



Pre-analytical errors that affect laboratory test results and interpretation: validity of an educational technology for veterinarians

Erros pré-analíticos que afetam os resultados e a interpretação dos exames laboratoriais: validação de uma tecnologia educacional para veterinários

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ABSTRACT: Laboratory tests are conducted in three phases: pre-analytical, analytical, and post-analytical. The pre-analytical phase has a high incidence of errors that can affect laboratory test results and interpretation. Therefore, continuing education in clinical analysis is crucial to reducing or, ideally, eliminating pre-analytical errors. This study aimed to validate, with the help of experts, the content (stage 1), appearance (stage 2), and semantics (stage 3) of an educational technology (ET), in the form of a manual, for veterinary clinical pathologists. In stages 1 and 3, a Likert-type scale was applied to calculate the Content Validity Index (CVI) and Semantic Validity Index (SVI), with a minimum validity threshold of 80%. For stage 2, the Suitability Assessment of Materials (SAM) form was used, with a minimum acceptability score of 40%. Content validity yielded an overall CVI of 90%, while appearance assessment reached 89% acceptability; both was approved in the first assessment round. After incorporating expert recommendations, the manual underwent semantic validity, reaching an SVI of 99% with the target audience. The manual was validated and deemed suitable for use in professional education initiatives in clinical analysis and in routine veterinary practice. The ET was registered with the National Library, and is available on the eduCAPES Repository. The validity process is essential to provide high-quality educational technologies to promote continuing education, improve veterinary care, enhance laboratory test results, and consequently, animal health.

Keywords: validity study; veterinary complete blood count; pre-analytical errors; laboratory medicine.

RESUMO: Os exames laboratoriais são realizados em três fases: pré-analítica, analítica e pós-analítica. A fase pré-analítica apresenta elevada incidência de erros que podem afetar os resultados e a interpretação dos exames. Portanto, a educação permanente em análises clínicas é crucial para reduzir ou, idealmente, eliminar erros pré-analíticos. Esse estudo teve como objetivo validar, com auxílio de especialistas, o conteúdo (etapa 1), a aparência (etapa 2) e a semântica (etapa 3) de uma tecnologia educacional (TE), no formato de manual, para patologistas clínicos veterinários. Nas etapas 1 e 3, uma escala do tipo Likert foi aplicada para calcular o Índice de Validade de Conteúdo (IVC) e o Índice de Validade Semântica (IVS), com um limite mínimo de validação de 80%. Para etapa 2, utilizou-se o formulário "Suitability Assessment of Materials" (SAM) com escore de aceitabilidade mínima de 40%. A validação de conteúdo produziu um IVC geral de 90%, enquanto a de aparência atingiu 89% de aceitabilidade, ambos aprovados na primeira rodada de avaliação. Após incorporar recomendações dos especialistas, o manual passou por validação semântica, alcançando um IVS de 99% com o público-alvo. O manual foi validado e considerado adequado para uso em iniciativas de educação profissional em análises clínicas e na rotina de veterinários. A TE foi registrada na Biblioteca Nacional e está disponível no Repositório eduCAPES. O processo de validação é importante para disponibilizar tecnologias educacionais de qualidade para promover ações de educação permanente, aprimorar os cuidados veterinários, melhorar os resultados dos exames laboratoriais e, conseqüentemente, a saúde animal.

Palavras-chave: estudo de validação; hemograma veterinário; erros pré-analíticos; medicina laboratorial.

INTRODUCTION

Laboratory tests are widely used tools in veterinary medicine to assess and monitor patient health. Among the wide variety of available tests, complete blood count (CBC) is the most commonly requested in veterinary consultations. Its main advantages include ease of sample collection, simple execution, low cost, and the ability to provide general information about patients' clinical status (Farias; Santos, 2019).

Laboratory tests are performed in three

phases: pre-analytical, analytical, and post-analytical. The pre-analytical phase includes test requisition, patient data entry, biological sample collection, identification, storage, transportation to the laboratory, and acceptance assessment. In the analytical phase, the sample is processed, either through automation or manual methods, using validated techniques and ensuring result reliability through internal and external quality controls. The post-analytical phase involves data entry, report issuance and interpretation by a qualified professional, sample storage after processing, and

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appropriate waste disposal (ISO, 2012; Braun *et al.*, 2015; Braz; Brasil; Rodrigues Garcia, 2018).

The pre-analytical phase accounts for up to 75% of the errors that can affect veterinary laboratory test results, with the majority of these occurring outside the clinical laboratory (Whipple; Leissinger; Beaty, 2020). Inadequate procedures during this phase can lead to delayed results, inaccurate outcomes, material waste, and increased laboratory costs (Oliveira; Fernandes, 2016).

To minimize pre-analytical errors that affect test results, and consequently clinical decisions, continuing education for veterinary doctors and technicians is essential. This includes guidance on proper procedures during blood sample collection, preservation, and transportation to ensure the quality of submitted materials (Whipple; Leissinger; Beaty, 2020).

In this context, educational technologies are necessary to disseminate knowledge regarding sample collection, handling, and transportation among veterinarians, laboratories, clinics, and offices, thereby reducing potential errors during the pre-analytical phase. Despite notable advancements in technologies across veterinary clinics, laboratories, training, and professional development, there remains a lack of educational materials applied to teaching that directly contribute to learning on this subject (Franco; Norte, 2007; Muca *et al.*, 2022).

The development of educational products and materials involves three stages: creation, validity, and application. The first stage involves gathering theoretical references on the subject, followed by educational technology development (e.g., booklets, pamphlets, manuals) using language appropriate to the target audience. The second stage is validity, which may include content, appearance, and semantic validity. The third stage involves applying the material in the context of the target audience to assess satisfaction, engagement, and other relevant attributes (Teixeira *et al.*, 2016; Baia, 2018).

Content validity is performed by expert professionals in the subject area of the educational material. Through a methodological system with measurable criteria, they assess the importance of included information and content presentation (Medeiros *et al.*, 2015). Appearance validity ensures that the educational technology is visually appropriate and understandable for the target audience, including assessment of the graphic design, layout, formatting, and visual elements (Lima, 2014). Semantic validity aims to ensure that the educational material is clear, accurate, relevant, and aligned with the learning objectives for its intended audience (Silva *et al.*, 2015).

From this perspective, a manual entitled "Pre-analytical Factors Influencing the Complete Blood Count in Dogs and Cats" was developed. Its creation was based on an extensive literature review in the SciELO, PubMed, Google Scholar, Google, and the CAPES Journals Portal electronic databases. The manual was organized into 10 topics, with 28 pages (Santos, 2021), but it was not submitted to the validity stage.

Given the above, this study aimed to validate the produced manual using different validity modalities, in order to provide a high-quality educational technology for continuing education, and

to raise awareness among veterinarians about the importance of the pre-analytical phase in ensuring reliable laboratory test results, particularly for CBC, the most requested test in veterinary practice.

MATERIAL AND METHODS

This study was submitted to and approved by the Research Ethics Committee of the Institute of Health Sciences, Universidade Federal do Pará, under Opinion number 5.496.131 and CAAE 57671922.8.0000.0018. All specialists signed the Informed Consent Form (ICF).

This was a methodological study aimed at validating the content (stage 1), appearance (stage 2), and semantics (stage 3) of an educational manual. All stages were conducted in a virtual environment, starting with the sending of invitations and the ICF to specialists via email. Upon acceptance, an electronic form was sent, developed using Google Forms, containing statements related to the content (verbal and non-verbal) along with the manual.

Stage 1 – Content validity:

A Likert-type scale instrument was used to measure agreement among specialists. Each response allowed for corrections or suggestions as deemed necessary. The Content Validity Index (CVI) was used to measure the level of agreement among experts based on the proposed criteria. The instrument included ratings from 1 to 4 for each item, where 1 = fully adequate, 2 = adequate, 3 = partially adequate, and 4 = inadequate. This method enabled assessing each item both individually and collectively (Alexandre; Coluci, 2011; Cunha, de Almeida Neto; Stackfeth, 2016).

The following selection criteria were adopted for specialists: graduate qualifications in veterinary clinical pathology; veterinary practitioners with more than 3 years of experience in laboratory work; and clinical pathology and/or veterinary laboratory medicine professors at public or private institutions.

Statistical analysis was guided by the calculation of the CVI score index, determined by summing the number of items rated as "1" or "2" by specialists and dividing it by the total number of responses (Polit; Beck; Hungler, 2011). A CVI score of 0.80 (80%) or higher was required for the manual to be considered validated. Sample characterization data were compiled in a database created using Microsoft Office Excel®.

Stage 2 – Appearance validity:

For appearance validity, the Suitability Assessment of Materials (SAM) was used. This tool includes a list of attributes related to motivation, writing, and appearance, with the following scoring: 2 points for adequate; 1 point for partially adequate; and 0 points for inadequate. A minimum acceptability score of 40% was required (Hoffmann; Ladner, 2012).

For this stage, communication specialists were selected using the following criteria: professionals working within the national territory in pedagogy, advertising, communications, graphic design, marketing, and related fields. Statistical analysis followed the calculation of the SAM score, based on the total points received in each expert's questionnaire. A score above 6 points was considered adequate.

Stage 3 – Semantic validity:

For semantic validity, a four-level Likert-type scale was used to assess the Semantic Validity Index (SVI) (Siqueira *et al.*, 2020). The target audience was selected using the following criteria: veterinary professionals working in small animal clinical medicine and surgery (dogs and cats).

Statistical analysis followed the same methodology used for content validity specialists (Polit; Beck; Hungler, 2011), with an overall SVI score of 0.80 (80%) or higher required for the manual to be considered validated.

RESULTS

In the content validity stage, 19 specialists participated in the manual assessment. The majority of specialists were female, accounting for 73.68% (14/19). The most common academic degree was specialization (42.11%; 8/19), followed by PhD (36.84%; 7/19), a bachelor's degree (15.79%; 3/19), and a master's degree (5.26%; 1/19). The mean time since graduation was 15.2 ± 6.8 years. The regions of professional practice were quite diverse, with representation from nearly all regions of the country, except for the Central-West.

Questions related to the manual content yielded a CVI of 0.93 (Table 1), thus reaching the threshold required for validity. The lowest score was observed for the item regarding the manual's potential for circulation in the scientific community, which received one rating of "inadequate". In the suggestions section, two specialists made the following remarks: "I suggest delving deeper into the topic, for instance, by explaining in detail the reasons/mechanisms by which time, temperature, and other factors alter morphology". "I would recommend including samples from icteric patients".

Table 1 – Content Validity Index (CVI) results for the three question chunks of the form.

Question chunks	CVI
1. Manual content	0.96
2. Appearance and structure	0.90
3. Manual relevance	0.94
Mean form score	0.93

The statement that assessed whether the manual contributes to behavior changes related to the pre-analytical phase received a CVI of 1.0. However, it was suggested that the manual should encourage the habit of preparing a blood smear at the time of collection.

The chunk of questions related to appearance achieved a CVI of 0.91, with special mention of the use of a QR code. According to a specialist, "This is the kind of feature that appeals to today's audience. It brings dynamism and offers a practical tool for clinicians". The only item with a concordance index below the 0.80 threshold was question 16, regarding the illustrations. Among the observations, it was noted that the cover illustration was not attractive enough, and it was recommended to include the sources of the images.

The chunk of statements related to the manual's relevance to the target audience had a CVI of 0.94, representing the highest agreement index among the chunks. However, almost all items received suggestions. For instance, it was recommended to reduce the overall length of the material and make the content more applicable to real-world practice. It was noted that the literature often addresses only ideal samples, which are not always attainable in clinical settings. Therefore, it is important to establish the threshold between an acceptable and an ideal sample.

The content validity form received an overall CVI score of 0.90. This score indicates that specialists considered the material to be of high quality and approved it in the first round of validity testing. Therefore, the content was deemed robust and suitable for use in continuing education initiatives for veterinarians.

In the appearance validity phase, eight specialists completed all stages of the material assessment. The majority of specialists were male (62.50%; 5/8). Their professional backgrounds included social communication (37.50%; 3/8), design (12.50%; 1/8), journalism (12.50%; 1/8), language studies (12.50%; 1/8), computer science (12.50%; 1/8), and pedagogy (12.50%; 1/8). The regions in which appearance specialists worked were limited to the North (75%; 6/8), Northeast (12.50%; 1/8), and South (12.50%; 1/8) of Brazil.

The developed material succeeded in appearance validity in the first round of submission, scoring above the minimum threshold of 6.4 points (40%) on the SAM. It reached an overall score of 14.3 points (89.6%) for acceptability. Nevertheless, several contributions and suggestions were made to further improve the overall aesthetic and content quality.

The statements concerning the manual content (Table 2) received scores above the cut-off point. The manual objective was considered sufficiently clear for understanding, and professionals were able to grasp the recommended positive practices. One suggestion was to change the font to improve readability.

Table 2 – Suitability Assessment of Materials items.

Question chunks	Points	SAM (%)
1. Manual content	15.6	97.5
2. Manual language	14.6	91.2
3. Graphic illustrations	12.5	78.1
4. Manual motivation	14.0	87.5
5. Cultural appropriateness	15.0	93.7
Mean form score	14.3	89.6

Note: SAM - Suitability Assessment of Materials.

The section related to the educational technology language included a suggestion to create a checklist to facilitate quick reference. Additionally, adjustments were recommended for the text layout, such as justification, font modification, and line spacing improvements.

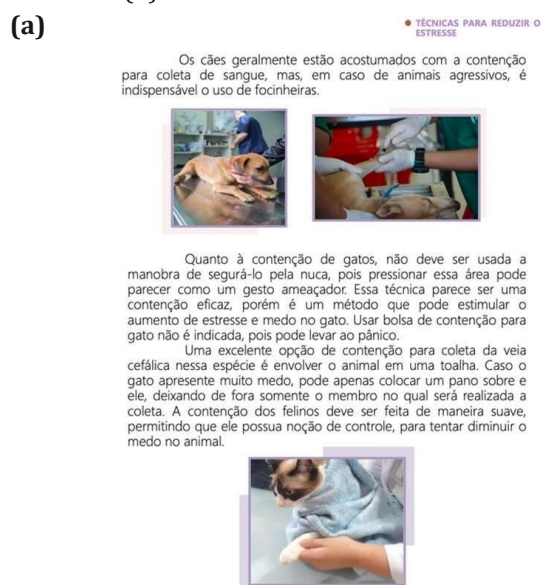
The chunk of statements that received the most suggestions and comments was related to graphic illustrations. Regarding the cover, comments included the "lack of graphic enhancement", suggestions to fill

empty spaces, and the use of more vibrant colors. For the internal illustrations, it was recommended to modify a flowchart to improve understanding and to use a consistent illustration style throughout the manual.

In terms of the manual's motivational appeal, one specialist reported the need to better categorize the images in relation to the text to ensure a clearer correlation between visuals and written content. Regarding the second statement in this chunk, it was noted that the manual could include more diagrams or illustrations of professional behavior. In the chunk concerning cultural adequacy, only one comment was made, recommending improved manual organization and better content segmentation.

Following specialists' recommendations, an updated version of the manual was produced. This revised version included real images to create a closer connection between the reader and the information presented, aiming to better reflect their professional reality. After being validated in a single round by content and appearance evaluators, version I underwent visual adjustments, resulting in version II, which was then submitted to semantic specialists (Figure 1).

Figure 1 – Page 20 of the manual: version I (a) and version II (b).



Source: author's collection.

Semantic validity involved 12 veterinary medical specialists. The majority of specialists were female (83.33%, 10/12). Regarding areas of practice—where professionals could select more than one—the most common was small animal internal medicine, practiced by 58.33% (7/12), followed by small animal surgery at 41.67% (5/12). The most frequent academic degree was specialization (75%, 9/12), followed by a master's degree (16.66%, 2/12), and a bachelor's degree (16.66%, 2/12). The professionals' regions of residence were limited to the North and Northeast of Brazil.

The second version of the manual was validated in the first round of submission with an overall SVI of 0.99 (Table 3). The specialists in this phase made few comments in the section concerning the manual organization, structure, presentation strategy, coherence, and formatting. There were two suggestions related to the cover: one to make the title more prominent; and another to include institutional logos identifying the organization involved (Figure 2).

Table 3 – Questions from the semantic validity form and Semantic Validity Index.

Question chunks	SVI
1. Manual objectives	1.0
2. Organization, structure, strategy, presentation, and formatting	0.98
3. Linguistic characteristics, comprehension, and writing style	1.0
4. Educational technology appearance	1.0
5. Material motivation, potential impact, and educational technology significance level	1.0
Mean form score	0.99

Note: SVI – Semantic Validity Index.

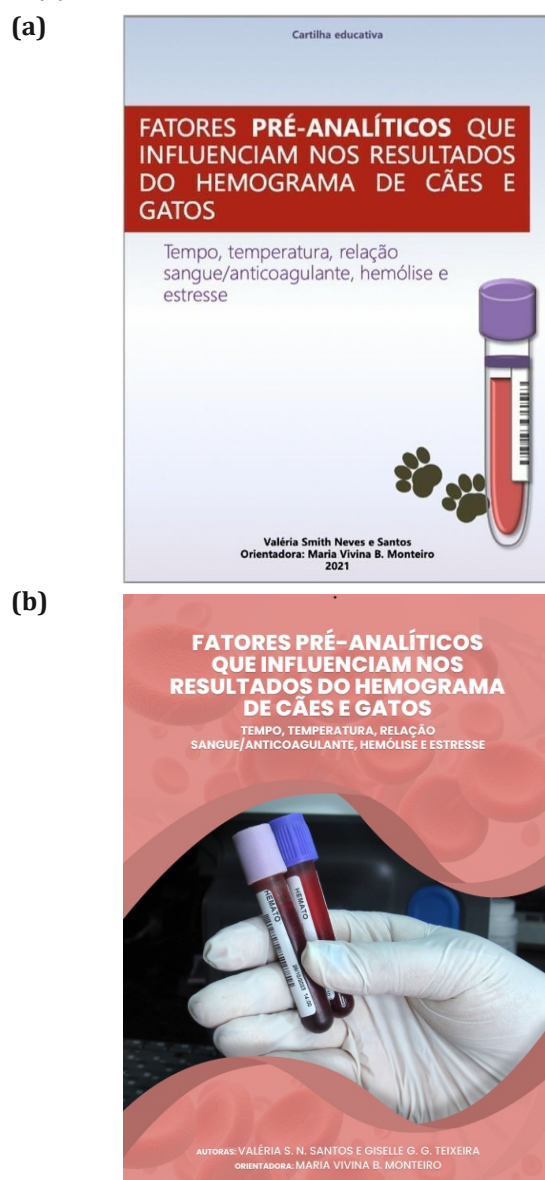
The last group of specialists, although composed almost entirely of professionals from the North region, demonstrated diversity in their fields of practice—ranging from work with small animals, hematology, and diagnostic imaging to large animals and wildlife. Most professionals worked in more than one area within veterinary medicine, indicating that the manual is suitable even for professionals from different specialties.

DISCUSSION

The participation of specialists with advanced academic qualifications in the laboratory field, combined with an average duration of professional experience, provides significant contributions to enhancing the educational technology. Members of the review committee must be thoroughly selected, with an emphasis on participants' qualifications and academic background. It is recommended that the specialists have clinical experience and be researchers in the specific area under assessment (Cunha; de Almeida Neto; Stackfleth, 2016).

The specialists' geographical diversity, representing different regions of the country, grants legitimacy to the national applicability of the manual—not only due to the adequacy of the content but also due to the relevance of the topic in veterinary practice

Figure 2 – Cover of the manual: version I (a) and version II (b).



Source: author's collection.

nationwide. Concerning the appearance evaluators, geographical and professional diversity is also evident, despite all being involved in the fields of language, imagery, and pedagogy.

The manual's inadequacy score for the statement regarding its "potential to circulate in scientific circles" may be linked to its simplified approach. However, educational manuals aim to create messages with language tailored to the target audience—engaging and easy to understand—supported by well-crafted illustrations and texts that enhance accessibility and visual communication (Moreira *et al.*, 2018). The educational technology in question was designed as an easily accessible resource, intended to clarify doubts and improve practices in work settings, offering tools for the professional development of clinical laboratory personnel and veterinarians. Therefore, the manual does not intend to address in detail the mechanisms behind pre-analytical variations in CBC in dogs and cats, given the existing availability of literature and scientific studies on the subject (Farias; Santos, 2019; Thrall *et al.*, 2022; Zitzer, 2023).

In the first version of the manual, illustrations received criticism for lacking attractiveness, as

evidenced by the CVI score falling below the cut-off point for the statement "The illustrations are expressive and sufficient". This trend was reinforced during appearance validity, in which the statement "The cover draws attention and reflects the purpose of the material" received one of the lowest SAM scores. The particularities of visual language make it highly effective in contexts where the goal is to promote, critique, guide, or influence. The systematic and continuous educational process can be enhanced when images are used to generate new knowledge, integrating them into the educational effort. The inclusion of appealing visuals is essential for facilitating learning and content retention (Castro; Zuin, 2018). Following a specialist's recommendation, the second version of the manual was updated to include real images, aiming to establish a closer connection between the reader and the presented information, in order to reflect their professional reality.

Semantic validity specialists showed a positive reception toward the final material, as indicated by both the individual and overall SVI. A specific comment regarding the cover font led to modifications in the manual, resulting in the final version. Additionally, acknowledgment pages for contributors and an author biography page were included.

Although acquiring new knowledge alone may not be sufficient to drive behavioral change regarding a given issue, it is evident in society that, on many occasions, what is actually lacking is technical knowledge. When such knowledge is clearly and convincingly conveyed to people, it can indeed lead to behavioral change (Wild *et al.*, 2019).

It was observed that the target population recognizes the importance of the validity process in ensuring the quality of educational materials and promoting professional development and animal welfare. Therefore, investing in this process is an investment in the future of education, aiming to achieve animal well-being through good practices and actions that prevent errors affecting laboratory test results and their interpretation.

CONCLUSION

The pre-analytical phase is a critical point in conducting laboratory tests. The manual addresses this essential stage of CBC, which is often neglected in veterinary practice, resulting in interferences in laboratory test results.

The manual validity provided evidence of its scientific reliability and suitability for the target audience. Approved by three groups of specialists, the educational technology was considered appropriate to be made available to veterinarians. The validated manual was registered at the National Library, is available in the eduCAPES Repository (<https://educapes.capes.gov.br/handle/capes/917493>), and can be used in continuing education initiatives and training of professionals in laboratory medicine and other areas of veterinary medicine.

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