Revista Española de Educación Médica

Competency profile in the pre-analytical phase in Medical Technology students: curricular implications.

Perfil de competencias en la fase preanalítica en estudiantes de Tecnología Médica: implicaciones curriculares.

Anthony Rosber Aguilar Galvez [1*,] María Elena Muñoz Zambrano [2]

[1] Academic Department of Medical Technology, Faculty of Medicine, National University of San Marcos, Lima, Peru. Email: anthony.aguilar1@unmsm.pe ORCID: https://orcid.org/0009-0007-7462-8318
[2] Department of Medical Technology. Faculty of Medicine. Deputy Director of Monitoring and Evaluation of the Directorate of Public Health. National Institute of Health. Lima, Peru. Email: mmunozz1@unmsm.edu.pe ORCID: https://orcid.org/0000-0002-2560-3903

* Correspondence: anthony.aguilar1@unmsm.pe

Received: 18/2/26; Accepted: 12/3/26; Published: 16/3/26

Summary:

Objective: To analyze the competency acquisition profile in the pre-analytical phase among advanced Medical Technology students at the National University of San Marcos, Peru, identifying areas of opportunity for curriculum strengthening. **Methods:** A cross-sectional analytical study was conducted with 112 fourth- and fifth-year students. A validated 15-item questionnaire on the pre-analytical phase, adapted from Dukic et al., was administered. Statistical analysis included descriptive statistics, tests of association (Chi-square), and logistic regression. **Results:** The sample showed a balanced distribution by sex (50.9% male, 49.1% female). A solid theoretical foundation was identified (98.2% in tube ordering), along with specific areas for further practical development (homogenization: 30.4%; transport for coagulation: 27.7%; handling of lipemic samples: 39.3%). Clinical experience showed a positive impact on directly practiced skills ($p<0.05$). Age ≥25 years was associated with greater knowledge integration (OR=2.85; p=0.021). **Conclusion:** The findings provide an empirical basis for optimizing training through greater theory-practice integration, representing a strategic opportunity to strengthen technical skills that directly impact diagnostic quality in Peru.

Keywords: Medical technology education, skills development, pre-analytical phase, curriculum innovation, supervised practice, patient safety, Peru.

Resumen:

Objetivo: Analizar el perfil de adquisición de competencias en la fase preanalítica entre estudiantes avanzados de Tecnología Médica de la Universidad Nacional Mayor de San Marcos, Peru, identificando áreas de oportunidad para el fortalecimiento curricular. **Métodos:** Estudio transversal analítico con 112 estudiantes de cuarto y quinto año. Se aplicó un cuestionario validado de 15 ítems sobre la fase preanalítica adaptado de Dukic et al. El análisis estadístico incluyó estadística descriptiva, pruebas de asociación (Chi-cuadrado) y regresión logística. **Resultados:** La muestra presentó una distribución equilibrada por sexo (50.9% masculino, 49.1% femenino). Se identificó una base teórica sólida (98,2% en orden de tubos) junto con áreas específicas para profundizar la práctica (homogeneización: 30,4%; transporte para coagulación: 27,7%; manejo de muestras lipémicas: 39,3%). La experiencia clínica mostró impacto positivo en habilidades directamente practicadas ($p<0,05$). La edad ≥25 años se asoció con mayor integración del conocimiento (OR=2,85; p=0,021). **Conclusión:** Los hallazgos ofrecen una base empírica para optimizar la formación mediante mayor integración teoría-

práctica, representando una oportunidad estratégica para fortalecer las competencias técnicas que impactan directamente en la calidad diagnóstica en el Perú.

Palabras clave: Educación en tecnología médica, desarrollo de competencias, fase preanalítica, innovación curricular, práctica supervisada, seguridad del paciente, Perú.

1. Introduction

In recent decades, the educational field has undergone significant changes, driven by the need to train professionals capable of functioning effectively in a global, ever-changing context marked by technological advances. In this scenario, Competency-Based Education (CBE) has emerged as a pedagogical approach that surpasses the traditional model focused solely on the unidirectional transmission of knowledge. Unlike the latter, CBE is characterized by its flexibility, comprehensiveness, and focus on developing activities applicable to real-world situations, promoting the integration of knowledge, skills, and attitudes necessary for effective professional performance (1).

The pre-analytical phase, which encompasses everything from patient preparation to initial sample processing, accounts for 60-70% of total errors and forms the basis for subsequent diagnostic validity. In today's global context, marked by increasing complexity in laboratory tests and higher quality standards, training medical technologists competent in pre-analytical management has become an educational and healthcare imperative (2-3).

In Latin America, and particularly in Peru, this challenge takes on specific dimensions. The region's health systems frequently operate with limited resources and an unequal distribution of technology, where the professional's technical competence plays an even more crucial role (4). According to the Pan American Health Organization, in many Latin American countries there is a significant gap between the competencies developed in training programs and the actual demands of laboratory services, especially in primary and secondary care facilities. This disconnect not only affects operational efficiency but also has direct implications for patient safety and the quality of healthcare (5). Medical technology education faces the universal challenge of balancing the acquisition of theoretical knowledge with the development of applicable practical skills. International comparative studies, such as the one conducted by Dukic et al. in the European context, have shown that this integration is especially complex in the pre-analytical phase, where seemingly simple technical procedures can have significant consequences if not performed correctly (6). However, there is little empirical evidence on how these skills are developed specifically in the Peruvian educational context, which limits the ability to design contextualized and effective educational interventions (7).

The National University of San Marcos (UNMSM), as the leading institution for training health professionals in Peru, has the historical responsibility to lead the generation of knowledge about its own educational processes. This research aligns with the principles of evidence-based continuous improvement, contributing to closing the gap between university education and the needs of the Peruvian health system (8). This study seeks to answer fundamental questions for educational innovation in medical technology in Peru: What is the current profile of pre-analytical skills acquisition among students nearing graduation? In what specific aspects are opportunities identified to strengthen practical training? How do factors such as clinical experience and individual characteristics influence this skills development process? The answers to these questions will not only enrich the academic discussion but will also provide concrete input for curriculum strengthening, thus contributing to the training of professionals better prepared for the challenges of the Peruvian health system.

2. Methods

2.1 Design and Population

A quantitative, analytical, cross-sectional investigation was carried out between June and July 2025.

2.2 Population and sample

The study population consisted of fourth- and fifth-year students from the School of Medical Technology at UNMSM. A total of 112 participants were included using non-probability convenience sampling, with a response rate of 85%. Inclusion criteria were: students enrolled in their fourth or fifth year, over 18 years of age, who provided voluntary informed consent. The sample size was determined by considering the accessible population of students enrolled in both academic years during the study period. Due to the sampling method used, there is a possibility of selection bias, as participation depended on student availability and voluntary acceptance. Furthermore, because the sample comes from a single institution, external representativeness is limited. Therefore, the results should be interpreted as contextual evidence specific to the institution studied and should not be automatically extrapolated to other educational programs at the national or Latin American level.

2.3 Instrument and validation

The instrument used was a questionnaire adapted from Dukic et al. (6), consisting of 15 items that assess integrated theoretical-practical knowledge of competencies in the pre-analytical phase. Each correct answer received one point (0–15 points). In accordance with the competency-based education approach, scores were classified into three achievement levels: low (0–8), medium (9–12), and high (13–15), defined by percentage ranges of correct answers (<50%, 50–79%, and ≥80%). The instrument underwent content validation through expert review and pilot testing with students of similar characteristics, achieving adequate internal consistency (Cronbach's α = 0.813). The instrument is shown in the appendix.

2.4 Data collection

Data was collected using electronic forms, ensuring confidentiality and anonymity. R Commander 4.2.1 software was used for descriptive analysis (frequencies, percentages), tests of association (Chi-square), and predictive modeling (logistic regression) to identify the association between sociodemographic variables (age, sex, and year of study) and competence level, estimating odds ratios (OR) with 95% confidence intervals. The significance level was set at α=0.05. The 95% confidence intervals were calculated using Wilson's method, which is especially recommended for binary variables or proportions because it offers more precise limits than the traditional method, particularly when percentages approach 0% or 100% or when the sample size is moderate. This method adjusts the interval considering sample variability and avoids obtaining limits lower than 0% or higher than 100%.

2.5 Ethical considerations

The study was approved by the ethics committee of the Faculty of Medicine at the National University of San Marcos (Act No. 0052-2025), in compliance with the principles of the Declaration of Helsinki. Participants were provided with a digital informed consent form explaining the study's objectives, the voluntary nature of participation, the confidentiality of the information, and the option to withdraw at any time. Only students who provided informed consent were granted access to the questionnaire.

3. Results

The sample (n=112) had a balanced distribution by sex: 57 male participants (50.9%) and 55 female participants (49.1%). 68.8% were in their fourth year of studies and 31.3% in their fifth year. Table 1 shows the distribution of pre-analytical competence levels. The majority of students were at an intermediate level (n=83, 74.1%, 95% CI), followed by a high level (n=24, 21.4%, 95% CI). Only a few participants were at a low level (n=5, 4.5%, 95% CI).

Table 1. Distribution of the global level of pre-analytical competence.

Level of Competence	n	%
High (13-15 points)	24	21.4
Medium (9-12 points)	83	74.1
Low (0-8 points)	5	4.5

n = number of students; % = percentage with respect to the total sample.

Table 2 shows that students master theoretical concepts such as tube ordering (n=110, 98.2%, 95% CI: 93.7–99.5), but exhibit critical deficiencies in practical skills such as the proper handling of lipemic samples (n=44; 39.3%; 95% CI: 30.7–48.5), adequate homogenization (n=34; 30.4%; 95% CI: 22.5–39.4), and transport for coagulation (n=31; 27.7%; 95% CI: 20.2–36.5). The confidence intervals confirm that these practical skills would not exceed 40% in the general population, highlighting priority areas for strengthening the curriculum.

Table 2. Distribution of students with adequate mastery in specific procedures.

No.	Procedure	n	%	95% CI*
1	Tube order	110	98.2%	93.7-99.5
2	Sample identification	107	95.5%	89.9-98.0
3	Collection technique	95	84.8%	77.1-90.3
4	Proper Centrifugation	80	71.4%	62.5-79.0
5	Temporary storage	77	68.8%	59.7-76.7
6	Recognition of hemolysis	75	67.0%	57.8-75.0
7	Management of lipemic interferences	44	39.3%	30.7-48.5
8	Proper homogenization	34	30.4%	22.5-39.4
9	Transport for coagulation	31	27.7%	20.2-36.5

n = number of students with correct answer; % = percentage with respect to the total sample (N=112).

Table 3 shows the positive effect of clinical experience on skills directly practiced during the clinical internship by year of study. Fifth-year students significantly outperformed fourth-year students in practical skills such as hemolysis recognition (85.7% vs. 58.4%; p = 0.004) and collection technique (94.3% vs. 79.2%; p = 0.044), demonstrating the benefit of the clinical internship. However, in procedures such as homogenization, there was no significant improvement (28.6% vs. 34.3%; p = 0.543), indicating that certain competencies require specific supervised training beyond clinical exposure.

Table 3. Proportion of students who demonstrated adequate mastery of each competency.

Competence	Fourth year (n=77)	Fifth year (n=35)	p-value
Recognition of hemolysis	58.4%	85.7%	0.004*
Collection technique	79.2%	94.3%	0.044*
Tube order	97.4%	100%	0.352
Sample identification	94.8%	97.1%	0.576
Proper Centrifugation	68.8%	77.1%	0.367

Homogenization	28.6%	34.3%	0.543

*, p<0.05

Logistic regression analysis identified that age ≥25 years was a factor positively associated with a higher level of competence (OR=2.85; p=0.021).

4. Discussion

The findings of this study offer a contextualized perspective on the development of competencies in the pre-analytical phase of future Peruvian medical technologists, allowing for valuable comparisons with international evidence and highlighting specific opportunities for strengthening training in the local context. Although the sample (n=112) was obtained through non-probability convenience sampling, which limits the generalizability of the results, the sample size allowed for the exploration of relevant patterns of competency performance within the analyzed educational context.

The majority of students were at an intermediate level (n=83, 74.1%, 95% CI). In this context, a high level suggests adequate mastery of the knowledge necessary for the proper management of the pre-analytical phase, while an intermediate level reflects partial learning achievement requiring reinforcement in specific aspects, and a low level indicates significant gaps in knowledge of the process. However, these levels should be interpreted as an approximation of cognitive mastery in the educational context, rather than as a direct measure of professional performance in real clinical settings, which also depends on practical experience, supervised training, and the conditions of the work environment.

The strong theoretical mastery observed in fundamental aspects such as tube ordering (98.2%) aligns favorably with international standards. Similar studies in other contexts, such as the one conducted by Dukic et al. (6) with European laboratory science students, report comparable percentages (86%) in knowledge of basic pre-analytical principles. This agreement suggests that, in terms of theoretical foundations, medical technology training in Peru reaches quality levels comparable to those of more established educational systems. However, as Lima-Oliveira et al. (9) point out in their review on pre-analytical phase management, the real educational challenge lies not in teaching theoretical concepts, but in competent, effective practice.

The areas identified for further practical training, especially homogenization (30.4%) and transport of specialized samples (27.7%), show significantly lower percentages than those reported in contexts with more developed practical infrastructure. Simundic et al. (10), in their call to action on the need to improve pre-analytical education, document that in European programs, the systematic implementation of guidelines, practical training, and mastery of specific technical procedures is associated with better performance and adherence to good practices.

The lower proportion of students with adequate mastery of the procedures evaluated in the present study does not necessarily reflect a lower capacity of Peruvian students, but is probably related to structural variables identified by the Pan American Health Organization (11) as common in Latin American educational systems: less availability of supervised laboratory work hours, limited access to high fidelity simulation equipment, and disconnection between the practical content taught and the real demands of local laboratory services.

The positive effect of clinical internships on directly practiced and observable skills, such as hemolysis recognition (85.7% in the fifth year versus 58.4% in the fourth year), aligns with internationally reported findings, as demonstrated by a medical study in which 62.5% of participants were familiar with the term “pre-analytical error.” However, many technical procedures achieved percentages lower than 40% (Kulkarni et al.) (12). The limited transfer of this experience to more

complex technical procedures suggests that, as Hawkins (13) points out in his analysis of pre- and post-analytical phase management, observational learning in clinical settings may be insufficient to develop in-depth technical skills without explicit instruction and structured feedback. This phenomenon appears to be particularly relevant in contexts like Peru, where clinical internships take place in laboratories with varying levels of technical standardization.

The association between older age (≥25 years) and more robust competency development (OR=2.85) is echoed in international research on health sciences education. Sepúlveda et al. (7), in their systematic review of educational interventions to improve the pre-analytical phase, observed that structured educational interventions significantly improve theory-practice integration, which could explain the better performance observed in subgroups with more prior training or work experience. This characteristic could be particularly relevant in the Peruvian context, where, according to data from the Ministry of Health (14), many health sciences students enter higher education after work experience in the sector, which could represent an opportunity for pedagogical strategies that capitalize on this diversity of prior experiences.

The results suggest that older students may have accumulated greater academic exposure or formative experience, which facilitates the development of skills in the pre-analytical phase. However, the possible relationship of this variable with other contextual factors, such as year of study and gender, was considered. Although these variables did not reach statistical significance (fifth year: OR=1.92; 95% CI: 0.85–4.35; p=0.118; male: OR=1.15; 95% CI: 0.52–2.54; p=0.728), their inclusion allowed for adjusting the estimated effect of age and exploring possible collinear relationships. Consequently, the results should be interpreted with caution, as the observed competence likely stems from a combination of formative and experiential factors that cannot be fully captured by a single predictor in the model.

The implications of these findings become especially relevant when considering the specific characteristics of the Peruvian healthcare system. García-Del-Pino et al. (15) highlight the importance of pre-analytical management in systems with limited automation, as is common in many primary and secondary care facilities in Peru, where reliance on the professional's manual technical skills is particularly critical. This reality contrasts with that of countries where automation reduces dependence on specific manual technical skills, as documented in their retrospective analysis of pre-analytical errors in Spain.

From an educational innovation perspective, our findings align with the call by Frenk et al. (3) to transform health education, suggesting the need to strengthen the instructional design of pre-analytical training through more structured, performance-oriented pedagogical strategies to meet the specific needs of healthcare systems. In curricular terms, this could translate into the incorporation of simulation modules of pre-analytical scenarios, standardized practical workshops on critical procedures (e.g., sample handling, proper homogenization, and transport), as well as the use of checklists and competency-based formative assessment during clinical internships.

These strategies allow for the identification of areas where practical training can be deepened and facilitate the design of targeted educational interventions that, as suggested by the evidence of Lippi et al. (16), could be implemented even in contexts with limited resources. Structured practical training programs, with specific feedback and formative assessment, have been shown to significantly improve competence in specific pre-analytical procedures in various international contexts.

In summary, this study situates the analysis of medical technology training in Peru within a global discussion on the quality of health sciences education. While fundamental theoretical aspects show levels comparable to international standards, gaps are identified in specific practical

competencies that reflect common structural challenges in Latin American educational systems. The evolution toward training models that more effectively integrate theory and practice, considering the specific characteristics of the Peruvian context, represents not only a pedagogical improvement but also a strategic investment in the quality of the national health system. As Plebani (17) concludes in his work on quality in clinical laboratories, in contexts where technological resources are limited, the professional's technical competence becomes the most important factor in guaranteeing diagnostic quality and patient safety.

5. Conclusions

- Peruvian medical technology students demonstrate a solid theoretical foundation comparable to international standards.
- Specific opportunities are identified to strengthen practical training in technical procedures that show lower mastery percentages than those reported in contexts with greater development of practical infrastructure.
- Clinical experience shows differentiated impacts, significantly improving directly observable skills, but having less effect on complex technical procedures.
- The age diversity of the student population represents an opportunity for differentiated pedagogical strategies that capitalize on previous experiences.
- The findings provide contextualized evidence for the design of curricular innovations that respond to the specific needs of the Peruvian health system.

Annex 1: Questionnaire used.

Funding: There has been no external funding for this study.

Declaration of conflict of interest: The authors declare that they have no conflict of interest.

Authors' contributions: AGAR: conception, design, data collection, analysis, writing. MZME: design, methodological supervision, critical review, final approval.

Sponsorship: National University of San Marcos, National Institute of Health.

Ethical approval: Ethics Committee of the Faculty of Medicine. National University of San Marcos.

Data availability: The data supporting the results of this study are available upon reasonable request to the corresponding author. Because the dataset contains academic information of participating students, access is restricted to protect participant confidentiality.

6. References.

1. Altamirano T, Macías C, et al. Competency-Based Education: Approach and Challenges. *Polo del Conocimiento.* **2025,** 10, 4. https://doi.org/10.23857/pc.v10i4.9396.
2. Cornes M. The preanalytical phase – Past, present and future. *Ann Clin Biochem.* **2020,** 57, 1. https://doi.org/10.1177/0004563219867989.
3. Frenk J, Chen L, Bhutta ZA, Cohen J, Crisp N, Evans T, et al. Health professionals for a new century: transforming education to strengthen health systems in an interdependent world. *Lancet.* **2010,** 376, 9756. https://doi.org/10.1016/S0140-6736(10)61854-5.
4. of Health of Peru. Technical Health Standard for the Management of Clinical Laboratory Processes No. 021-MINSA-DGSO-V.03. Lima: Ministry of Health of Peru. **2022.** https://cdn.gacetajuridica.com.pe/laley/NORMA%20T%C3%89CNICA%20DE%20SALUD%20N%C2%BA021-MINSA-DGSP-V.03_LALEY.pdf
5. Pan American Health Organization. Quality indicators for clinical laboratories: implementation manual. Washington, DC: Pan American Health Organization. **2021.** https://iris.paho.org/items/cf41af22-aa33-40b1-bd4c-1d11595c844c.
6. Dukic L, Jokic A, Kules J, Pasalic D. The knowledge and understanding of preanalytical phase among biomedicine students. *Biochem Med.* **2016,** 26, 1. https://doi.org/10.11613/BM.2016.009.
7. Sepúlveda F, Azocar I, González ML, et al. The Contribution of Education to the Correction of Preanalytical Errors in Laboratory Testing: A Systematic Review. *Health Science and Technology.* **2025,** 5, 1781. https://doi.org/10.56294/saludcyt20251781.

8. National University of San Marcos. Institutional Strategic Plan 2026-2030. Lima: National University of San Marcos. 2026. https://www.gob.pe/institucion/unmsm/informes-publicaciones/1943021-plan-estrategico-institucional-pei.
9. Lima-Oliveira G, Volanski W, Lippi G, et al. Pre-analytical phase management: a review of the procedures from patient preparation to laboratory analysis. *Scand J Clin Lab Invest.* **2017,** 77, 3. https://doi.org/10.1080/00365513.2017.1295317.
10. Simundic AM, Cornes M, Grankvist K, Lippi G, Nybo M, Kovalevskaya S, et al. Survey of national guidelines, education and training on phlebotomy in 28 European countries. *Clin Chem Lab Med.* **2013,** 51, 8. https://doi.org/10.1515/cclm-2013-0283.
11. Pan American Health Organization. Universal health in the 21st century: 40 years of Alma-Ata. Report of the High-Level Commission. Washington, DC: Pan American Health Organization. **2019.** https://iris.paho.org/server/api/core/bitstreams/2cde7c43-fdca-4a4b-a5b7-375d562de22d/content
12. Kulkarni KK, Ramalingam IT, Kalaimani V, Alur SS, Bylappa L, Rao M. Questionnaire-based Study to Assess Knowledge of Preanalytical Phase of Laboratory Testing Among Trainee Doctors in a Tertiary Care Hospital Medical College. *J Lab Physicians.* **2020,** 12, 3. https://doi.org/10.1055/s-0040-1720945.
13. Hawkins R. Managing the pre- and post-analytical phases of the total testing process. *Ann Lab Med.* **2012,** 32, 1. https://doi.org/10.3343/alm.2012.32.1.5.
14. Ministry of Health of Peru. Yearbook of Health Statistics 2022. Lima: Ministry of Health of Peru. **2023.** https://www.gob.pe/institucion/susalud/informes-publicaciones/4443829-anuario-estadistico-2022.
15. García I, Bauça JM, Gómez C, et al. Preanalytical issues related to routine and diagnostic glucose tests: Results from a survey in Spain. *Biochem Med.* **2020,** 30, 1. https://doi.org/10.11613/BM.2020.010704.
16. Lippi G, Cadamuro J, von Meyer A, et al. Practical recommendations for managing hemolyzed samples in clinical chemistry testing. *Clin Chem Lab Med.* **2018,** 56, 5. https://doi.org/10.1515/cclm-2017-1104.
17. Plebani M. The detection and prevention of errors in laboratory medicine. *Ann Clin Biochem.* **2010,** 47 2. https://doi.org/10.1258/acb.2009.009222.