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Communicating Sustainable Science Education: A Lasswell Model Analysis of Chemical Computing Literacy Using Chemdraw in Pharmacy Vocational Education

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ABSTRACT

The pharmaceutical industry's quick development of digital tools necessitates matching advancements in vocational science education. Nevertheless, there is still little use of specialized software like ChemDraw in pharmacy vocational schools in poor nations. For chemical computing literacy to be, adopted sustainably, effective communication techniques are essential. Harold Lasswell's communication model (who says what, in which channel, to whom, and with what effect) served as the conceptual-analytical foundation for this study's qualitative descriptive design. In addition to document analysis and pertinent literature, data were collected through semi-structured interviews with five pharmacy vocational students taking part in ChemDraw training. The results were mapped onto the Lasswell framework in order to do thematic analysis. Credible academic facilitators enhanced message legitimacy, while sustainability-oriented messages combined with experiential hands-on practice significantly improved students' conceptual understanding, practical skills in molecular visualization, and confidence in digital tools. All respondents reported positive shifts in attitude toward digital innovation and recognized the relevance of ChemDraw for future professional practice. A strong strategic foundation for creating long-lasting digital scientific education is provided by the Lasswell model. In order to support SDGs 4 (Quality Education), 9 (Industry, Innovation, and Infrastructure), and 12 (Responsible Consumption and Production), structured communication can successfully close the gap between conventional vocational education and industry expectations. Long-term effects require systematic curricular integration and ongoing teacher development.

Keywords: ChemDraw; Digital Chemical Literacy; Lasswell Communication Model; Science Communication; Sustainable Development Goals; Vocational Education

Background

Education plays a vital role as a transformative force in achieving sustainable development, particularly through SDG 4 (Quality Education). In the pharmaceutical industry, digital competencies such as molecular visualization and computational modeling have become essential skills. However, many pharmacy vocational schools in developing countries still rely on traditional manual methods, creating a significant gap between classroom practices and industry demands. Although digital literacy has been widely studied, the adoption of chemical computational tools at the vocational level still faces technical adaptation challenges (Haleem *et al*., 2022).

This gap highlights not only technological limitations but also communication challenges. Effective integration of digital tools like ChemDraw requires more than infrastructure; it demands strategic communication to help educators and students understand, accept, and sustain technological innovation.

Although digital literacy and sustainable education have been widely studied, few studies have applied classical communication models to examine the integration of chemical computing tools in vocational pharmacy education. This study addresses the gap by using Harold Lasswell's communication model (who says what, in which channel, to whom, and with what effect) to analyze the communication dynamics of ChemDraw integration (Alowais *et al*., 2024). The study aims to evaluate how this process contributes to sustainable science education and aligns with SDG 4, SDG 9, and SDG 12.

Literature Review

Sustainable Development and Education Transformation Sustainable development has repositioned education as a transformative force capable of shaping socially responsible, technologically adaptive, and innovation-driven societies. The 2030 Agenda for Sustainable Development, introduced by the United Nations, highlights education as a central pillar for achieving long-term environmental, social, and economic resilience. In particular, SDG 4 emphasizes quality and inclusive education, while SDG 9 and SDG 12 underscore the importance of technological innovation and responsible production systems. Within science and vocational education, sustainability increasingly intersects with digital transformation and also with adaptive technical competencies in accordance with global industry standards (Teräs, 2022). Educational institutions are expected not only to transmit disciplinary knowledge but also to cultivate digital literacy, computational competence, and adaptive technological skills. Similarly, Eriyagama and Mohammed (2023) emphasized the growing importance of digital literacy within technology-supported educational environments, highlighting the role of educators in facilitating students' development of digital competencies through innovative pedagogical approaches. In pharmaceutical and chemical education, molecular visualization and computational tools are no longer optional supplements; they represent core competencies aligned with industrial standards (Selwyn, 2011).

However, vocational education systems in many developing contexts continue to face gaps in digital integration. Traditional instructional methods still dominate vocational classrooms, resulting in a gap with industrial demands, whereas the integration of ChemDraw has been shown to significantly enhance students' conceptual understanding compared to conventional approaches (Yaayin & Hayford, 2025). This structural gap indicates a communication problem in conveying, contextualizing, and institutionalizing innovation inside educational systems in addition to a technological shortcoming (Walsh, Banerjee & Murphy, 2022).

Communication for Sustainable Development Communication for Sustainable Development (CSD) has evolved from modernization-based paradigms toward participatory and empowerment-oriented approaches. Scholars such as Jan Servaes emphasize that sustainable communication must move beyond linear information transmission to foster dialogue, community ownership, and structural change. Similarly, Linje Manyozo conceptualizes development communication as simultaneously a tool, a process, and a social arena for negotiation. In educational contexts, the success of technological innovation is inseparable from communication strategy. The adoption of new digital tools depends on how knowledge is framed, legitimized, and socially integrated within institutional cultures. Effective communication determines whether innovation becomes embedded within curriculum structures or remains a temporary intervention (Guitert, Romeu & Romero, 2015).

Despite extensive scholarship on development communication and digital literacy, limited attention has been given to systematically applying classical communication models to the design of digital science literacy initiatives in vocational education. This gap opens space for theoretical innovation. Innovation Diffusion and Technological Transition in Vocational Education the diffusion of innovation theory developed by Everett Rogers explains that adoption depends on perceived relative advantage, compatibility, complexity, trialability, and observability. In vocational education settings, these perceptions are shaped primarily through structured communication processes between Institutions, educators, and learners, (Kolb, 2021).

In pharmacy vocational education, digital chemical computing tools such as ChemDraw represent an innovation aligned with contemporary pharmaceutical industry practices, (Alowais, Nazar & Tolley, 2024). These tools facilitate molecular modeling, chemical structure documentation, and visualization processes that support efficiency and environmentally conscious research practices. Nevertheless, integration at the secondary vocational level remains uneven, indicating a need for structured communication frameworks that guide technological transition.

The Lasswell Communication Model in Contemporary Educational Contexts

The classical communication model proposed by Harold Lasswell conceptualizes communication through five guiding questions: Who says what, in which channel, to whom, and with what effect. Although often characterized as linear, the model remains analytically powerful for examining structured communication interventions

a. **Who** discusses institutional authority and communicator credibility,
b. **Says what** examines message framing and relevance,
c. In **Which** Channel evaluates media selection and delivery mechanisms,
d. To **whom** focuses on audience characteristics and contextual factors,
e. **What** Effect considers cognitive, skill-based, and attitudinal outcomes.

In development communication research, revisiting classical models enables systematic mapping of institutional communication processes while allowing critical reflection on power dynamics and sustainability implications. Applying the Lasswell framework to digital chemical computing education provides an opportunity to bridge foundational communication theory with contemporary digital literacy challenges.

Research Gap and Conceptual Positioning

While sustainable education, digital literacy, and development communication have been widely examined as separate domains, no study has systematically applied a classical communication framework to design and evaluate digital chemical computing literacy within pharmacy vocational education. Existing research rarely integrates sustainability discourse, innovation diffusion, and structured communication analysis into a unified conceptual model. This study addresses that gap by proposing a modified application of the Lasswell communication model tailored to sustainable chemical computing education. By positioning communication not merely as information transmission but as a strategic design mechanism for technological empowerment, this framework contributes to both development communication scholarship and vocational digital education practice.

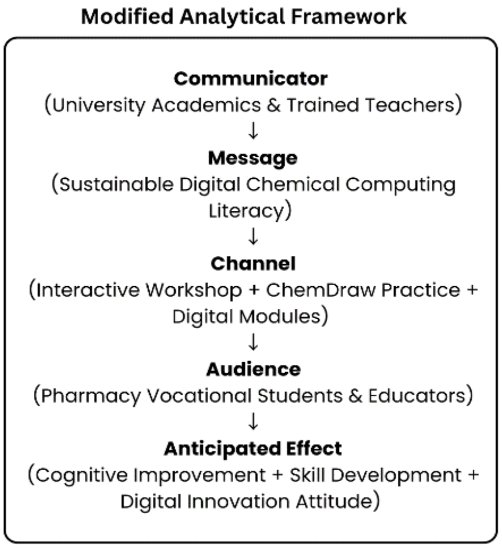

Figure 1. Proposed Modified Lasswell Communication Model for Sustainable Chemical Computing Literacy in Pharmacy Vocational Education

Figure 1: The suggested adaptation of the Lasswell communication model for sustainable digital chemistry computer literacy in pharmacy vocational education is shown in Figure 1. In order to integrate technology innovation into vocational science programs, the approach rethinks traditional linear communication elements as structured design parameters. Each element serves as a strategic lever for institutional transformation and digital empowerment in addition to being a transmission mechanism. Based on the explanation above, this study offers three novelties:

a. First, it reconceptualizes Lasswell's communication model from a linear transmission model into a strategic design framework for sustainable digital science education.

b. Second, it introduces the concept of "communicative technology mediation" in vocational education, positioning ChemDraw not merely as software but as a structured communication infrastructure.

c. Third, it bridges the discourse of sustainable development with computational chemistry literacy in secondary pharmacy education. This area remains rarely discussed in communication studies.

Thus, this study extends classical communication theory to the realm of digital vocational transformation.

Methods

This study employed a conceptual-analytical approach and a qualitative descriptive design. Through interviews, the study sought to create and methodically test a proposed communication framework for integrating computational chemistry literacy into pharmacy vocational education, rather than assessing implemented educational interventions. This study positions communication as a strategic design mechanism for sustainable digital science education. Communication is positioned in this study as a strategic design tool for long-term teaching in digital science. Within the framework of a pharmacy vocational school in Jakarta, Indonesia, the study is organized as a theoretical case design. The proposed communication framework underlying the integration of ChemDraw as a digital molecular visualization and chemical modeling tool within the vocational science program serves as the unit of analysis. The goal is to integrate sustainability-oriented learning principles and align educational practices with current pharmaceutical industry standards. The main analytical framework is the Lasswell communication model, which was developed using the guiding questions "Who says what, in which channel, to whom, and with what effect?" Each of the five elements serves as a criteria for strategic design:

a. **Who:** Identification of credible communicators, including university academics, facilitators, and trained vocational teachers.
b. **Says What:** Construction of sustainability-oriented digital chemical computing messages.
c. **In Which Channel:** Selection of blended instructional channels, such as interactive workshops, guided ChemDraw practice, and digital learning modules.
d. **To Whom**: Targeting pharmacy vocational students and educators with heterogeneous levels of technological familiarity.
e. **Whit What Effect:** Projection of cognitive enhancement, skill acquisition, and attitudinal transformation toward digital scientific innovation. Data sources consist of curriculum frameworks, vocational education policy documents, sustainability education literature, development communication scholarship, and technical documentation related to ChemDraw.

These materials are examined to construct a coherent communication blueprint aligned with Sustainable Development Goals (SDG 4, SDG 9, and SDG 12). To strengthen analytical rigor, the study applies theoretical triangulation by integrating perspectives from communication for sustainable development, innovation diffusion theory, and digital science literacy studies. The purpose of this methodological design is not to measure empirical impact but to formulate a theoretically grounded and strategically structured communication model capable of guiding future implementation and evaluation. By framing the research as a communication model design rather than an impact assessment, the methodology maintains conceptual integrity while offering practical relevance for sustainable vocational science education.

Results and Discussion

This chapter presents a structured analytical evaluation of the proposed communication framework for integrating chemical computing literacy into pharmacy vocational education. Because the study adopts a conceptual-analytical design, the discussion does not report empirical findings but instead evaluates the coherence, strategic feasibility, and sustainability alignment of the proposed model using the Lasswell communication framework. The analysis systematically examines how each communication component, Who, Says What, In Which Channel, To Whom, and With What Effect, functions within the integration of ChemDraw as a digital scientific communication medium, (Ng, 2012).

Who: Communicator Authority and Technological Mediation

University-level pharmacy academics, facilitators, and vocational instructors make up the communicators in the suggested structure. Communicator credibility determines message validity and institutional trust in development communication environments. While teacher involvement guarantees contextual adaptation in the occupational learning environment, academic authority offers epistemic support for the introduction of digital chemical computing.

Importantly, in this model, communicators do not merely transmit content. They function as technological mediators who interpret and translate ChemDraw from a technical software application into a professional scientific communication tool. The communicator’s role, therefore, includes:

a. Framing ChemDraw as an industry-standard instrument.
b. Demonstrating its sutainability relevance.
c. Reducing perceived technological complexity.
d. Building institutional confidence toward digital transition.

For long-term sustainability, participatory curriculum co-design and institutional collaboration are required to prevent dependency on external expertise. Thus, within the "Who" component, ChemDraw is positioned not merely as software but as an innovation requiring interpretative guidance and communicative legitimacy.

Says What: Message Framing and Sustainability Orientation

The central message of the proposed intervention focuses on digital chemical computing literacy using ChemDraw as a tool for molecular visualization, structural modeling, and pharmaceutical documentation. However, the message is not framed solely as technical skill acquisition. Instead, it is constructed around three interrelated dimensions:

1. Digital Scientific Competence – Aligning vocational education with contemporary pharmaceutical industry standards.
2. Sustainability Awareness – Emphasizing digital simulation as a means of reducing laboratory trial and error processes and minimizing chemical waste.
3. Professional Readiness – Positioning ChemDraw literacy as part of industry-relevant competence.

Becomes a symbolic representation of modern pharmaceutical practice. It communicates not only molecular structures but also values of efficiency, innovation, and environmental responsibility. The message aligns conceptually with:

a. SDG 4 (Quality Education),
b. SDG 9 (Industry, Innovation, and Infrastructure),
c. SDG 12 (Responsible Consumption and Production).

Nevertheless, the analysis indicates that the sustainability narrative must be explicitly integrated into instructional discourse. Without conscious framing, ChemDraw risks being perceived merely as technical software rather than as a sustainability-supporting scientific medium.

In Which Channel: ChemDraw as Experiental Communication Medium

The proposed communication channels include interactive instruction, guided ChemDraw practice sessions, and digital learning modules. Among these, ChemDraw occupies a dual role:

a. As a technological channel enabling experiental learning.
b. As a symbolic communication interface, translating abstract molecular knowledge into standardized visual codes.

In vocational education contexts, experiential learning is critical. ChemDraw enables learners to actively construct molecular representations, transforming theoretical chemistry into manipulable digital objects. This process enhances cognitive engagement and supports deeper conceptual processing. However, the effectiveness of ChemDraw as a communication channel depends on:

a. Infrastructure availability.
b. Software accessibility.
c. Teacher competence.
d. Curriculum integration.

These conditions are consistent with Qurban and Mohammed (2023), who identified multiple barriers affecting teachers' implementation of ICT in educational settings, reinforcing the view that successful technology integration depends not only on access to digital tools but also on the conditions supporting their effective pedagogical use.

If institutional embedding is weak, ChemDraw may function as an episodic workshop tool rather than a sustained pedagogical medium. Thus, within the channel dimension, ChemDraw is positioned as a communicative infrastructure rather than merely a supplementary application.

To Whom: Audience Positioning and Technological Readiness

The primary audience includes pharmacy vocational students and educators with varying levels of digital familiarity. Communication design acknowledges heterogeneous technological readiness and therefore incorporates progressive scaffolding mechanisms. Form a communication for development perspective, audience empowerment requires more than exposure to technology. It involves:

a. Reducing technological anxiety,
b. Building confidence,
c. Encouraging exploratory engagement,
d. Supporting institutional ownership.

In this framework, ChemDraw may initially be perceived as complex. The communicator's role is therefore crucial in transforming perception from "technical barrier" to "professional empowerment tool." The audience dimension also highlights the need for participatory planning. While the conceptual model anticipates audience needs, future empirical implementation would require structured needs assessment to enhance contextual responsiveness.

With What Effect: Projected Cognitive, Skill-Based, and Institutional Outcomes

Given the conceptual nature of the study, effects are analytically projected rather than empirically measured. The anticipated outcomes are categorized into three levels:

1. Attitudinal Level Cognitive Level. Improved conceptual understanding of molecular visualization and structural representation through interactive digital modeling.
2. Skill Level. Development of practical competence in using ChemDraw for pharmaceutical documentation and learning tasks.
3. Attitudinal Level. Increased openness toward digital innovation and sustainability-oriented scientific practices. At the institutional level, the model projects potential contribution to digital transformation in vocational science education. However, long-term sustainability depends on curriculum embedding, teacher training continuity, and institutional partnerships.

Analytical Synthesis Table

To strengthen structural clarity, Table 1 summarizes the analytical mapping of the proposed Lasswell-based communication design, (H.D. Lasswell., 1972).

Table 1. Analytical Mapping of the Proposed Lasswell-Based Communication Design

Lasswell Component	Strategic Role	Role of ChemDraw	Sustainability Alignment	Potential Limitation	Strategic Recommendation
Who	Establish communicator legitimacy	Tool requiring guided interpretation	SDG 4	Semi top-down initiation	Participatory co-design
Says What	Frame digital literacy message	Symbol of industry-aligned molecular modeling	SDG 4, 9, 12	Over-technical framing	Integrate sustainability narrative
Channel	Enable experiential learning	Digital symbolic interface	SDG 4	Infrastructure dependency	Curriculum integration

To Whom	Empower vocational learners	Innovation object for technological readiness	SDG 4	Digital skill disparity	Scaffolded training
With What Effect	Project transformation outcomes	Instrument of cognitive and skill development	SDG 4, 9	Short-term exposure risk	Institutional embedding

Integrative Discussion

Strong analytical utility in organizing sustainable digital education design is demonstrated by the implementation of the Lasswell communication model. The model explains the strengths and structural weaknesses of the suggested framework by methodically mapping communicator roles, message framing, channel selection, audience positioning, and expected outcomes. ChemDraw's incorporation into every communication dimension guarantees that the digital tool is viewed as a primary communication tool in practical science education rather than as an optional extra. As a result, the model connects traditional communication theory with current issues in digital literacy (Alsulami, 2025). To guarantee long-term institutional reform, complementary participatory approaches are necessary, as indicated by the Lasswell model's linear nature. Beyond initial program design, sustained communication, cooperative planning, and structural embedding are necessary for lasting educational reform. All things considered, this analysis shows that traditional communication frameworks are still applicable when carefully modified for use in digital scientific education settings, especially when it comes to integrating sustainable development principles into vocational training. Within the communication framework, this research seeks to contribute to the Sustainable Development Goals (SDGs) in a specific and measurable way. The SDGs are used as ethics through SDG 4 (Quality Education), SDG 9 (Industry, Innovation, and Infrastructure), and SDG 12 (Responsible Consumption and Production) to support the integration of literacy in vocational pharmacy education, (Servaes, 2022). The use of ChemDraw as a technology-communicative medium contributes to strengthening technical competencies, enhancing technological capabilities within educational institutions, and promoting resource-efficient scientific practices through digital simulations. This connection demonstrates that the results of this research are not only theoretically aligned with sustainable development discourse but can also strategically support educational and institutional transformation, (ChemOffice, 1998). The results of the interview method were obtained by interviewing 5 people out of a total of 30 participants. The questions were as follows:

Initial Understanding

1. What was your level of understanding of ChemDraw before participating in this program?
2. How often did you use digital tools to draw chemical structures prior to this training?

Learning Process

3. How clear was the facilitator's explanation during the training?
4. Did the training method help you understand chemical computing literacy concepts?
5. How effective were the demonstrations and hands-on practice sessions?

Learning Impact

6. Do you feel more confident using ChemDraw after this program?
7. Is this skill relevant to pharmacy vocational education?
8. How does this training improve your readiness for higher education or employment?

Sustainability & Recommendation

9. Would you be interested in attending advanced training?
10. Do you think this program should be implemented regularly at the school?

Table 2: Interview Results From 5 Respondents

Respondent	Grade Level	Initial Condition	Perceived Impact	Key Outcome	Overall Response

A	Grade XI Pharmacy	No prior experience using ChemDraw	Better understanding of digital chemical structure drawing	Increased confidence and accuracy	Very Positive
B	Grade XI Pharmacy	Used manual drawing methods in notebooks	Learning became more modern and interactive	Improved chemical computing literacy	Very Positive
C	Grade XI Pharmacy	Limited to theoretical knowledge without digital practice	Able to draw structures faster and more neatly	Improved task efficiency	Very Positive
D	Grade XI Pharmacy	Not familiar with chemistry software	Felt more prepared for practical examinations	Enhanced digital competence	Positive
E	Grade XI Pharmacy	Had general knowledge of ChemDraw only	Greater confidence to pursue pharmacy studies	Increased academic and professional readiness	Very Positive

Table 3: Impact Analysis Based on Laswell Model

Lasswell Component	Program Implementation	Observed Effect
Who	Competent facilitators with chemical computing expertise	High credibility and structured delivery
Says What	Chemical computing literacy using ChemDraw	Clear understanding of digital structure drawing
In Which Channel	Demonstration + guided hands-on practice	Effective skill acquisition
To Whom	Pharmacy vocational students and educators	Active participation and engagement
With What Effect	Improved digital competence and professional readiness	Increased confidence and sustainable learning practices

Table 4: Overall Community Services Outcomes

Indicator	Result
Increase in Chemical Computing Literacy	100% respondents reported improvement
Confidence Level	Significantly increased among students
Teaching Innovation	Enhanced integration of digital tools
Industry Relevance	Skills aligned with higher education and pharmaceutical standards
Sustainability Recommendation	All respondents support regular implementation

The results of this study show that the Lasswell communication model is still a useful and practical analytical framework for comprehending and planning the incorporation of digital resources in vocational science education. By methodically mapping the five elements Who, Says What, In Which Channel, To Whom, and With What Effect this study shows that the quality of the communication process surrounding the implementation of ChemDraw is more crucial to its successful adoption than the technology's accessibility.

Building confidence and legitimacy was greatly aided by credible communicators (Who), who included university scholars and seasoned lecturers. Students responded well to the message (Says What) that included digital competency, sustainability consciousness, and professional preparation. Additionally, the primary channel (In Which Channel) of experiential hands-on practice proved to be quite successful in converting abstract chemical principles into concrete digital skills. These components provided favorable cognitive, skill-based, and attitudinal outcomes (With What Effect) and effectively addressed the varied technology preparedness of vocational students (To Whom).

By adopting a classical communication viewpoint to the particular setting of chemical computing tools in pharmacy vocational education an area that has received little scholarly attention this study expands on earlier research on ICT integration and digital literacy in education. The findings support the idea that integrating sustainability principles into technological innovation might improve student involvement and the process' perceived relevance. The results support Lasswell's model's adaptation in modern digital learning environments from a theoretical perspective. Practically speaking, the study recommends that rather than viewing the adoption of digital technologies as merely a technological improvement, vocational schools should view them as a strategic communication intervention. Moving beyond short-term workshops toward long-term educational reform requires systematic curriculum integration, ongoing teacher training, and improved academia-industry partnership.

This study has a number of shortcomings despite its merits. The limited number of interviewees restricts how far the results may be applied. Furthermore, long-term retention and wider institutional influence were not assessed because this was an exploratory study with a conceptual-analytical approach. To assess the long-term impact of such interventions, future research should include mixed-methods approaches, larger samples, pre- and post-test designs, and longitudinal studies.

Conclusion

Using a Lasswell-based communication framework, this project has conceptually investigated the integration of digital molecular visualization tools, specifically ChemDraw, inside vocational science education. The study reframes technology as a communicative medium that forms meaning, professional identity, and institutional transformation instead of viewing it as a strictly technical tool. Using the Lasswell formula, which stands for Who says What in Which Channel to Whom with What Effect, the study shows that the coherence of the communicator (educators), message (molecular representation and scientific documentation), channel (interactive digital modeling), audience (vocational learners), and projected effects (cognitive, skill-based, and institutional outcomes) are more important factors in determining the effectiveness of ChemDraw integration than software availability alone. ChemDraw facilitates conceptual clarity in structure representation and molecular visualization at the cognitive level. By helping students go from abstract chemical formulas to structured, comprehensible models, the tool improves scientific literacy and symbolic comprehension. The platform improves technical proficiency related to laboratory and pharmaceutical documentation at the skill level. In order to match learning objectives with professional expectations and industry norms, students gain practical expertise in digital scientific representation. The model predicts greater receptivity to digital innovation and sustainability-focused scientific methods at institutional and attitudinal levels. Nonetheless, the study highlights that systematic lecturer training, controlled curricular integration, and alignment with more general digital transformation objectives are necessary for long-term institutional impact.

Declarations

Ethics Approval and Consent to Participate: This study obtained informed consent from all participants prior to data collection. Participants were informed about the purpose of the study, the nature of the data collected, and any potential risks or benefits. All data were treated confidentially, and participant privacy and anonymity were strictly protected.

Conflicts of Interest: The authors declare that they have no competing interests.

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