etc.)	1.00	-	1.00	-	1.00	-	1.00	-
15. Map a health care process in order to analyze ways of optimizing it	1.00	1.00	1,00	1.00	1.00	1.00	1.00	1.00
16. Develop a criterion or indicator to measure the quality of health care	1.00	1.00	1.00	1.00	0.93	1.00	1.00	1.00
17. Collecting data on a criterion or indicator	1.00	0.92	1.00	0.92	0.93	0.92	0.79	0.83
18. Critically analyze the validity of criteria or indicators designed to measure the quality of health care	1.00	0.92	1.00	0.92	0.93	0.92	0.93	0.92
19. Set clear targets for improving health care (e.g. SMART, etc.)	1.00	1.00	1.00	1.00	0.93	1.00	0.93	1.00
20. Create a multi-faceted improvement intervention (e.g. steering diagram, affinity diagram, etc.)	1.00	0.92	1.00	0.92	0.93	0.92	0.86	0.83
21. Testing changes on a small scale before promoting their implementation (e.g. PDSA)	0.93	0.92	0.93	0.92	0.86	0.92	0.86	0.92
22. Use tools to monitor the implementation of improvement actions (e.g. Gantt chart, 5W2H, etc.)	1.00	0.92	1.00	0.92	1.00	0.92	0.93	0.83
23. Disseminate the improvements achieved in one service to a group of similar health services	1.00	0.92	1.00	0.92	0.93	0.92	0.93	0.92
24. Use a quality measure to estimate health service performance	1.00	1.00	0.93	1.00	0.93	1.00	0.86	1.00
25. Apply tools to analyze which criteria are priorities for improving quality (e.g. Pareto diagram)	0.93	1.00	0.93	1.00	0.86	1.00	0.93	0.92
26. Analyze whether there is an association between two variables	0.79	1.00	0.86	1.00	0.79	1.00	0.79	0.83

Notes: Item 14 was merged into item 13 after round 1; therefore, it was not re-rated in round 2.

Item	Relevance		Adequacy		Usefulness		Clarity	
	CVI1	CVI2	CVI1	CVI2	CVI1	CVI2	CVI1	CVI2
to identify causes of poor quality (e.g. scatter diagram, etc.)								
27. Stratify the results of an indicator to identify causes of poor quality	1.00	0.92	1.00	0.92	1.00	0.92	0.93	0.83
28. Construct a baseline in trend charts or control charts	1.00	1.00	1.00	1.00	1.00	1.00	0.93	1.00
29. Identify significant improvement by looking at trend graphs or control charts	1.00	1.00	1.00	1.00	1.00	1.00	0.86	0.92
30. Differentiating whether process data is stable or unstable	1.00	1.00	1.00	1.00	1.00	1.00	0.86	1.00
31. Selecting a good profile of participants for an improvement team	0.93	1.00	0.93	1.00	0.86	1.00	0.71	1.00
32. Defining responsibilities within an improvement team	1.00	1.00	1.00	0.92	0.93	0.92	1.00	1.00
33. Monitoring teamwork during a complete improvement project	0.93	1.00	1.00	1.00	0.93	1.00	1.0	1.00
34. Managing interpersonal conflicts	0.86	1.00	1.00	0.92	0.93	1.00	0.93	1.00
35. Activate the intrinsic motivation of team members	1.00	0.92	1.00	1.00	0.93	0.92	0.93	0.92
36. Encourage team members to speak up, question and propose ideas for quality improvement	0.93	1.00	1.00	1.00	0.93	1.00	0.93	1.00
37. Communicate openly with team members to solve problems when an improvement project runs into difficulties	1.00	1.00	1.00	1.00	0.93	1.00	1.00	1.00
Overall assessment	**0.96**	**0.96**	**0.97**	**0.97**	**0.92**	**0.97**	**0.90**	**0.95**
Notes: Item 14 was merged into item 13 after round 1; therefore, it was not re-rated in round 2.								

Table 1 - Characterization of Delphi experts (n = 14).

Table 2 - Content Validity Indexes (CVI) by item and criteria in rounds 1 and 2

Following content approval, the research team reviewed all qualitative suggestions and consolidated overlapping content. Sections 1 (knowledge about quality improvement) and 2 (attitudes toward quality

improvement) were merged, retaining items focused on beliefs and attitudes toward QI. Items 1 and 4, which addressed technical nuances already captured by items in the technical-skills domain, were removed. Items 5 and 6 showed similar content; we retained Item 5 because of clearer wording. Item 9, although below the relevance threshold in Round 2, was maintained due to its conceptual importance and earmarked for empirical testing.

The resulting version taken forward to cognitive pre-test comprised 31 items organized into three sections: (1) beliefs/attitudes about QI, (2) technical-analytical skills, and (3) behavioural (soft) skills.

Cognitive pre-testing

Ten participants completed cognitive interviews. Mean completion time for the full instrument was seven minutes (range: 4–16 minutes), indicating good feasibility for educational and service contexts. Participants did not report comprehension difficulties or problems related to item order or response options. Only minor editorial standardization (e.g. wording consistency and layout) was applied. No content-related changes to items were required as a result of this step.

Structural Validity (EFA)

Model fit and factor retention

The 31-item QualiComp was administered to 155 respondents from the three predefined groups. We estimated a series of one- to five-factor EFA solutions using polychoric correlations, the WLSMV estimator, and oblique Geomin rotation.

Parallel analysis based on polychoric correlations supported a three-factor solution, which was also consistent with the underlying competency model. Table 3 summarises the global fit indices for models with one to five factors, considering both the full set of items and the solution after removing Item 5.

Table 3
Model fit indices for 1–5-factor EFA solutions (all items vs. minus Item 5).

Factors	χ^2(df)	RMSEA [90%]	CFI	TLI	SRMR	Prob. RMSEA ≤ 0.05
A. All items						
1	1527.293(434)	0.127 [0.121; 0.134]	0.845	0.834	0.143	0.000
2	952.204(404)	0.094 [0.086; 0.101]	0.922	0.910	0.105	0.000
3	686.895(375)	0.073 [0.065; 0.082]	0.956	0.945	0.075	0.000
4	534.427(347)	0.059 [0.049; 0.069]	0.973	0.946	0.058	0.069
5	438.212(320)	0.049 [0.037; 0.060]	0.983	0.976	0.053	0.559
B. Item 5 deleted						
1	1519.30(405)	0.133 [0.126; 0,140]	0.841	0.829	0.146	0.000
2	935.12(376)	0.098 [0.090; 0.106]	0.920	0.908	0.106	0.000
3	667.77(348)	0.077 [0.068; 0.086]	0.954	0.943	0.075	0.000
4	519.29(321)	0.063 [0.053; 0.073]	0.972	0.962	0.058	0.018
5	420.13(295)	0.052 [0.040; 0.064]	0.982	0.974	0.052	0.361

Note. Estimation = WLSMV; rotation = geomin; data = polychoric correlations; response scale = Likert (1–5); *n = 155; RMSEA 90% confidence interval in brackets; pclose reported as "Prob. RMSEA < 0.05". Bold values indicate the selected factor solution.*

For the 31-item three-factor model, global fit indices were acceptable (RMSEA = 0.073, CFI = 0.956, TLI = 0.945, SRMR = 0.075). After removing Item 5, the three-factor solution showed a very similar fit (RMSEA = 0.077, CFI = 0.954; TLI = 0.943; SRMR = 0.075. Four- and five-factor solutions yielded marginal improvements in global fit (e.g., for the five-factor model without Item 5: RMSEA = 0.052, CFI = 0.982), but at the cost of conceptually weak or sparse factors, increased cross-loadings, and imbalance in the distribution of items across factors.

On grounds of parsimony, theoretical coherence with the competency model, and interpretability, we retained the three-factor solution with Item 5 removed as the final structural model.

Table 3 - Model fit indices for 1–5-factor EFA solutions (all items vs. minus Item 5).

Item performance and factor loadings

Table 4 presents the factor loadings for the initial three-factor solution including all items. In this model, Item 5 exhibited a negative primary loading (–0.22 on Factor 3) and instability across factors, suggesting poor conceptual alignment with the emergent structure. Unlike most items, which targeted competencies or attitudes, Item 5 emphasised a perceived adverse effect of QI (increased workload), which likely contributed to its inconsistent performance. Item 6 displayed notable cross-loadings on Factors 1 and 2.

Table 4
Standardized factor loadings for the three-factor solution (all items).

Item	Factor 1	Factor 2	Factor 3	Main factor
1	**0.786**	0.004	0.002	Factor 1
2	**0.759**	0.144	-0.008	Factor 1
3	**0.662**	-0.011	0.135	Factor 1
4	**0.469**	0.204	-0.012	Factor 1
5	-0.056	0.029	**-0.220**	Factor 3
6	0.376	**0.551**	0.262	Factor 2
7	0.294	**0.813**	0.061	Factor 2
8	0.223	**0.870**	-0.065	Factor 2
9	0.118	**0.813**	-0.045	Factor 2
10	0.028	**0.953**	-0.099	Factor 2
11	-0.045	**0.865**	-0.074	Factor 2
12	-0.019	**0.876**	-0.023	Factor 2
13	0.162	**0.757**	0.099	Factor 2
14	-0.057	**0.692**	0.070	Factor 2
15	-0.001	**0.644**	0.237	Factor 2
16	-0.002	**0.689**	0.295	Factor 2
17	0.059	**0.522**	0.399	Factor 2
18	-0.186	**0.622**	0.218	Factor 2
19	-0.226	**0.716**	0.194	Factor 2
20	-0.386	**0.737**	-0.060	Factor 2
21	-0.474	**0.748**	0.005	Factor 2
22	-0.599	**0.671**	0.023	Factor 2
23	-0.583	**0.735**	-0.023	Factor 2
24	-0.318	**0.726**	0.060	Factor 2
25	0.008	0.098	**0.768**	Factor 3
26	-0.032	0.159	**0.759**	Factor 3

Item	Factor 1	Factor 2	Factor 3	Main factor
27	0.030	0.237	**0.665**	Factor 3
28	0.106	0.097	**0.687**	Factor 3
29	-0.093	-0.053	**0.737**	Factor 3
30	-0.034	-0.016	**0.824**	Factor 3
31	-0.079	0.006	**0.714**	Factor 3

After removing Item 5, the three-factor solution (Table 5) exhibited a cleaner and more interpretable pattern of loadings. Cross-loadings were reduced, and Item 6 loaded primarily on Factor 2, aligning with its intended classification as a technical-analytical skill.

Table 5
Standardised factor loadings for the three-factor solution (minus item 5).

Item	Factor 1	Factor 2	Factor 3	Main factor
1	**0.788**	0.002	0.202	Factor 1
2	**0.759**	0.142	-0.006	Factor 1
3	**0.661**	-0.008	0.127	Factor 1
4	**0.469**	0.205	-0.015	Factor 1
6	0.374	**0.556**	0.251	Factor 2
7	0.293	**0.693**	0.056	Factor 2
8	0.220	**0.874**	-0.075	Factor 2
9	0.115	**0.814**	-0.049	Factor 2
10	0.024	**0.958**	-0.108	Factor 2
11	-0.048	**0.867**	-0.079	Factor 2
12	-0.022	**0.878**	-0.028	Factor 2
13	0.160	**0.761**	0.092	Factor 2
14	-0.059	**0.697**	0.060	Factor 2
15	-0.001	**0.650**	0.226	Factor 2
16	-0.002	**0.695**	0.284	Factor 2
17	0.058	**0.528**	0.388	Factor 2
18	-0.187*	**0.624**	0.214	Factor 2
19	-0.228	**0.718**	0.190	Factor 2
20	-0.388	**0.736**	-0.059	Factor 2
21	-0.476	**0.750**	0.000	Factor 2
22	-0.602	**0.668**	0.027	Factor 2
23	-0.586	**0.732**	-0.020	Factor 2
24	-0.320	**0.727**	0.057	Factor 2
25	0.010	0.101	**0.763**	Factor 3
26	-0.030	0.161	**0.758**	Factor 3
27	0.034	0.238	**0.663**	Factor 3

Item	Factor 1	Factor 2	Factor 3	Main factor
28	0.110	0.098	**0.685**	Factor 3
29	-0.087	-0.055	**0.742**	Factor 3
30	-0.029	-0.016	**0.825**	Factor 3
31	-0.073	0.003	**0.717**	Factor 3

The final configuration was as follows:

- Factor 1 – Beliefs and Attitudes toward Quality Improvement

Comprised Items 1–4, all with loadings above 0.66, capturing respondents' views on the importance and role of QI in routine professional practice.

- Factor 2 – Technical-Analytical Competencies

Comprised Items 6–24, with most loadings near or above 0.70. This factor encompassed skills related to identifying opportunities for improvement, using diagnostic tools (e.g. cause-and-effect diagrams, Pareto analysis, stratification), constructing and interpreting indicators, designing and monitoring interventions, and using time-series or control charts.

- Factor 3 – Behavioral (Soft) Skills for Improvement

Comprised Items 25–31, with strong and predominantly exclusive loadings (e.g., Item 30: 0.83; Item 31: 0.72). This factor reflected competencies in team selection and coordination, conflict management, activation of intrinsic motivation, psychological safety (speaking up and questioning), and open communication during QI projects.

Table 4 - Standardized factor loadings for the three-factor solution (all items).

Table 5 - Standardised factor loadings for the three-factor solution (minus item 5).

Overall, the loading pattern was statistically robust and conceptually coherent with the a priori competency model. The statistical consistency of the structure was corroborated by eigenvalues and explained variance: the first three factors accounted for 42.4%, 11.6%, and 8.5% of the total variance, respectively, for cumulative variance explained of 62.5%. Additional factors contributed little and incremental variance and increased interpretive dispersion, reinforcing the choice of a three-factor solution.

Removing Item 5 improved the overall structure by eliminating a source of conceptual noise, and reducing cross-loadings, thereby sharpening factor boundaries and yielding a more parsimonious and theoretically aligned measurement model for QualiComp.

Discussion

Principal’s findings

We developed QualiComp, a competency questionnaire for QI in health services, and obtained initial evidence of its measurement properties. Content validity indices showed high agreement across criteria, cognitive testing indicated good acceptability (mean completion time ~ 7 minutes, no comprehension issues), and exploratory factor analysis supported a parsimonious three-factor structure aligned with the conceptual model: Beliefs/Attitudes (F1), Technical-Analytical Competencies (F2), and Behavioral/Soft Skills (F3). Although four- and five-factor solutions marginally improved global fit indices, they introduced conceptually weak or sparse factors and increased cross-loadings. We therefore retained the three-factor solution on grounds of parsimony and interpretability. The proportion of explained variance (62.5%) and the cleaner factor structure after removing one misfitting item further support the clarity and coherence of the configuration.

Interpretation and theoretical alignment

In complex health systems, both the multidimensional nature of quality and the choice of appropriate measurement tools remain central concerns for delivering high-quality services. Instruments that jointly assess technical capability and behavioral (non-technical) skills, such as leadership, communication, teamwork, and stress management, tend to relate more closely related to performance in academic and service settings. Evidence from systematic reviews of non-technical skills in complex clinical environments supports improvements in team behaviours, leadership, and communication, with tangible effects such as reduced response times in ICU cardiac arrest scenarios (32).

QualiComp was designed to integrate motivational, technical, and behavioral components and, in this study, showed initial structural validity consistent with that intent. This integration is particularly relevant in settings with high staff turnover or frequent role rotation of roles, where competencies must be trained and reassessed at short intervals to approximate quality outcomes in care. In both real and simulated training environments, robust tools are needed to detect gaps and guide target adjustments - whether technical or behavioral - so that team performance can be improved in a systematic and iterative manner.

Our final factor solution coheres with established theory. Factor 1 (Beliefs/Attitudes) captures willingness to improve, recognition of variation, and normalisation of improvement as part of everyday work - elements that map closely to the motivation component in COM-B (10). Factor 2 (Technical-Analytical Competencies) consolidates the operational core of QI (prioritising opportunities, cause analysis, process mapping, indicators, control charts, impact evaluation), aligning with the capability component in COM-B and with performance determinants emphasised by MUSIQ at the microsystem level (9). Factor 3 (Behavioral/Soft skills) brings together collaborative leadership, communication, teamwork, and conflict management—competencies repeatedly linked to reliability and safety in complex environments.

Although models with four or five factors slightly improved global fit, they fragmented constructs and increased cross-loadings. From a measurement perspective, a model that sacrifices interpretability and practical usability for marginal gains in fit may be less useful for educational and managerial purposes. Retaining a three-factor configuration preserves conceptual coherence and supports the formative use of QualiComp in training and service settings.

Motivational beliefs as a measurable target

A distinctive contribution of this study is to explicitly positioning of beliefs and attitudes within a motivational domain, analysed alongside technical and behavioral competencies in the same measurement model. Beliefs frequently observed in practice - such as perceptions that QI increases workload or merely adds “more checklists” - surfaced in our data and loaded strongly on the motivational domain (loadings > 0.66 across four items). Prior studies hint at the same mechanism: with workload complaints undermining engagement in QI (33), and tensions between clinical time, administrative burden, and improvement activities acting as barriers to implementation (34). Together, these findings support treating motivational beliefs as a measurable and actionable target in QI capacity-building strategies, rather than as an unobserved or implicit background factor.

The content validity process was also important for legitimacy and applicability. Experts from multiple Brazilian regions and Spanish-speaking contexts (Spain, Mexico) participated, in line with Delphi guidance that recommends diversity of origin and perspective to enhance judgement quality (35). This diversity likely contributed to item clarity and relevance across different service realities and organizational cultures.

Parsimony and Formative Utility

Although four- and five factor solutions yielded marginal gains in global fit indices, these came at the expense of conceptual coherence and parsimony. We therefore favoured the three-factor configuration to maximise interpretability and practical usability as a formative and managerial tool, consistent with the emphasis on actionable capability and motivation in COM-B and microsystem-focused implementation in MUSIQ (10, 9).

In QI programmes, simpler and clearly interpretable models reduce burden on teams and facilitate incorporation into routine workflows. This, in turn, supports cycles of training, reassessments, and feedback, thereby enhancing the formative utility of measurement (36, 37). In this sense, the primary value of QualiComp is not the distal total score per se, but its capacity to guide continuous improvement through dimension-specific diagnosis and mentoring (36, 37). Results can be used to identify which domain—motivational, technical-analytical, or behavioural—requires more investment, and to tailor curricula and supervision accordingly.

Comparison with existing instruments

There is a growing emphasis on non-technical (soft) skills across educational and organizational contexts, accompanied by dedicated assessment tools and systematic reviews (32, 38, 39). Evidence

also links combinations of technical knowledge with skills in communication, management, emotional intelligence, and confidentiality to better organisational performance in healthcare (40, 41). In line with this trend, previous studies have proposed integrating technical and behavioral competencies and have shown their influence on performance across clinical and surgical settings (42, 43). From a training perspective, it is therefore reasonable that the quality of instruction - and ultimately service quality - be monitored with instruments that are sensitive to multiple competency axes rather than single-domain measures.

Within this landscape, QualiComp advances beyond instruments that traditionally privilege one axis at a time (44–47) by integrating three domains in a single measure: attitudes and beliefs, technical-analytical competencies, and behavioural (soft) skills. Compared with tools that focus on narrower targets - such as reflective domains or application of aims/measures/changes - BASiC-QI (14) is among the most innovative we identified for encompassing more than one axis; still, it addresses two domains, whereas QualiComp captures three. This broader scope supports richer formative diagnoses to design training and mentorship pathways and enhances applicability in multiprofessional teams, while maintaining a brief administration time suitable for repeated use in educational and service contexts.

Practical implications

We envisage three immediate uses of QualiComp:

1. Formative diagnosis by dimension, to plan curricula and on-the-job training based on the specific profile of beliefs, technical-analytical skills, and behavioural competencies in a given cohort or service.
2. Mentoring allocation and goal setting by domain, for example emphasising behavioural skills in services with high staff turnover or psychological safety issues or strengthening analytical capability where complex process redesign is required).
3. Longitudinal monitoring of competencies across QI cycles, enabling programmes to test responsiveness to training, track progress over time, and tailor supports where gaps persist.

In addition to valid instruments for evaluating QI competencies, it is essential to train professionals and managers to use such tools as indicators for designing and adjusting training strategies. The results of QualiComp are most useful when interpreted by teams who can translate dimension-specific findings into concrete educational and organizational interventions.

The statements and themes included in the instrument allow its application in undergraduate courses, specialist training programs, and collaborative improvement projects, as it covers knowledge and skills addressed in the methodologies widely used in Brazil, including diagnostic-oriented cycles and rapid-cycle improvement.

Strengths, limitations and future research

Strengths of this study include explicit theoretical grounding (COM-B; MUSIQ), a transparent content-validation process with experts from multiple regions and countries, appropriate methods for ordinal data (polychorics correlations, WLSMV estimator, oblique rotation), and evidence of operational feasibility (short completion time and good acceptability). The integrated scope across beliefs/attitudes, technical-analytical and behavioural domains is a practical advance for multiprofessional teams working in QI.

Several limitations should be acknowledged. First, findings derive from a single-context convenience sample and rely on self-report Likert responses, which may limit generalizability and introduce social desirability or common-method variance. Second, cross-sectional design did not allow assessment of temporal stability (test-retest) or responsiveness to training and mentoring interventions. Third, we report initial structural validity based on EFA; confirmatory factor analysis (CFA) in an independent sample is still required. Fourth, we did not examine measurement invariance across subgroups (e.g. profession, sex/gender, experience) or convergent validity with external instruments or objective performance indicators. Finally, data were collected in Portuguese in a Brazilian academic-service setting; generalization to other languages, regions, and service configurations should be made cautiously until cross-cultural adaptation and validation studies are conducted.

Future research should: (i) conduct CFA in independent, multicentre samples (e.g. undergraduate health courses and frontline services), with detailed fit indices and model refinement; (ii) test measurement invariance (configural, metric, scalar) across profession, sex/gender, and experience strata; (iii) extend evidence on reliability, including ω and α with confidence intervals and test–retest reliability over 2–4 weeks; (iv) examine responsiveness to training and mentoring programmes using pre-post and repeated measures designs; (v) investigate convergent and criterion-related validity through associations with external measures (e.g. BASiC-QI) and, when feasible, objective process or performance indicators; (vi) assess ceiling and floor effects and potential differential item functioning (DIF); (vii) explore item response theory (IRT) models to refine item hierarchy and information; and (viii) develop interpretation norms or cut-points by context (teaching vs. service, primary vs. hospital care) to support formative decision-making.

Conclusion

QualiComp provides an integrated, practical perspective on QI competencies, capturing Beliefs/Attitudes, Technical-Analytical skills, and Behavioral/Soft skills in a single, brief instrument. This study offers initial evidence of content validity, acceptability, and structural validity, supporting its use as a formative tool to diagnose needs, guide training and mentorship, and monitor competency development across QI cycles.

Further confirmatory studies and longitudinal studies are needed to consolidate its measurement properties, including reliability, invariance, and responsiveness. In parallel, careful implementation and

interpretation in educational and service settings may help QualiComp contribute to strengthening QI capacity and, ultimately, to improving the quality and safety of care.

Declarations

Acknowledgments

We are grateful to The Federal University of Rio Grande do Norte for supporting the graduate program in improving the quality of health services.

Funding

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors. The study was supported by the authors' host institutions as part of their standard research activities.

Ethics approval and consent to participate.

All methods were carried out in accordance with relevant guidelines and regulations. The study was conducted in compliance with the ethical standards of the institutional and national research committees, specifically following Resolutions 466/12 and 510/16 of the Brazilian National Health Council (CNS), which regulate research involving human participants in Brazil. Furthermore, the protocol adhered to the principles of the Declaration of Helsinki (1964) and its subsequent amendments.

Ethical approval was formally granted by the Research Ethics Committee of the Onofre Lopes University Hospital at the Federal University of Rio Grande do Norte (HUOL-UFRN), under protocol number 6.099.338.

Participation was strictly voluntary, and all individuals were informed of their right to withdraw from the study at any stage without penalty. Informed consent was obtained from all participants prior to data collection, utilizing either electronic or paper-based formats as appropriate. All collected data were handled with strict confidentiality and anonymity to protect the privacy of the participants.

Consent for publication

Not applicable.

Author Contribution

E.P.S, S.S.B,A.L.B.L, Z.A.S.G These authors contributed in the conception, supervision of the study, collection and analysis of data, statistical analysis, critical review and writing of the manuscript.A.C.P.A.S, P.J.M, M.R.F These authors contributed to the collection of data, interpretation, critical review and writing of the manuscript.All authors approved the final version of the manuscript.

Data Availability

The anonymized dataset supporting the findings of this study has been deposited in the Figshare repository. It can be accessed via the following DOI/Link: https://doi.org/10.6084/m9.figshare.30889727

References

1. World Health Organization, Organisation for Economic Co-operation and Development, International Bank for Reconstruction and Development. Delivering quality health services: a global imperative for universal health coverage. Geneva: World Health Organization. 2018. Available from: https://iris.who.int/handle/10665/272465
2. Kruk M, Gage AD, Arsenault C, Jordan K, Leslie HH, Roder-Dewan S, Adeyi O, Barker P, Daelmans B, Doubova SV. High-quality health systems in the Sustainable Development Goals era: time for a revolution. Lancet Glob Health. 2018;6(11):e1196–252.
3. WHO. Global Patient Safety Action Plan 2021–2023. Geneva: World Health Organization; 2021.
4. Institute of Medicine. Health professions education: a bridge to quality. Washington (DC): National Academies; 2003.
5. National Academies of Sciences, Engineering, and Medicine. Crossing the Global Quality Chasm: Improving Health Care Worldwide. Washington, DC: National Academies; 2018. https://doi.org/10.17226/25152.
6. Cox R, Kendall M, Molineux M, Miller E. Building successful consumer and staff partnerships in healthcare quality improvement: a coproduced eDelphi study. Health Expect. 2022;25(4):1563–79.
7. Chauhan A, Lahiru R, Manias E, Harrison R. Assessing the environment for engagement in health services: The Audit for Consumer Engagement (ACE) tool. Health Expect. 2022;25(6):3027–39.
8. World Health Organization. Global patient safety action plan 2021–2030: towards eliminating avoidable harm in health care. Geneva: World Health Organization; 2021.
9. Kaplan HC, Provost LP, Froehle CM, Margolis P. The Model for Understanding Success in Quality (MUSIQ): building a theory of context in healthcare quality improvement. BMJ Qual Saf. 2012;21(1):13–20.
10. Michie S, van Stralen MM, West R. The behaviour change wheel: a new method for characterising and designing behaviour change interventions. Implement Sci. 2011;6:e42.
11. da Silva EP, Saturno-Hernández PJ, de Freitas MR, da Silva Gama ZA. Motivational drivers for health professionals in a large quality improvement collaborative project in Brazil: a qualitative study. BMC Health Serv Res. 2024;24(1):183.
12. Morrison LJ, Headrick LA. Teaching residents about practice-based learning and improvement. Jt Comm J Qual Patient Saf. 2008;34(8):453–9.
13. Wittich CM, Beckman TJ, Drefahl MM, Mandrekar JN, Reed DA, Krajicek BJ, Haddad RM, McDonald FS, Kolars JC, Thomas KG. Validation of a method to measure resident doctors' reflections on

quality improvement. Med Educ. 2010;44(3):248–55.

14. Brown A, Nidumolu A, McConnell M, Hecker K, Grierson L. Development and psychometric evaluation of an instrument to measure knowledge, skills, and attitudes towards quality improvement in health professions education: the Beliefs, Attitudes, Skills, and Confidence in Quality Improvement (BASiC-QI) Scale. Perspect Med Educ. 2019;8(3):167–76.
15. Saturno-Hernandez PJ. Training for quality management: report on a nationwide distance learning initiative for physicians in Spain. Int J Qual Health Care. 1999;11(1):67–71.
16. Saturno-Hernández PJ. Métodos y herramientas para la realización de ciclos de mejora de la calidad en servicios de salud. Cuernavaca (MX): Instituto Nacional de Salud Pública; 2015.
17. Universidade Federal do Rio Grande do Norte. Programa de Pós-Graduação em Gestão da Qualidade em Serviços de Saúde - QualiSaúde [Internet]. Natal: UFRN; 2023 [citado em 2024 nov 4]. Disponível em: https://posgraduacao.ufrn.br/qualisaude
18. Juran JM. Juran's quality handbook. 5th ed. New York: McGraw-Hill; 1999.
19. McNab D, McKay J, Shorrock S, Luty S, Bowie P. Development and application of 'systems thinking' principles for quality improvement. BMJ Open Qual. 2020;9(1):e000714.
20. Langley GJ, Moen RD, Nolan KM, Nolan TW, Norman CL, Provost LP. The improvement guide: a practical approach to enhancing organizational performance. San Francisco: Wiley; 2009.
21. Quality and Patient Safety Directorate. A practical guide to clinical audit. Dublin: Health Service Executive. 2013. (Document reference no.: QPSD-D-029-1. Version 1).
22. Mendes EV. As redes de atenção à saúde. Brasília: Organização Pan-Americana da Saúde; 2011. p. 549.
23. New South Wales. Health Department. Easy guide to clinical practice improvement: a guide for healthcare professionals. Sydney: NSW Health Department; 2002. p. 40.
24. Gabbay J, le May A, Connell C, Klein JH. Skilled for improvement? London: Health Foundation; 2014.
25. Higham H, Greig PR, Rutherford J, Vincent L, Young D, Vincent C. Observer-based tools for non-technical skills assessment in simulated and real clinical environments in healthcare: a systematic review. BMJ Qual Saf. 2019;28(8):672–86.
26. Goldman J. Wong BMNothing soft about ‘soft skills’: core competencies in quality improvement and patient safety education and practice. BMJ Qual Saf. 2020;29:619–22.
27. Institute for Healthcare Improvement. The Breakthrough Series: IHI’s Collaborative Model for Achieving Breakthrough Improvement. IHI Innovation Series white paper. Boston: Institute for Healthcare Improvement. 2003. Available from: http://www.ihi.org
28. Institute for Health Improvement. Quality Improvement Essentials Toolkit. Massachusetts, USA: IHI; 2017.
29. Alexandre NMC, Coluci MZO. Validade de conteúdo nos processos de construção e adaptação de instrumentos de medidas. Ciência Coletiva. 2011;16(7):3061–8.

30. Waltz CF, Strickland OL, Lenz ER. Measurement in Nursing Research. Philadelphia: Ed. F.A. Davis Company; 1991.
31. Ikart EM. Questionnaire pretesting methods: a comparison of cognitive interviewing and respondent debriefing vis-à-vis the study of the adoption of decision support systems by knowledge workers. Int J Bus Inf. 2018;13(2).
32. Pimenta ID, Mata ÁN, Bezerra IN, de Araújo RM, Santana JL, Capucho HC, de Souza-Oliveira AC, Echevarría-Pérez P, Guillén-Martínez D, Piuvezam G. Effectiveness of non-technical skills training in intensive care units: a systematic review. BMC Med Educ. 2025;25(1):847.
33. Lalani M, Hall K, Skrypak M, Laing C, Welch J, Toohey P, Seaholme S, Weijburg T, Eyre L, Marshall M. Building motivation to participate in a quality improvement collaborative in NHS hospital trusts in Southeast England: a qualitative participatory evaluation. BMJ open. 2018;8(4):e020930.
34. Hibbert PD, Basedow M, Braithwaite J, Wiles LK, Clay-Williams R, Padbury R. How to sustainably build capacity in quality improvement within a healthcare organisation: a deep-dive, focused qualitative analysis. BMC Health Serv Res. 2021;21(1):588.
35. Pereira RD, Alvim NA. Técnica Delphi no diálogo com enfermeiros sobre a acupuntura como proposta de intervenção de enfermagem. Escola Anna Nery. 2015;19(1):174–80.
36. Stetler CB, Legro MW, Wallace CM, Bowman C, Guihan M, Hagedorn H, Kimmel B, Sharp ND, Smith JL. The role of formative evaluation in implementation research and the QUERI experience. J Gen Intern Med. 2006;21(Suppl 2):S1–8.
37. Meyer GS, Nelson EC, Pryor DB, James B, Swensen SJ, Kaplan GS, Weissberg JI, Bisognano M, Yates GR, Hunt GC. More quality measures versus measuring what matters: a call for balance and parsimony. BMJ Qual Saf. 2012;21(11):964–8.
38. McMullan RD, Urwin R, Sunderland N, Westbrook J. Observational tools that quantify nontechnical skills in the operating room: a systematic review. J Surg Res. 2020;247:306–22.
39. Higham H, Greig PR, Rutherford J, Vincent L, Young D, Vincent C. Observer-based tools for non-technical skills assessment in simulated and real clinical environments in healthcare: a systematic review. BMJ Qual Saf. 2019;28(8):672–86.
40. Abujbara N. Development of Assessment Tool to Measure Soft Skills of Healthcare Providers. 2020.
41. Aridi M, Ahmad M, Ghach W, Charifeh S, Alwan N. Development and Validation of the Soft Skills Questionnaire for Nurses. SAGE Open Nurs. 2023;9.
42. Riem N, Boet S, Bould MD, Tavares W, Naik VN. Do technical skills correlate with non-technical skills in crisis resource management: a simulation study. Br J Anaesth. 2012;109(5):723–8.
43. Hull L, Birnbach D, Arora S, Fitzpatrick M, Sevdalis N. Improving surgical ward care: development and psychometric properties of a global assessment toolkit. Ann Surg. 2014;259(5):904–9.
44. Leenstra JL, Beckman TJ, Reed DA, Mundell WC, Thomas KG, Krajicek BJ, Cha SS, Kolars JC, McDonald FS. Validation of a method for assessing resident physicians' quality improvement proposals. J Gen Intern Med. 2007;22(9):1330–4. (QIPAT-7).

45. Singh MK, Ogrinc G, Cox KR, Dolansky M, Brandt J, Morrison LJ, Harwood B, Petroski G, West A, Headrick LA. The quality improvement knowledge application tool revised (QIKAT-R). Acad Med. 2014;89(10):1386–91. (QIKAT-R).
46. Steele EM, Butcher R, Carluzzo KL, Watts BV. Development of a tool to assess trainees' ability to design and conduct quality improvement projects. Am J Med Qual. 2020;35(2):125–32. (QIPER).
47. Abraham C, Johnson-Martinez K, Tomolo A. A Scoring Rubric for the Knowledge Section of the Systems Quality Improvement Training and Assessment Tool. MedEdPORTAL. 2022;18:11290. . (SQITAT).

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- Supplementarymaterial.docx