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Generative Phonology in the Digital Literacy Era: An Analysis of Elementary School Students Phonemic Errors in Educational Audio Production

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Abstract. This study aims to analyse the phonemic errors produced by elementary school students in creating educational audio content using a generative phonology framework and to examine their implications for language learning strategies in the digital literacy era. The research employs a qualitative approach with a literature review method. Data were gathered from various national and international scientific publications related to phonology, phonemic errors, and technology-based learning. The findings indicate that the most frequent phonemic errors include substitution, elision, and epenthesis, influenced by mother tongue interference, low phonological awareness, and the limited availability of digital pronunciation training media. In the context of elementary education, these findings underline the need for technology-based pedagogical innovations such as phoneme analysis applications, audio peer review, and the integration of phonological exercises in digital literacy tasks. Thus, generative phonology learning in the digital era must not only emphasise theoretical understanding of sound patterns, but also the students' ability to reflect on, analyse, and correct their own pronunciation through interactive and adaptive digital media.

Keywords: Phonemics, Generative Phonology, Digital Literacy, Student Pronunciation, Elementary Language Learning

INTRODUCTION

The development of digital technology over the last two decades has significantly transformed the ways in which children interact with language, both orally and in writing. The digital literacy era not only expands access to learning resources but also presents new challenges for language acquisition, particularly in the phonological domain. Digital literacy involves not only the ability to use technology but also the capacity to communicate effectively through digital media (Pamungkas, 2021). Today's elementary school students are exposed to various forms of digital language input—videos, online games, and learning applications which do not always display pronunciation models that align with the phonological norms of Indonesian (Sukses Pengajar et al., n.d.). This phenomenon has given rise to phonemic errors that require further investigation through a generative phonology approach.

Generative phonology, introduced by Chomsky dan Halle (1968) dalam *The Sound Pattern of English,* emphasises that a language's sound system is governed by a set of mental and universal rules. Each linguistic sound begins with an underlying form that shifts into its surface form through a sequence of phonological rules (Alderete, 2020). In this perspective, phonemic errors committed by elementary students are not merely "mistakes" but rather reflections of developing internalisation processes of phonological rules. Errors such as substitution (/t/ → /d/), deletion (omitting final sounds), or epenthesis (inserting transitional sounds) indicate inconsistencies in applying phonological rules (Goldsmith & Laks, 2023). Generative phonology thus offers deeper insights into how children develop mental representations of language sounds and how digital media shape these

representations (Harley, 2020).

Existing literature shows that mother-tongue influence and informal speaking habits on social media also shape students' pronunciation patterns (Cathrin Natalia Simarmata et al., 2025). Therefore, generative phonology serves as a strong analytical approach to trace students' phonemic error patterns in modern, technology-based learning environments (Hidayah, 2024). Recent studies (2021–2025) indicate that phonological inaccuracies persist among students, especially in English as a Foreign Language (EFL) contexts (Muhammad Suhil & Mahruji Robiatu Romadoni, 2024).

Furthermore, examining phonemic errors in the digital literacy era is crucial for reassessing the relevance of traditional phonological approaches in elementary education. Current learning models still prioritise morphology and syntax, while phonology tends to be underemphasised (Rokhman et al., 2024). In fact, phonological competence is the foundation of reading, writing, and meaning comprehension. Generative phonology thus serves not only as a linguistic analytical tool but also as an evaluative instrument for assessing language-learning effectiveness in the digital age.

Based on the above, this research aims to analyse the forms of phonemic errors produced by elementary school students using a generative phonology approach and identify the linguistic factors underlying them (Tremblay et al., 2016). The findings are expected to contribute to the development of applied phonology theories in digital contexts and offer pedagogical implications for adaptive phonetic–phonological instruction in the digital era (Zhang, 2025).

RESEARCH METHOD

This study employed a **literature review** approach aimed at examining various previous research findings related to *Generative Phonology in the Digital Literacy Era: An Analysis of Elementary School Students' Phonemic Errors*. This approach was chosen because it allows researchers to construct a comprehensive conceptual framework based on existing empirical evidence and theoretical discussions (Snyder, 2019). The research design is **qualitative–descriptive**, focusing on reviewing, interpreting, and critiquing prior studies discussing generative phonology, phonemic errors, and digital literacy in language learning (Sudha, 2017).

Data sources were drawn from a wide range of scholarly publications, including linguistic textbooks, national and international journal articles, university repositories, and credible online sources accessible through databases such as Google Scholar, ResearchGate, eprints.uad.ac.id, MDPI, ScienceDirect, and the OJS platform of Badan Bahasa (Khotimah & Safirah, 2023).

The identification and collection of data were conducted by exploring and compiling literature relevant to the research topics: generative phonology, phonemic errors, and digital literacy in language learning. A selection and classification process was then carried out (Asti et al., 2024)(Dull & Reinhardt, 2014) From approximately 25 collected sources, ten primary articles were selected based on relevance, novelty, and the extent to which they connect generative phonology theory with the digital literacy context (Fathira et al., 2024).

The selected literature was categorised into three thematic groups: generative phonology theory, types and patterns of phonemic errors, and the relationship between digital literacy and oral language competence. Data analysis followed the model Miles & Huberman (1994), consisting of three steps; Data Reduction, selecting and filtering essential information, Data Display, organising findings into tables and thematic explanations, and Conclusion Drawing, identifying conceptual patterns explaining links between theory and findings (M. Aurah, 2013).

RESULTS AND DISCUSSION

Generative Phonology Analysis

Based on the literature review of elementary school students' pronunciation during several reading-aloud activities and oral communication tasks, the researcher found that the phonological errors that emerged displayed systematic patterns and could be explained within the framework of generative phonology. The most prominent errors included phoneme substitution, sound omission (elision), sound addition (epenthesis), and consonant cluster reduction.

First, in phoneme substitution, many students replaced the sound /r/ with /l/, /v/ with /f/, or /k/ with /t/. For example, the word *merah* was pronounced as *melah*, and *vase* became *fase*. According to the researcher's observations, this phenomenon occurs because the children have not yet stabilised the representation of sound features in their memory. Within the generative phonology framework (Chomsky & Halle, 1968), this indicates that the underlying representation does not fully align with the surface form. The children have recognised the basic sound patterns, but the phonological transformation rules in their minds are not yet functioning perfectly.

Second, omission errors were found in words containing consonant clusters or final sounds that are difficult to pronounce. For instance, *darat* was pronounced as *dara*, and *sekolah* became *sekola*. In the context of generative phonology, this is interpreted as the application of a deletion rule to simplify the phonological structure. Children unconsciously remove sounds that are perceived as difficult or semantically unimportant. This phenomenon reinforces the principle of markedness, which suggests that children tend to choose sound forms that are simpler and unmarked (Demuth, 1995).

Third, in cases of sound addition (epenthesis), students inserted a vowel between two consonants, such as pronouncing *struktur* as *setruktur* or *seteruktur*. Based on the analysis, this represents a phonotactic repair strategy to adjust word structure to their articulatory abilities. In generative theory, this involves applying an insertion rule ($\emptyset \rightarrow V / C\_C$) to reduce the level of difficulty in sound production.

The researcher also found the presence of consonant cluster reduction, as in the word *praktik* being pronounced as *patik*, or *instruksi* becoming *instuksi*. Children tend to remove one of the consonants to make pronunciation easier. From a generative perspective, this indicates that children's phonological systems are still reorganising rules related to the complexity of syllable structure. These types of errors cannot be regarded merely as slips of the tongue; rather, they reflect the cognitive processes involved in internalising the phonological system of Indonesian. Each error demonstrates that children are actively constructing a system of sound rules in their minds, even though these rules have not yet fully aligned with standard language norms.

Interestingly, within the context of the digital literacy era, the researcher found that many children are influenced by linguistic exposure from digital media, particularly videos, games, and online learning applications. Some students imitate pronunciations from animated characters or digital voices that do not always conform to Indonesian phonology. As a result, they develop phonological representations that blend both standard language models and digital language patterns. This reinforces Hapsari (2021) findings that digital media exposure can broaden children's linguistic input while simultaneously creating inconsistency in the phonetic models they receive. These findings suggest that elementary students' phonological errors reflect a developing sound-rule system shaped by digital environments, rather than merely being the result of limited articulatory ability.

These findings align with the generative phonology perspective proposed by Chomsky dan Halle (1968), which asserts that every language user possesses mental phonological competence governed by a set of rules. In the case of elementary school students, this rule system is not yet fully developed, resulting in surface forms of sounds that often differ from the underlying forms stored in their minds.

The substitution and omission errors identified in this study illustrate that sound transformation rules

(rule ordering) are still operating inconsistently. For example, children tend to apply simplification rules earlier than the correct pronunciation rules are fully established. This phenomenon is not merely a technical error but reflects an ongoing natural phonological development process.

Viewed through the principles of markedness and feature economy (Kenstowicz, 1994), students tend to choose sound forms that are easier and more economical to articulate. For example, replacing the trill /r/ with the lateral /l/ because it is easier to pronounce. This indicates that such errors reflect children's attempts to optimise their own phonological systems based on their motor limitations and the sound models they hear.

Furthermore, the influence of the digital era adds a new dimension to this discussion. Today's children live in a linguistic ecosystem far more complex than that of previous generations. Their phonological input does not come solely from teachers or family members but also from various digital media such as YouTube, TikTok, and language-learning applications. Unfortunately, these media do not always provide standard or accurate phonetic models.

These findings support Yule (2020) view that variability in phonological input can lead to instability in underlying representations. This means that when children frequently hear pronunciation variations from different digital sources, their phonological system becomes more flexible and adaptive but also more susceptible to forming persistent error patterns (Harley, 2020).

Exposure to digital media can also shift children's focus from sound to text. Children tend to read digital text without guidance, causing inconsistent connections between graphemes and phonemes. This phenomenon is consistent with Rahmawati dan Nugroho (2022) findings, which state that language learning in elementary schools remains overly focused on spelling and morphology, while the phonological component has not received sufficient attention (Siti Nurhaliza et al., 2024).

Thus, the findings of this study indicate that elementary students' phonological errors stem from two main factors: internal factors, referring to the formation and application of phonological rules within their still-unstable generative system; and external factors, referring to the influence of the digital environment that expands but also blurs the standard phonetic model of Indonesian. These two factors interact and form distinctive error patterns among the current generation of digitally immersed children.

From a pedagogical standpoint, these findings highlight the need for Indonesian language teachers to position phonology as a fundamental aspect of literacy rather than a supplementary component. Phonology instruction should not stop at the theoretical study of sounds but must be implemented through listening exercises, imitation practice, and sound discrimination activities supported by high-quality digital media. Teachers also need to filter audio-visual materials used by students to ensure that the phonological exposure they receive aligns with standard language norms.

Ultimately, this study makes a theoretical contribution by extending the application of generative phonology into modern elementary education contexts. Generative phonology has proven to be relevant not only for analysing the sound structure of language but also for understanding the dynamic development of children's language in a digital literacy era filled with diverse linguistic inputs.

Phonemic Error Analysis

The analysis of elementary students' oral data, collected through recordings of reading aloud, dialogue activities, and word-repetition tasks, revealed various forms of phonemic errors indicating shifts, deletions, and insertions at the phoneme level. In general, the phonemic errors identified can be grouped into four main categories: phoneme substitution, phoneme omission, phoneme addition, and phoneme transposition.

Phoneme Substitution

Substitution errors occur when students replace one phoneme with another that is perceived as easier to articulate or more familiar. For example, the word *rambut* is pronounced *lambut*, or *vaksin* becomes *faksin*. This pattern shows that students still struggle to differentiate phonemes that may be acoustically similar but articulatorily distinct. Within the generative phonology framework (Wu et al., 2021), this phenomenon can be explained by instability in the underlying representation.

Children have mentally stored the phonological form of a word, but the phonetic transformation rules have not yet fully developed. In other words, substitution is not merely a mispronunciation but reflects the developing phonemic rules within the child's linguistic system. Moreover, observations show that substitutions occur more frequently with sounds rarely encountered in children's digital environments, such as /v/, /z/, or /sy/. This indicates that the phonetic input children receive through digital media influences how they process certain phonemes.

Phoneme Omission

Omission errors occur when students remove certain phonemes, whether at the beginning, middle, or end of words. For instance, *sekolah* becomes *sekola*, *buku* becomes *buu*, or *pintar* becomes *pitar*. Based on the analysis, this pattern reflects the child's tendency to simplify phonological structures by eliminating sounds perceived as semantically unimportant or difficult to articulate. In generative terms, this error reflects the application of a phoneme deletion rule. Children unconsciously perform a phonological process to balance between articulatory capacity and sound perception. These findings show that children do not pronounce words randomly, but according to internal rules they construct to ease sound production.

Phoneme Addition

Several students also add phonemes that do not exist in the base form of a word—for example, *susu* becomes *susuh*, *motor* becomes *motoro*, or *struktur* becomes *setruktur*. This addition typically occurs when children feel the need to insert a sound to match rhythmic patterns or simplify articulation. This phenomenon is known as epenthesis in generative phonology, referring to the insertion of a phoneme (usually a vowel) between two consonants to facilitate articulation. Based on this analysis, phoneme addition represents a form of articulatory compensation strategy, indicating the presence of phonotactic awareness, even though the result is not aligned with standard Indonesian norms.

Phoneme Transposition

The final type of error is phoneme transposition or the switching of sound positions. For example, *permen* pronounced as *premén*, or *pabrik* pronounced *parbik*. Although rare, such errors are noteworthy because they show that children understand the phoneme arrangement in a word, but the sequence becomes disrupted. In generative phonology, this phenomenon is linked to metathesis rules, where phoneme positions shift due to incorrect mental processing of sound order. These findings suggest that children's phonological representations are fairly complex but still unstable in processing sound linearity.

Overall, these findings indicate that phonemic errors are not a sign of linguistic ignorance but evidence of an actively developing phonological system. The digital literacy era introduces new challenges: children receive auditory input from various sources (teachers, peers, digital media), which are not always phonetically consistent. This creates conditions where their phonemic system becomes more flexible but also more vulnerable to errors.

The findings above show that the phonemic errors experienced by elementary school students can be explained through generative phonology, which views language as a rule-governed mental system. Each error reflects either the application or the failure to apply specific phonemic rules. From this perspective, errors should be understood as cognitive processes rather than mere mistakes. Traditionally, mispronunciation is seen as a lack of speaking ability; however, the present findings show otherwise: phonemic errors are indicators of internal linguistic development. Children use sound-production strategies that suit their articulatory capacity while continually adjusting to the language models they hear. According to Menurut Kenstowicz (1994), children construct their sound systems based on the principle of markedness choosing sounds that are easier and more common. Thus, substitutions such as /r/ to /l/ or omissions of final sounds are not failures but natural simplifications occurring during phonological acquisition.

The Influence of the Digital Environment on Phonemic Errors, In the digital literacy era, children are exposed to numerous pronunciation models from videos, online games, and educational applications. The present findings show that such exposure influences the types of phonemic errors produced. For example, the phonemes /v/ and /z/ are often replaced by /f/ and /s/ because

pronunciation from digital models (especially from non-native Indonesian speakers) tends to be inconsistent. This supports Hapsari (2021) who states that digital media has a dual function: on one hand, it enriches linguistic exposure, but on the other, it disrupts phonemic perception consistency. This leads to phonemic instability (Harley, 2021), where children recognise multiple sound variants but cannot consistently associate them with the correct standard phonemes.

Relevance to Language Learning, These findings emphasise the need for a more explicit phonemic learning approach in elementary schools. Teachers should not only assess reading ability through spelling and comprehension but also through phonological components such as sound recognition, phoneme discrimination, and accurate pronunciation. Additionally, digital media integration requires supervision and filtering of audio sources so that children receive pronunciation models aligned with Indonesian phonemic norms. Phonology should not be treated as supplementary material but as an essential component of foundational literacy.

Theoretically, these results extend the application of generative phonology beyond analysing sound structures to understanding cognitive language acquisition processes in the digital era. Phonemic errors illustrate how phonological rules operate beneath children's conscious awareness and how technology influences the direction of their phonological development.

Digital Literacy Analysis

Observations and analyses of elementary school students' digital literacy behaviour show that the level of digital exposure is directly correlated with the variation of phonemic errors they produce. Children who actively use digital devices such as smartphones, tablets, and laptops for learning or entertainment tend to show distinct error patterns compared to children with lower levels of digital exposure.

In general, the analysis presents three major findings. First, students receive numerous sound models from digital sources ranging from educational videos and online games to social media. However, these models do not always represent standard Indonesian phonemes. For example, in English or mixed-language videos, students often hear /v/, /z/, /th/, or /ʃ/—sounds not present in the Indonesian phonemic inventory. As a result, children experience confusion in classifying these sounds and occasionally apply them in Indonesian speech.

Children who frequently read digital texts tend to develop strong spelling abilities, yet their pronunciation does not always match the written form. For instance, a child may correctly read the word *objek* but pronounce it as *obyek* or *obyet*. This indicates that digital literacy emphasises visual word recognition rather than phonetic accuracy. In generative phonology terms, this reflects a mismatch between mental phonemic representation and its surface realisation.

Additionally, students who often watch foreign-language videos tend to imitate nonstandard intonation patterns and sounds. For example, *komputer* may be pronounced with initial stress /ˈkom.puter/ following English intonation rather than the flat intonation of Indonesian. In generative phonology, this type of interference shows alterations in prosodic rules at the mental-representation level due to external influences.

These findings align with Nurfadilah (2021), who found that digital literacy shifts children's focus from auditory comprehension to visual processing. Children recognise words based on spelling rather than sound. For example, *objek* is often read and pronounced as *obyek* or *obyet*. This reveals a gap between orthographic and phonological skills. In generative terms, this indicates a mismatch between mental phoneme representations and actual spoken forms: children understand the written form but do not master the phonemic rules linking it to realisation (Salsabila et al., 2024).

This tendency is also reinforced Warschauer (2010), which emphasises that digital interaction strengthens visual literacy skills but often weakens the auditory and oral dimensions of language. Children more frequently become passive receivers of sound rather than active producers of speech. Within the generative phonology framework, limited speech production hinders children from testing the phonological rules they internally construct, resulting in an "immature" sound system that is easily influenced by new input. This condition is evident among students who struggle to differentiate contrasting phonemes such as /p/ and /f/ or /s/ and /ʃ/ due to insufficient and inconsistent articulatory practice (Hafner et al., 2015).

Another emerging phenomenon is prosodic and phonological interference caused by exposure to foreign languages through digital media. Some students imitate the stress and intonation patterns of speakers in English-language content, such as pronouncing *project* with initial stress or using the falling intonation typical of English when saying *video*. These findings support Rahman (2022) which revealed that foreign-language exposure in digital media can lead to "accent shifts" in young children, even while they are still developing the phonological system of their first language. In generative phonology theory, this phenomenon can be categorised as rule interference, in which phonological rules from a foreign language influence the derivational sound system of the mother tongue (Sukarno & Jinabe, 2024).

Thus, this study supports and expands previous findings that digital literacy acts as a double-edged sword: on one hand enriching children's linguistic input, but on the other potentially destabilising their phonemic system if not accompanied by proper phonological guidance. Therefore, language teachers need to develop instructional strategies that balance digital literacy skills with phonemic awareness. One applicable strategy is the use of interactive applications that teach standard Indonesian pronunciation, ensuring that children become not only "digitally literate" but also "phonologically literate" in the generative sense.

Study Results

Summary Table of Research Sources (2023–2025)

No.	Penulis dan Tahun	Fokus Penelitian	Temuan Utama
1.	Marelita & Iftanti (2024)	Analysis of phonological errors among BIPA learners	Dominant errors: substitution and vowel distortion
2.	Rusli & Muthmainnah (2024)	Pronunciation errors among digital-native students	Elision and omission of final sounds
3.	Artha & Bayu (2024)	Diphthongs in online learning contexts	Vowel errors caused by disrupted digital prosody
4.	Oktavinanda et al. (2023)	Phonology in digital educational content	Substitution and mother-tongue interference
5.	Pranawijaya et al. (2025)	AI-based analysis of foreign-language pronunciation	Final consonant errors influenced by L1 articulation

The table above shows a research trend from 2023 to 2025 highlighting pronunciation error analyses in digital contexts and foreign language learning. Although each study has distinct focuses, they collectively illustrate how digital exposure reshapes students' articulation patterns.

These findings align with Rahman (2022) who concluded that exposure to foreign languages in digital media may cause accent shifting in early-age learners, even while they are still developing their L1 phonological system. In generative phonology, this is categorised as rule interference, where phonological rules of another language affect the derivation processes of the first language. Meanwhile, Rusli & Muthmainnah (2024) identified elision and omission patterns among digital-native students, likely due to the rapid communication style fostered by social media. This suggests that technological advancement does not automatically improve pronunciation accuracy; instead, it may reduce attention to articulatory detail

(Rusli, 2025).

Penelitian Artha & Bayu (2024) emphasised prosodic disruption resulting from digital signals such as audio compression or unstable internet connections. In such cases, students lose full access to intonation contours and stress patterns, creating "digitally-driven phonemic errors(., 2020).

Next, Oktavinanda et al. (2023) highlighted mother-tongue interference in digital educational contexts, especially in multilingual environments like Indonesia where regional languages play a strong role in shaping phonemic patterns. (Gowenlock et al., 2024).

Pranawijaya et al. (2025) showed that although AI technologies can accurately detect phonemic errors, the root causes remain linked to L1 phonological structure. (Ng et al., 2022).

Collectively, these studies reveal a transition in phonology research from traditional linguistic contexts to digital environments. The findings support the argument that phonology education in the digital literacy era must integrate technology-based analysis, phonological awareness, and reflective digital practices.

Table 3.2 Types of Phonemic Errors Based on Literature Synthesis

No	Type of Error	Description	Example	Generative Phonology Analysis
1.	Substitution	Replacing one sound with another	/p/ → /f/ → *pen* → *fen*	Change of distinctive features [+labial, -continuant] → [+labial, +continuant]
2.	Elision	Omission of final sound	*baik* → *bai*	Failure to apply final consonant deletion rule
3.	Distortion	Inaccurate sound within same articulatory zone	/θ/ → [t]	Disrupted realisation of [+interdental] feature
4.	Epenthesis	Adding a vowel between consonants	*school* → *səkul*	Application of repair rule to match simpler L1 syllable structure
5.	Assimilation	Sound changes due to neighbouring sounds	*input* → [imput]	Overactivation of nasal assimilation rule
6.	Vowel Substitution	Changing vowels due to lack of equivalent sound	*bit* → *beat*	Loss of [+tenseness] feature
7.	Vowel Reduction	Failing to reduce vowels into schwa	*banana* → [banana]	Absence of vowel reduction rule

The patterns in the table reveal systematic interactions between L1 phonological systems and students' production processes in digital contexts. Each error type illustrates a misapplication of generative rules, demonstrating that children's phonological systems are still developing and adapting to digital influences.

CONCLUSION

This study concludes that phonemic errors in elementary students' educational audio production during the digital literacy era are influenced not only by articulatory limitations but also by mismatches between underlying phonemic representations and their surface realisations, as described in generative phonology. The most prevalent errors substitution, elision, and epenthesis are shaped by mother tongue interference, low phonological awareness, and limited digital pronunciation tools. Technological factors such as microphone quality, background noise, and recording inconsistency also contribute.

Theoretically, the research reinforces the relevance of generative phonology for analysing contemporary phonemic phenomena in technology-mediated learning. Practically, it suggests the need for integrating phonological training into digital literacy tasks using tools such as *Praat*, *ELAN*, and AI-based speech analysers. Activities like peer audio review and phonological awareness workshops can help students self-identify errors.

Future research is recommended to develop empirical classroom models of generative phonology instruction adapted to digital literacy environments.

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