

# Valide Editoras: Infrastructure to Support the Large-Scale Production of Digital Educational Books in the Ecosystem of PNLD

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**Abstract.** *This paper presents Valide Editoras, a tool designed to support the production and technical validation of digital educational textbooks within the ecosystem of Programa Nacional do Livro Didático - (PNLD). The platform integrates automated validators based on technical and regulatory requirements defined in official specification documents. The paper describes the validation architecture and workflow adopted by publishers during the development and revision of digital textbooks. Operational results characterize the use of the tool during submission and revision processes and show an observed reduction in automated nonconformities across the analyzed cycles. The proposed approach contributes to discussions on scalable infrastructures for the validation of digital educational resources.*

## 1. Introduction

The digital transformation of education has expanded the use of digital educational resources in different teaching and learning contexts [Selwyn 2021, UNESCO 2023]. In Brazil, this movement gained greater relevance within the scope of the *Programa Nacional do Livro e do Material Didático - PNLD* (Brazilian National Textbook and Educational Materials Program), which began incorporating digital textbooks, Objetos Educacionais Digitais – OEDs (Digital Educational Objects), and accessibility requirements as part of the official ecosystem for the production and distribution of educational materials for public basic education [FNDE 2021, FNDE 2024].

In this context, the technical quality of digital works directly impacts the educational experience of students and teachers. Problems related to accessibility, navigation, structural organization of content, or incompatibility with assistive technologies may compromise access, usability, and interaction with digital educational materials, especially in educational scenarios mediated by multiple devices and multimodal resources. Thus, mechanisms capable of supporting the technical conformity of digital works also contribute to strengthening educational accessibility, adequate content availability, and the operational quality of resources used in teaching and learning processes.

The adoption of the HTML5 format in the PNLD expanded the possibilities for producing more accessible, responsive, and interactive digital works, integrating different media, structured navigation, and support for assistive technologies

[W3C EPUB Working Group 2023, W3C EPUB Accessibility Working Group 2023]. In this context, publishers began incorporating new workflows related to digital content organization, accessibility, technical compliance, and validation of works before submission to the program.

With the expansion of large-scale production of digital educational books, technical verification became a relevant stage of the digital editorial workflow, especially given the need to ensure compliance with criteria defined in PNLD calls for proposals and technical documents [FNDE 2021]. Although there are tools focused on code validation, accessibility, and web compliance, solutions specifically developed to support editorial workflows associated with educational public policies and the technical requirements of PNLD Digital are still scarce [DAISY Consortium 2024b, World Wide Web Consortium 2025, Google Developers 2025].

In this scenario, Valide Editoras emerges as a tool integrated into the Valide ecosystem, designed to support publishers during the preparation, revision, and technical validation of digital educational works before official submission to the program. The tool performs automated verifications related to the structure of the digital work, accessibility, navigation, file integrity, and compliance with technical criteria established in the calls for proposals, providing structured feedback on possible nonconformities identified during the analysis of the works.

Despite advances in research on educational technologies, digital accessibility, and digital educational resources, there is still a gap related to the development of technical-operational support infrastructures aimed at the production and validation of digital educational books in large-scale public ecosystems [Márquez et al. 2024, UNESCO 2023]. In particular, studies discussing how automated validation mechanisms can support publishers and technical teams during the preparation and technical adaptation processes of digital works intended for national education programs remain limited. This work reports the design, deployment, and real-world operation of a technical validation infrastructure integrated into the PNLD Digital ecosystem. Its evidence is operational and observational rather than causal.

Given this scenario, this work investigates the following research question: **How can an automated validation infrastructure be integrated into the production and technical revision of digital educational books in the context of PNLD Digital?**

To answer this question, this article presents Valide Editoras and discusses its role as a support infrastructure for the digital editorial workflow in the context of the PNLD. As contributions, this work:

- reports the design, deployment, and real-world operation of a technical validation infrastructure integrated into a national-scale public policy ecosystem;
- describes a model based on specialized validators derived from technical and regulatory requirements;
- characterizes the operational use of automated validation during the production and revision of digital educational works;
- contributes to the discussion on technological infrastructures supporting large-scale digital educational ecosystems in public policies.

## 2. Context of PNLD Digital and the Production of Digital Educational Books

The incorporation of digital books into the PNLD represents an important advancement toward expanding access to educational content that is more accessible, interactive, and compatible with different learning contexts and assistive technologies [FNDE 2021, FNDE 2024]. In this scenario, the works began incorporating videos, audio, interactive infographics, clickable maps, and other OEDs integrated into the pedagogical content, expanding teaching, learning, and user experience possibilities for students and teachers [W3C EPUB Working Group 2023].

The production of these works began to involve more complex technical and editorial workflows, including content organization in HTML, multimedia production, metadata, accessibility, structural validation, and compliance with requirements defined in the program's calls for proposals and technical documents [FNDE 2021, FNDE 2024]. Resources such as textual image descriptions, support for screen readers, HTML semantics, responsiveness, and structured navigation became part of the production workflow of digital educational works [W3C EPUB Accessibility Working Group 2023, Caldwell et al. 2008]. Thus, the digital book no longer represents only a change in technological support and begins to act as a relevant element for expanding inclusion and access to educational content.

With the growth of the PNLD digital ecosystem, the need for mechanisms to support technical verification of works during production also increased. The existence of multiple requirements related to file structure, content organization, accessibility, and technical compliance made it relevant to use tools capable of supporting publishers in the early identification of possible nonconformities before the official submission of works [DAISY Consortium 2024b, DAISY Consortium 2024a]. In this context, technical validation support tools began to play a relevant role in the digital production ecosystem, contributing to support editorial workflows, increase transparency in the verification process, and assist technical teams during the preparation of digital educational works.

## 3. Related Work

Related work is situated at the intersection of technical validation of digital publications, web accessibility, quality assurance of digital educational resources, and infrastructures supporting digital educational ecosystems [Márquez et al. 2024]. In the context of the digital transformation of education, different studies have discussed challenges associated with the production, accessibility, standardization, and governance of digital educational resources at scale [Selwyn 2021, UNESCO 2023].

In the technical-operational context, the production of digital books is largely based on formal standards for structuring and accessibility. The EPUB 3.3 specification establishes criteria related to digital package organization, navigation, metadata, and HTML structure [W3C EPUB Working Group 2023]. The EPUB Accessibility 1.1 specification, aligned with the Web Content Accessibility Guidelines (WCAG), brings together recommendations related to structural semantics, image description, accessible navigation, and compatibility with assistive technologies [W3C EPUB Accessibility Working Group 2023, Caldwell et al. 2008].

Among the most widely used tools is EPUBCheck, an open-source project maintained by the W3C Publishing Working Group, focused on structural and syntactic valida-

tion of EPUB packages [DAISY Consortium 2024b]. For accessibility, ACE by DAISY performs automatic verifications based on WCAG criteria applied to digital publications [DAISY Consortium 2024a]. Other widely used tools include the W3C Markup Validation Service and Lighthouse, used for HTML validation, accessibility, and auditing of web applications [World Wide Web Consortium 2025, Google Developers 2025].

However, most existing solutions focus on generic HTML, EPUB, or web accessibility verifications, without addressing integrated editorial production workflows, validation contextualized by regulatory criteria, or operational support mechanisms for the large-scale production of digital educational books [UNESCO 2023].

Valide Editoras has a distinct technical and operational scope. Its validators are independently developed from PNLD calls for proposals and technical specifications. Validators may be reused across PNLD objects when requirements remain applicable, while new validators are developed for object-specific criteria. EPUBCheck, ACE by DAISY, the W3C Markup Validation Service, and Lighthouse are used solely as comparative references and are not incorporated into Valide Core.

4. The Valide Ecosystem

4.1. Validator Evolution and Deployment Cycle

The Valide ecosystem adopts a continuous cycle for the construction, evaluation, and evolution of validators. As presented in Figure 1, the process begins with the analysis of calls for proposals and technical documents, in which the requirements and criteria used for validating digital works are defined.

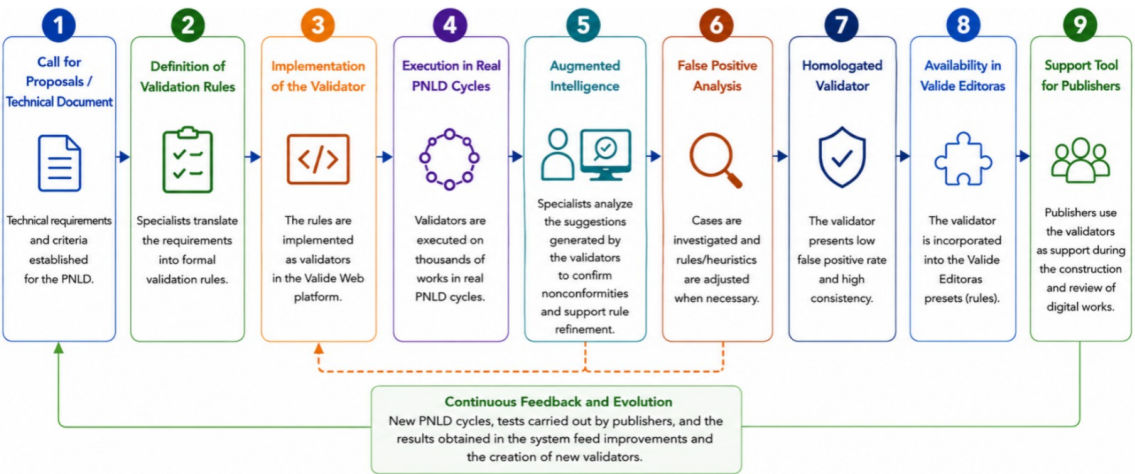


Figure 1. Validator evolution and deployment cycle in the Valide ecosystem.

Based on these requirements, specialists translate the criteria established in the calls for proposals into formal validation rules. These rules are then implemented as validators in the Valide ecosystem, composing the initial set of automated verifications available for execution.

After implementation, the validators are executed in real PNLD cycles, allowing the evaluation of their behavior at scale over digital works submitted to the program.

During this stage, metrics related to validator performance, frequency of occurrences, consistency of results, and possible limitations observed during execution are collected.

In this work, augmented intelligence refers to the combination of deterministic automated validation and specialized human review during the validator development and homologation cycle. Validators generate candidate nonconformities and associated technical evidence, which are subsequently reviewed by analysts responsible for confirming or discarding the findings according to the applicable regulatory criteria. Human analysis of false positives and context-dependent cases provides evidence for refining rules, conditions, and heuristics before validators are made available to publishers.

Findings classified by specialists as false positives are analyzed to identify the source of the inconsistency. This analysis may result in adjustments to validation conditions, rule parameters, exception handling, or other deterministic heuristics. As illustrated in Figure 1, the results of human review feed back into the validator implementation stage, supporting the continuous revision and evolution of automated checks.

Validators that present low false-positive rates and consistent behavior throughout execution cycles become homologated within the Valide ecosystem. After this process, the validators are incorporated into Valide Editoras presets, becoming available as support tools for publishers during the construction and revision process of digital works.

The cycle also incorporates a continuous feedback mechanism, in which new PNLD cycles, adjustments made by publishers, and results obtained during system use contribute to the evolution of existing validators and the creation of new verifications.

## 4.2. General Architecture of the Valide Ecosystem

Figure 2 presents the general architecture of the Valide ecosystem and the validation processing workflow performed by Valide Editoras.

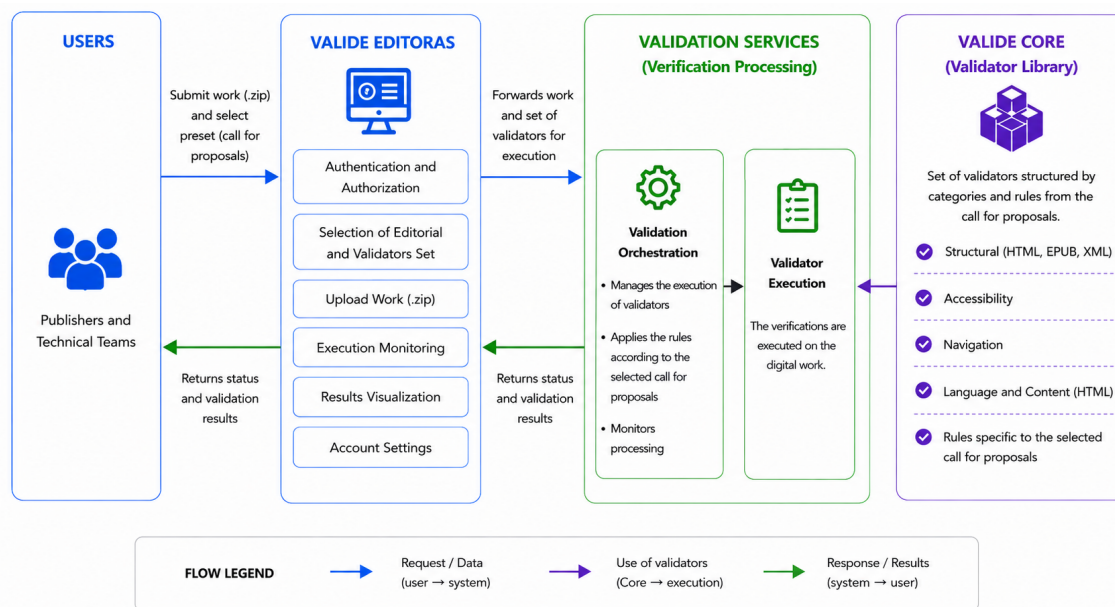
The workflow begins with the interaction between publishers, technical teams, and Valide Editoras, which provides the tool's user interface. The user uploads the digital work in compressed (.zip) format and selects the corresponding call for proposals according to the validation context of the work.

Valide Editoras acts as an intermediary layer between users and validation services, organizing the processing workflow, execution management, and structured visualization of results. The validation services are responsible for orchestrating and executing the automated verifications. During this stage, the digital work is processed and the validators are executed according to the set of rules defined by the selected call for proposals.

The central core of the ecosystem is Valide Core, a library containing independently implemented validators derived from PNLD technical and regulatory requirements, rather than wrappers for external tools. The validators are organized into different categories, including structural verifications, accessibility, navigation, and specific rules associated with calls for proposals. This modular organization enables incremental platform evolution and continuous adaptation to new technical requirements.

The architecture also enables decoupling between interface, processing, and validation library, favoring validator reuse across different workflows and execution contexts. Valide Editoras delegates the verification processing to Valide Core, which is responsible

for the effective execution of validators over the content of the digital work. The validation results are returned to Valide Editoras and made available to publishers through structured reports, allowing monitoring of identified failures, executed verifications, and approved items during processing. The system generates reports in XLSX format, facilitating technical analysis and integration into publishers' editorial workflows.



**Figure 2. General architecture of the Valide ecosystem and validation processing workflow.**

Another relevant aspect of the architecture is the processing model adopted by Valide Editoras. Digital works remain stored only locally on the publisher's machine during the validation process, without persistence of content on external servers. This approach seeks to reduce barriers related to privacy, editorial confidentiality, and security of digital works under development.

## 5. Use of Valide Editoras in the Digital Editorial Workflow

This section presents how Valide Editoras is used by publishers during the production and revision process of digital works. The operational workflow of the tool, the mechanisms supporting the identification of nonconformities, the types of validation provided, and initial evidence of tool usage within the digital editorial ecosystem are described.

### 5.1. Operational Validation Workflow

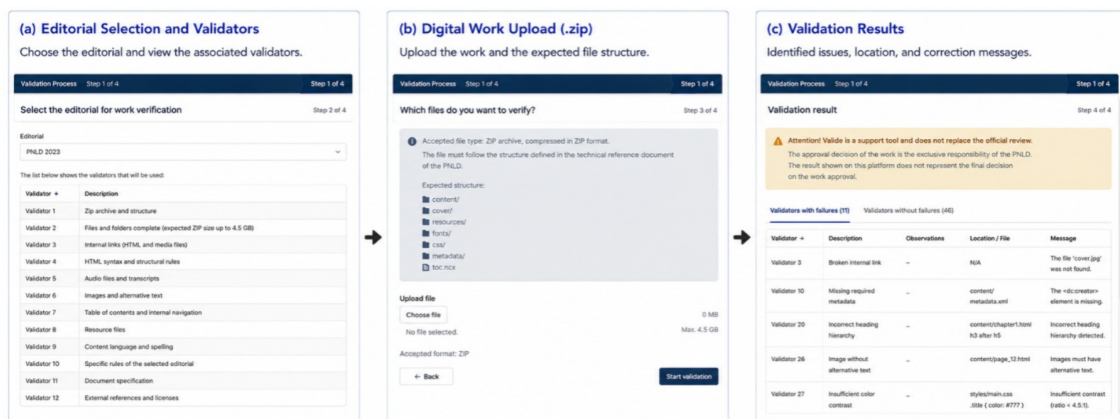
The use of Valide Editoras begins with the selection of the call for proposals associated with the digital work to be analyzed. As presented in Figure 3, the system provides the validators related to the selected call for proposals, enabling transparency regarding the technical criteria considered during the execution of the verifications.

After selecting the call for proposals, the publisher uploads the digital work in compressed (.zip) format, as illustrated in Figure 3(b). During this stage, the system also presents guidance related to the expected structure of the digital work, including the

organization of directories and mandatory files defined in the technical specifications of the corresponding call for proposals.

Once the work upload is completed, Valide Editoras automatically executes the validators associated with the selected preset. Processing occurs in a structured manner, allowing the application of the rules and verifications defined for the editorial context of the analyzed work.

The validation results are organized in a structured interface, as presented in Figure 3(c), enabling separate visualization between validators with failures and validators without failures. For each identified nonconformity, the system presents the description of the detected failure, the location of the occurrence in the digital work, additional observations, and explanatory messages containing guidance for correction.



**Figure 3. Validation workflow interface in Valide Editoras.**

In addition to the structured presentation of failures, the interface also reinforces the role of Valide Editoras as a support tool for the editorial workflow, highlighting that the presented results do not replace the official institutional evaluation processes of digital works.

The operational workflow of the system was designed to support iterative cycles of technical revision, allowing publishers to perform successive validations during the digital work construction process. This approach is intended to support the early identification of technical nonconformities and the adaptation of works to the criteria established in the calls for proposals.

## 5.2. Support for the Construction of Digital Works

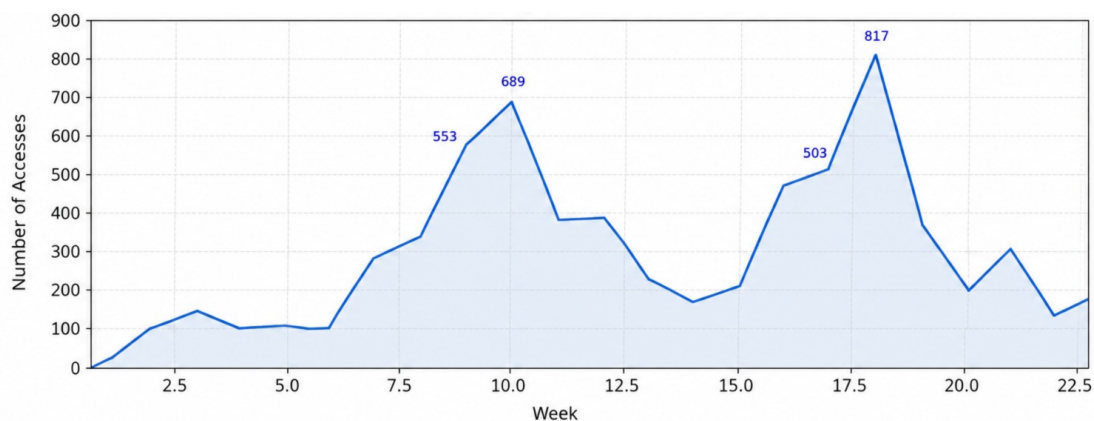
The consolidation of HTML5 digital books within the scope of the PNLD began to gain greater formalization starting with PNLD 2023, when the program's technical documents started defining HTML5 as the standard format for receiving digital works in the PNLD Digital ecosystem [FNDE 2021]. With the expansion of automated validations within the PNLD Digital ecosystem, the use of tools supporting technical compliance became part of the operational workflow for the production of digital educational books, serving as support tools for editorial and technical teams during different stages of the construction and revision process of digital works.

In addition to preventive use during work development, the tool can also assist during the *diligências* period (formal notices of nonconformity issued during the PNLD evaluation process). In this process, after the technical evaluation conducted by the teams responsible for institutional validation, publishers receive notices of nonconformities identified in the submitted works and are given a limited deadline to correct and resubmit the adjusted materials. In some program cycles, this period occurs within approximately five days, requiring rapid identification, analysis, and correction of the reported problems. In this context, Valide Editoras assists editorial teams in performing new technical verifications on corrected works, providing additional support during the process of adapting the nonconformities identified in the *diligências*.

One of the main mechanisms used by the tool is the use of validation presets associated with different calls for proposals and analysis contexts. Each preset automatically defines the validators, rules, and strategies applicable to the digital work, reducing manual configurations and favoring greater standardization of the technical verifications performed by publishers.

In addition to identifying failures, the system presents information related to the location of the occurrence within the digital work and explanatory messages containing guidance for correction. This approach seeks to support not only the detection of technical problems, but also the revision and adaptation process of digital works by editorial teams.

Since being made available to publishers in 2025, Valide Editoras has been used in different PNLD Digital cycles, supporting large-scale production and technical validation workflows. To date, the platform has registered 237 publishers, 462 registered users, and more than 6,500 accesses during periods associated with the submission and *diligências* stages of digital works.

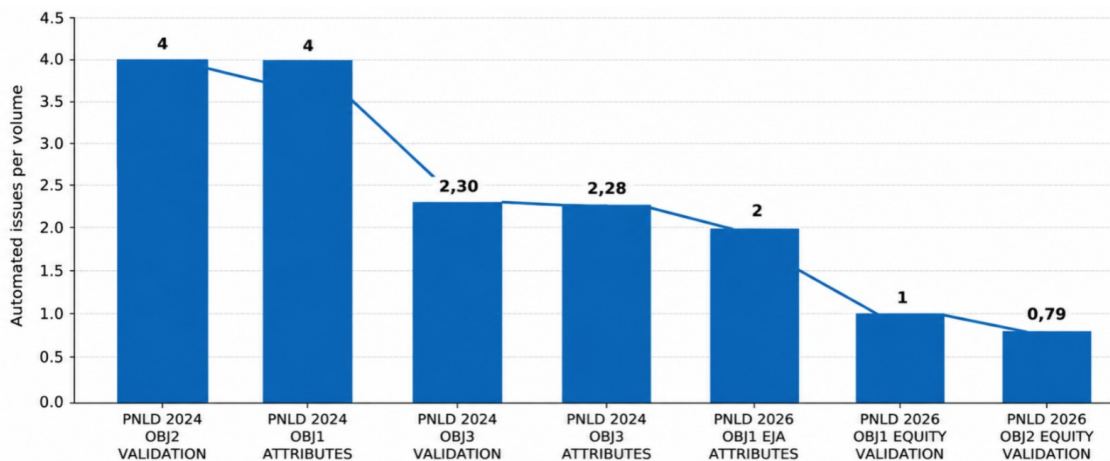


**Figure 4. Evolution of the number of weekly accesses to Valide Editoras.**

It was also possible to observe behavior associated with the operational calendar of the PNLD. As illustrated in Figure 4, system accesses increase during periods close to the submission and revision stages of digital works, showing a temporal pattern aligned with the PNLD operational calendar. These access counts reflect operational use but should not be interpreted as direct measures of usability, satisfaction, or effectiveness.

In addition to usage indicators, a trend toward reduction in the number of automated *diligências* per volume was observed across different program cycles, especially in

more recent PNLD 2026 objects. Figure 5 presents the evolution of automated *diligências* per volume across different PNLD objects after Valide Editoras was made available for publisher use, including validation and attribute analysis cycles.



**Figure 5. Evolution of automated *diligências* per volume across different PNLD Digital objects.**

The results indicate a reduction in the average number of automated nonconformities per volume in part of the analyzed objects, especially in the most recent equity and EJA cycles. However, the data do not establish a causal relationship between this trend and the use of Valide Editoras.

The prior availability of validators to publishers may have supported the early identification of structural inconsistencies during the development of digital works. Nevertheless, the observed trend may also reflect the maturation of editorial workflows, greater familiarity with PNLD Digital requirements, reuse of digital structures, differences among objects and cycles, changes in technical criteria, and varying levels of team experience. Therefore, the indicators should be interpreted as operational and observational rather than causal.

### 5.3. Validation Types and Scope of Verifications

Valide Editoras currently provides 59 validators independently implemented from technical and regulatory requirements defined in PNLD calls for proposals and specification documents. Validators may be reused across PNLD objects when the corresponding requirements remain applicable, while new validators are developed for object-specific criteria. Table 1 organizes the current validators by technical category and presents representative examples of the verifications performed.

The validators implemented in the Valide ecosystem are predominantly deterministic and are derived from formalized technical rules contained in PNLD specification documents. Each validator represents an independently implemented verification rule, enabling automated and auditable execution and supporting standardization, traceability, and reproducibility. The categories presented in Table 1 cover packaging and file organization, publication metadata, navigation and resource integrity, HTML5 semantics, accessibility, and digital-media conformity.

**Table 1. Categories and representative checks of validators available in Valide Editoras**

| Validation category                | Validators | Representative checks                                                                                                                                                   |
|------------------------------------|------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Package and file organization      | 23         | ZIP integrity and size; mandatory files and directories; file naming; location of <code>index.html</code> , <code>content.opf</code> , and <code>toc.ncx</code> .       |
| Publication metadata and manifest  | 6          | Structure of <code>content.opf</code> ; mandatory metadata; consistency among <code>manifest</code> , <code>spine</code> , media types, and packaged files.             |
| Navigation and resource references | 6          | External references; missing files; broken internal links; malformed navigation files; references to nonexistent resources.                                             |
| HTML5 structure and accessibility  | 19         | HTML5 DOCTYPE; language attributes; required elements in <code>head</code> , <code>body</code> , and <code>main</code> ; accessibility metadata and semantic structure. |
| Media and cover requirements       | 5          | Audio and video formats; video resolution; cover format, dimensions, and location.                                                                                      |

Another relevant aspect of the model adopted by Valide Editoras is the separation between automatable verifications and analyses that depend on human evaluation. The validations made available to publishers focus mainly on deterministic criteria for which objective rules can be established to identify potential nonconformities.

However, some requirements contained in PNLD calls for proposals involve contextual or interpretative dimensions that cannot be fully automated. In these cases, the Valide ecosystem adopts an augmented intelligence approach, combining automated findings with specialized human review without transferring final institutional decisions to automated mechanisms.

This separation prevents automated verification from being treated as a substitute for the specialized evaluations conducted by the technical teams responsible for analyzing digital works. Valide Editoras therefore focuses on auditable and technically objective checks, providing operational support for the digital editorial workflow.

#### 5.4. Data Collection and Analysis Procedures

The data analyzed in this study were obtained from the operational records of the Valide ecosystem during real usage cycles in the context of the PNLD. The information used includes validator execution logs, system access records, and metrics associated with automated *diligências* identified during the technical validation processes of digital works. The temporal scope considered comprises the period between February and August 2025, corresponding to the usage cycles of Valide Editoras by publishers during the submission, revision, and *diligências* stages of digital works.

The analysis covered different PNLD Digital objects and stages, including PNLD 2024 Object 2 (460 volumes), PNLD 2024 Object 3 (1,074 volumes), PNLD 2026 Object 1 (374 volumes), and PNLD 2026 Object 2 (465 volumes) during the submission validation stage, as well as PNLD 2024 Object 1 (725 volumes), PNLD 2024 Object 3 (530 volumes), and PNLD EJA (128 volumes) during the attribute analysis stage.

For comparative analysis among the different objects, the metric used was the average number of automated *diligências* per volume. This metric was calculated as the ratio between the total number of nonconformities automatically identified by the valida-

tors and the total number of volumes analyzed in each program object.

The system access indicators were produced from the authentication and usage logs of Valide Editoras, allowing identification of the number of accesses performed throughout the analyzed weeks. The graphs presented in this work were generated from the statistical consolidation of the operational records stored by the Valide ecosystem during the execution of automated validations.

## 6. Discussion

The results presented in this work highlight the potential of Valide Editoras as a support tool for the production workflow and technical revision of large-scale digital educational books. More than a technical verification mechanism, the tool becomes integrated into the editorial process of digital works, supporting stages of construction, adaptation, and revision associated with the criteria defined in PNLD calls for proposals.

In the context of digital educational ecosystems, the model adopted by Valide Editoras contributes to bridging the gap between the program's regulatory requirements and publishers' operational workflows. This integration favors the early identification of structural and technical inconsistencies during the development of digital works, allowing adjustments to be made before the official submission and *diligências* stages.

In addition to supporting the construction of works, the system also assists publishers during *diligências* periods, when rapid correction of nonconformities identified by the teams responsible for institutional evaluation is required. In this scenario, successive cycles of technical validation are intended to support the correction and adaptation of digital works within the limited period available to publishers.

Although informal feedback provided by publishers during operational meetings has indicated perceived support in identifying and correcting technical nonconformities, this feedback was not collected through a structured research protocol. Future work will combine controlled evaluations, including RCT designs, with acceptance questionnaires, usability instruments, workload measures, and qualitative interviews with publishers and technical teams.

Another relevant aspect of the architecture is the local processing model adopted by Valide Editoras. The files comprising the digital work remain on the publisher's machine during validation and are not transferred to or persistently stored on external servers. This decision reduces the exposure of unpublished works protected by copyright and other commercially sensitive editorial assets, preserving publishers' control over content under development. The approach is also aligned with principles of data minimization, security, and prevention associated with the Brazilian General Data Protection Law (Lei Geral de Proteção de Dados Pessoais — LGPD), while primarily addressing editorial confidentiality, intellectual property protection, and information-security requirements. The review and homologation process supports the refinement of validators before they are made available in Valide Editoras. Since these validators are implemented from formal rules derived from PNLD calls for proposals and technical specifications, the process also strengthens traceability, auditability, and standardization of the verifications performed on digital works.

The number of registered users and the temporal distribution of accesses provide

evidence that the infrastructure has been used operationally across multiple PNLD cycles and publishers. However, these indicators characterize use at scale and should not be interpreted as direct evidence of usability, satisfaction, or effectiveness.

The results also highlight the limits of automation in the technical validation of digital educational resources. Although many structural requirements can be represented through deterministic rules, other criteria depend on contextual interpretation and supervised analysis, particularly in accessibility-related cases and in the confirmation of certain nonconformities. Validators associated with these context-dependent criteria are not made available in Valide Editoras for autonomous use by publishers. Instead, they remain within the institutional evaluation workflow, where automated findings are combined with specialized human review and analysts retain responsibility for interpreting the evidence, confirming the results, and refining the validators.

Finally, although the architecture may offer design principles relevant to other document-validation contexts, the evidence presented in this study is restricted to the PNLD. The applicability of the model to other regulatory, publishing, or educational environments therefore remains to be investigated.

## 7. Conclusion

This work presented Valide Editoras, a support tool for the production and technical validation of digital educational books in the context of the PNLD. The article discussed the role of the tool in supporting the digital editorial workflow, describing its architecture, validator evolution cycle, automated validation mechanisms, and use by publishers during the construction, revision, and *diligências* processes of digital works.

By supporting publishers during the preparation and technical revision of digital educational books, the proposed approach may also contribute indirectly to the educational process itself. The early identification of technical and accessibility-related nonconformities may support the production of more accessible and technically consistent digital works, improving compatibility with assistive technologies and digital reading environments.

The observed operational results indicate the tool's potential to support large-scale technical validation processes by providing standardized verifications and operational support for editorial teams during the adaptation of works to the criteria defined in calls for proposals. In addition, the work contributes to the discussion on technological infrastructure supporting digital educational ecosystems in public policies, especially in scenarios that require traceability, auditability, and document analysis based on technical and regulatory requirements.

As future work, the set of validators will be expanded, and controlled studies with publishers, including Randomized Controlled Trial (RCT) designs, will evaluate nonconformities, task completion time, workload, usability, and acceptance. RCTs in the PNLD context involve challenges related to heterogeneity among publishers, differences in team experience, variation in work complexity, regulatory changes across objects and cycles, and constraints on random assignment within an ongoing public program. Future studies should therefore use stratification or matching, comparable tasks, and complementary operational and user-perception measures.

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