XML as a Basis for Interoperability in Technical Education Documents.

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Abstract. Technical Education in Brazil faces challenges in standardizing digital certificate issuance and exchange across diverse platforms, affecting compliance, efficiency, and workforce integration. Unlike higher education, technical education has unique structural and regulatory demands that require a tailored interoperability solution. This study proposes an XML Schema Definition (XSD) designed specifically for technical education, extending beyond existing mod- els used in higher education. Leveraging XML's flexibility, the schema creates machine-readable digital certificates that improve security, transparency, and fraud prevention by providing a struc- tured framework. The research aims to facilitate regulatory compliance and streamline data ex- change between technical institutions and the Ministry of Education. A systematic literature re- view and comparative analysis highlight gaps in current digital document practices and support the schema's development. The findings demonstrate XML's potential as a transformative stan- dard for managing educational records in technical education, optimizing accessibility and en- abling seamless platform integration. Unlike prior efforts focused on higher education, this model addresses the specific operational and regulatory complexities of technical education. Implement- ing this schema tackles critical interoperability challenges and lays the foundation for advancing digital certification. By fostering innovation and collaboration, this work supports a unified, se- cure, and accessible digital certification system, promoting modernization and trust in Brazil's educational environment.

Keywords. Interoperability, Interoperability Standards, XML, Technical Education.
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1. Background

Technical education improves employability, with rising employment rates highlighting the need for modernized document management. However, fragmented systems in Brazil hinder data exchange and increase fraud risks (Costa et al., 2020; de Barros & Ferraz, 2023; dos Anjos, 2019; Lepiane et al., 2019). Digitally signed documents reduce costs and enhance security (Martina et al., 2019; Pereira, 2015), while interoperability enables standardized, regulation-compliant exchanges (Costa et al., 2020; Diallo et al., 2011). This study proposes an XSD-based framework for technical diplomas, supporting integration with the Ministry of Education and offering scalability to other education levels.

2. Research Methods

- Objective:
  - Develop an XML-based interoperability model tailored for technical education.
- Methodology:

- Qualitative research and comparative analysis of XML models.
- Literature review of XML for digital certification in higher education.
- Analysis of interoperability models to ensure data integrity, authenticity, and compliance.

• Proposed Solution:
- A customized XML schema for seamless data exchange between technical education institutions and the Ministry of Education.
- Incorporation of essential metadata, standardized structures, and security mechanisms.
- XSD aligned with regulatory guidelines, including fields to support diverse technical curricula.

3. Proposal for a Standardized Interoperability Model

Brazil faces challenges in student retention and completion, particularly in technical education, due to the lack of standardized diploma recognition (OECD, 2024). The absence of uniformity in technical diplomas complicates the validation of skills and competencies, hindering student mobility and reducing employment and educational opportunities, contributing to higher dropout rates.

Figure 1 shows the drop in out-of-school rates from 16% (2013) to 8% (2022), underscoring how digital diplomas support transparency, efficiency, and secure, standardized verification (Martina et al., 2019; OECD, 2024). In Brazil, technical diplomas are still paper-based (Pereira, 2015), unlike in higher education. This work reviews legislation (Brasil, 2019; Ministério da Educação, 2019) and suggests adapting higher education XML/XSD interoperability models to technical education (Murray, 2002), where XML remains underused.

Figure 1. Trends in out-of-school rates for children at upper secondary level (2013, 2019 and 2022)

Indicator SDG 4.1.4 (in per cent)

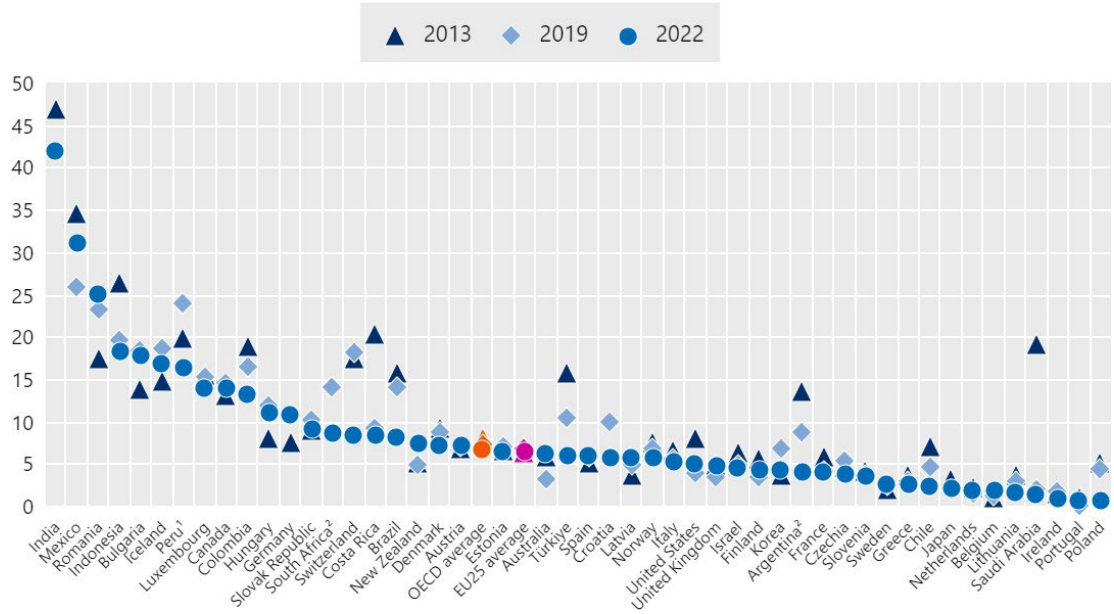

Fig. 1 – OCDE Trends in out-of-school rates for children at the upper secondary level (2013, 2019, and 2022)

Figure 2 demonstrates how XML enables secure, validated, and standardized academic record exchange between institutions. By replacing manual input with structured file exchanges, the interoperability standard ensures consistent communication. XML's flexible, hierarchical structure—combined with XSD—guarantees data consistency and enhances interoperability in technical education (Hedgebeth, 2008).

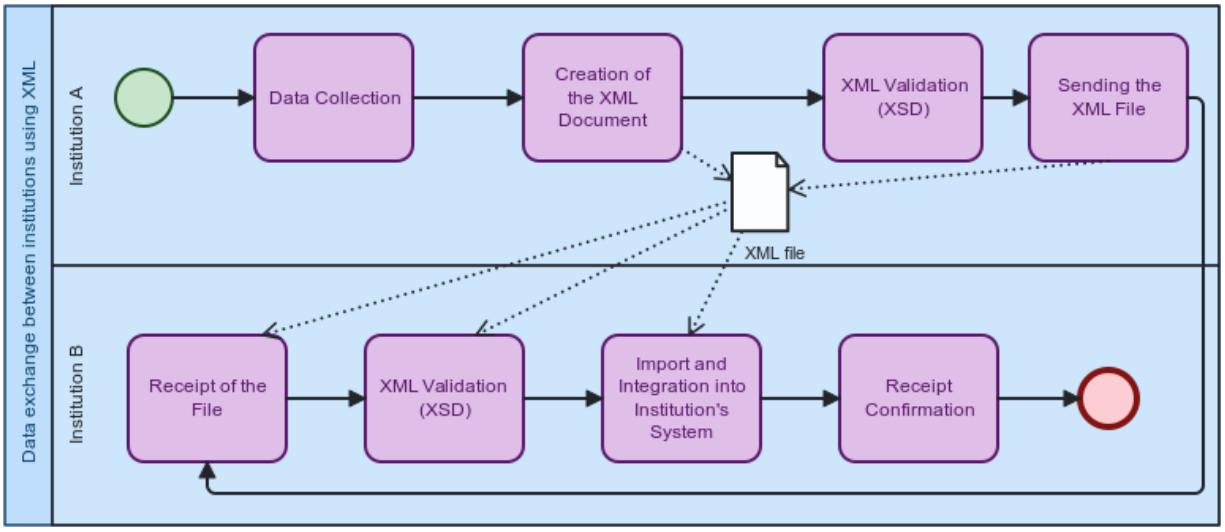

Fig. 2 – BPMN of data exchange between institutions using XML

4. Results

4.1. Academic Registration and Diploma Issuance Process

Figure 3 illustrates the graduation process at Technical Education Institutions (IEPT), where XML-based diplomas are generated, validated via SISTEC, digitally signed, and delivered to students. This automated workflow ensures secure, standardized, and interoperable credential exchange across educational systems.

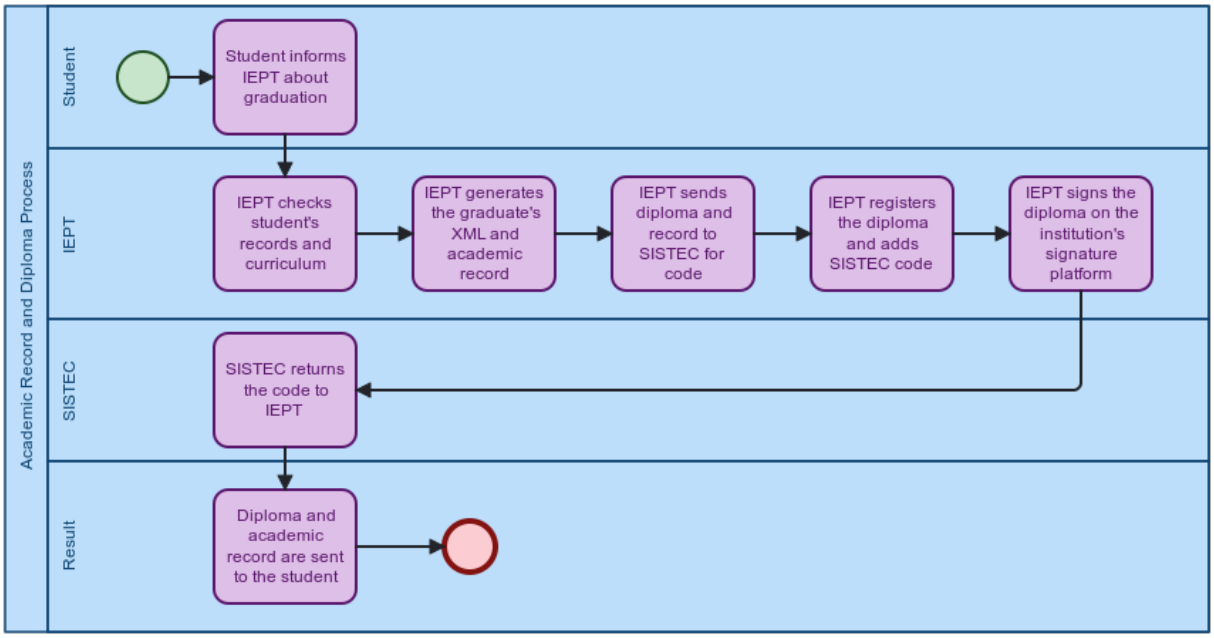

Fig. 3 – Academic Record and Diploma Process BPMN diagram

4.2. Classification of Digital Diploma Elements

We recommend directly adopting the same standard used in higher education to obtain the same advantages but with adjustments and specificities necessary for implementation in this teaching modality. Based on the higher education model, tags were classified according to their XSD structure:

- **General Diploma Information**
  - **Diploma tag:** Contains the diploma structure and signature.
  - **Diploma Information tag:** Includes diploma data, registration, and court decision information.
  - **Diploma Data tag:** Defines data about the graduate, completion date, course, issuing institution, and signatories.
  - **NSF tag:** Similar to Diploma Data but for institutions outside the federal system.
- **Registration**
  - **Registration Data tag:** Defines diploma registration data, such as educational system, record book, academic documentation, security, and additional info.
  - **NSF tag:** Similar to Registration Data but for institutions outside the federal system.
  - **Court Decision tag:** Defines registration information for diplomas affected by court decisions.
- **Graduate**
  - **Graduate Data tag:** Includes personal data such as nationality, birthplace, and personal IDs (e.g., CPF, ID).
  - **Data Diploma by Court Decision tag:** Similar to Graduate Data, but not all information will be inserted for court-affected diplomas.
- **Course**
  - **Course Data tag:** Defines course details, such as name, code, address, and authorization.
  - **NSF tag:** Similar to Course Data but for institutions outside the federal system.
  - **Course Data By Court Decision tag:** Defines course information for diplomas affected by court decisions.
- **Record Book**
  - **Record Book tag:** Defines documentation and control information for diplomas, including unique code, registration number, and diploma page.
  - **NSF tag:** Similar to Record Book but for institutions outside the federal system.
- **Judicial Process**
  - **Legal Process Information tag:** Contains details of legal processes related to the diploma, such as case number, judge, and decision.
  - **Statements About Process tag:** Defines statements about the diploma process.
- **Regulatory Act**
  - **Regulatory Act tag:** Defines information about regulatory acts to ensure educational service quality, such as type, number, date, and publication source.
  - **With or without systems tag:** Similar to the Regulatory Act, but with or without an information system.
- **Processing in systems**
  - Tag that contains information about degree processing in information systems.

The XSD schema is used to validate XML documents for digital diplomas by defining their required structure, including diploma details, course information, digital signatures, and academic records. The structure centers the diploma as the main element, with related data as subordinate elements. This flexible model supports special cases like judicial decisions or non-federal courses. At the end of the schema, a digital security layer ensures authentication and data integrity.

4.3. Data Control in Technical Education

SISTEC is the centralized system for managing technical education records in Brazil. Unlike higher education, where registration is decentralized, SISTEC unifies data, allowing seamless interoperability between institutions and the Ministry of Education. The system uses a unique locator code for diploma validation, replacing traditional registration books.

4.4. Digital Diploma Components

The digital diploma follows a structured XML schema, defining key elements such as diploma data, registration records, and legal decisions. Attributes like version, unique ID, and environment settings ensure standardization and interoperability across institutions.

4.5. Regulatory Framework Adaptations

Unlike higher education, which operates under a National Higher Education Assessment System and formal regulatory acts, technical education follows decentralized validation by State Education Councils. The XML model adjusts by excluding the higher education regulatory tag and focusing on course accreditation and authorization.

4.6. Tag Nomenclature Adjustments

Higher education terms like ”IesEmissora” were adapted to ”IeptEmissora” to reflect technical education institutions. Additionally, distinctions were made between federal and non-federal institutions, introducing ”NSFT” (Non-Federal Technical System) tags.

4.7. Structural Modifications for Technical Education

The XML schema was adjusted to incorporate state and federal guidelines, accommodate course diversity, and enhance interoperability. Advanced security features, such as XML Advanced Electronic Signatures (XAdES), were integrated to ensure document integrity and authentication.

4.8. Enhancing Security with Digital Signatures

Digital signatures, regulated by ICP-Brasil, provide authenticity and integrity to digital diplomas. Already used in higher education, this security measure is proposed for technical education to ensure reliable, tamper-proof certification.

4.9. Validation and Feasibility Analysis in the Literature

Fig. 4 – Signed digital technical diploma, using the XML format for interoperability.

We validated the technical digital diploma’s XSD using the ITI official validator (de Tecnologia da Informação (ITI), 2023), which ensures authenticity and compliance with digital signature standards in Brazil. Our validation process provided additional detailed information beyond the standard ITI output. The digitally signed diploma file diplomaTecnico_assinado.xml was successfully verified, as shown in Figure 4, containing three compliant signatures aligned with W3C XML Schema and ICP-Brasil standards. All cryptographic checks passed, and the certificates, issued by the Brazilian Federal Revenue and valid until 2025, showed no revocation issues, confirming the diploma’s security and compliance.

4.10. Feasibility Analysis

This feasibility analysis assesses technical and operational challenges of adopting the XML standard in technical education. It examines system compatibility, security, stakeholder acceptance, and adaptability. Using a sociotechnical framework (Inocêncio et al., 2024), the study compares literature findings with key criteria relevant to Technical Education:

- **Compatibility:** XML is compatible with systems used by Technical Education institutions, supporting integration and interoperability (Inocêncio et al., 2024).
- **Acceptance:** XML is already accepted and implemented in Higher Education, which facilitates its adoption in Technical Education (Inocêncio et al., 2024).
- **Ease of Implementation:** XML is simple to implement and does not require major changes to existing processes and systems (Inocêncio et al., 2024).
- **Efficiency:** XML supports effective data exchange between students, institutions, and the Ministry of Education, improving operational performance (Inocêncio et al., 2024).
- **Security:** XML ensures the confidentiality and integrity of student data, complying with privacy and information security standards (Inocêncio et al., 2024).
- **Flexibility:** XML can adapt to various institutional contexts and needs within Technical Education. The use of NSFT tags, for example, allows for multiple scenarios without requiring structural changes (Inocêncio et al., 2024).
- **Regulatory Compliance:** XML complies with existing Brazilian standards and regulations. It is already used in Higher Education under various ordinances and decrees issued by the Ministry of Education (Inocêncio et al., 2024).

Based on the presented criteria, the feasibility of implementing the interoperability standard in Technical Education is assessed positively. Additionally, the authors specify that Technical Education must be addressed to establish a viable interoperability standard, including the diversity of institutions providing these programs (Inocêncio et al., 2024).

5. Conclusions

This study explores how XML enhances interoperability in technical education diplomas in Brazil, building on its proven use in higher education. An XSD-based structure enables secure document exchange with the Ministry of Education, addressing risks like fragmentation and fraud. The proposed model offers a scalable foundation for global digital credentialing.

In addition to interoperability, XML supports transparency, policy development, and efficient education management. This work contributes to standardization efforts and proposes an XML-based framework for technical diplomas. Future research should assess its scalability across education levels. Aligned with dg.o's focus, this study addresses digital governance, secure data exchange, and open standards. It offers a model that improves trust, transparency, and efficiency in credential verification—relevant for attendees working in education policy, digital identity, and public administration.

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