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SCIENTIFIC AND TECHNOLOGICAL LITERACY IN UNDERGRADUATE COURSES IN BIOLOGICAL SCIENCES: AN INVESTIGATION IN BRAZILIAN PUBLIC INSTITUTIONS

A.O.NUNES*, R.F.LEITE, L.A.DELLA JUSTINA, M.F.RODRIGUES
Instituto Federal de Educação, Ciência e Tecnologia do Rio Grande de Norte
ORCID ID: http://orcid.org/0000-0002-3585-2137 *
albino.nunes@ifrn.edu.br*

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RESUMO

A alfabetização científica e tecnológica (ACT) é um dos principais objetivos da educação científica. Por entender que os/as professores/as de Ciências Biológicas têm um papel fundamental no desenvolvimento da ACT, é que o presente estudo se propõe a compreender como os projetos de curso das Licenciaturas em Ciências Biológicas de Instituições Públicas de Ensino Superior brasileiras abordam a ACT. Para tanto foram analisados com o auxílio do *software Iramuteq* 0.7 *alfa* 2 os PPC de quinze cursos do Brasil, distribuídos nas cinco regiões. Como resultados nota-se que tanto os objetivos como o perfil dos cursos analisados apresentam forte tendência a priorizar aspectos da formação científica e da formação para a docência, ficando (aparentemente) esquecidas questões sociais e epistemológicas. Infere-se que: a) os cursos de Ciências Biológicas poderiam incorporar objetivos voltados à ACT e que estudos mais detalhados sobre a ACT devem ser feitos sobre o currículo oculto de tais cursos

PALAVRAS-CHAVE. Alfabetização científica e tecnológica, PPC, Ciências Biológicas**.**

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ABSTRACT

Scientific and Technological Literacy (STL) is one of the main goals of scientific education. Considering that Biological Sciences teachers hold a fundamental role on the development of STL, the present study proposes to understand how the course projects of the Biological Sciences programs on Brazilian Higher Education public institutions approach STL. For such, the pedagogical proposals of fifteen Brazilian programms were analyzed with the help of the Iramuteq 0.7 alpha 2 software. As results, it is noticeable that both the goals and the profiles of the analyzed programs show a strong tendency to prioritize aspects of scientific and teaching formation, apperently setting aside social and epistemological aspects. It is inferred that: a) the Biological Sciences programs could incorporate goals aimed towards STL, and b) more detailed studies focusing on STL must be performed on the hidden curriculum of such programs.

KEYWORDS: Scientific and Technological Literacy, Pedagogical Program, Biological Sciences.

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1 INTRODUCTION

Scientific and Technological Literacy is one of the main objectives of scientific education, and it gains special significance on current discussions, also because of the emergency of movements contrary to scientific knowledge (such as flat-earth and anti-vaccines movements), and in the scope of the discussions promoted by the pseudo sciences and the inappropriate use of concepts and methods of Science.

It is in this landscape that Science teachers (pedagogues, chemists, physicists and biologists) have to teach, holding a dialogue with the reality in which the students are inserted. It is a context of widespread of fake news, in which scientific literacy may hold an important and relevant role, working with trusted information sources, one of the pillars of STL.

However, before thinking of the mobilization of STL, it is necessary to define which STL we are discussing. We know that, in Portuguese, there are four very similar expressions for this concept: *Literacia Científica*, *Letramento Científico*, *Enculturação Científica* and *Alfabetização Científica*. For some authors, this is a mere variation in terms, however, for others, there are pertinent conceptual variations.

In this context, we adopted the term *Alfabetização* (Literacy), since we agree with Sasseron and Machado (2017) in the defense of the term brought by Paulo Freire. We lean on this Freirean perspective to understand Scientific Literacy as something beyond the mere decoding of Science's codes. For such, we get closer to Auler and Delizoicov (2001) in the perspective of a Broad Scientific Literacy that opposes a restrictive SL, and that works the relationships between Science, Technology and Society in a critical and reflexive way.

But there is still another question to raise when speaking about SL: the question of technology as a knowledge for everyone. In a world where the acronym S&T, also known as technoscience (SANTOS, 2001), finds itself more and more intertwined and in which it is difficult to conceive projects without the presence of scientists and technologists working alongside, it becomes necessary to work the technological question as a type of knowledge necessary for the population (CAJAS, 2001). Thus, similarly to other authors (MILARÉ *et al*., 2021), we adopted the acronym STL (Scientific and Technological Literacy) to approach the theme.

However, this work, beyond the definitions of STL, is aimed specifically towards the education of Science teachers for STL. Thus, it must be clarified that this is a field which seems to be in effervescence in the last few years, with a vast production on how the Science teachers, approach STL, both in primary formation courses and in continuing education.

There is, though, in our perspective, gaps in the research about primary formation of the undergraduate student of Biological Sciences. To understand this process, we question: How the Pedagogical Projects of the Biological Sciences programs in Brazil approach STL. Thus, the main objective of this study is to analyze and understand how such programs spread across Brazil present STL. For such, we used as analysis categories the axes brought Sasseron and Carvalho (2011): I –

Understanding terms and scientific concepts; II – Understanding the nature of the Science and the processes of scientific production; III -Understanding the relationship between Science, Technology and Society (STS).

2 METHODOLOGY

Next, we will briefly report the methodological process of the investigation performed to achieve the main objective of the research.

As for the nature of the investigation, it is defined as a mixed-method research, in which elements of qualitative and quantitative research are used (HERNÁNDEZ-SAMPIERI; FERNÁNDEZ-COLLADO; BAPTISTA-LUCIO, 2016). The choice to work with mixed methods was made due to the large volume of data produced by the analysis of the Pedagogical Projects of the programs investigated, and the understanding that only the quantitative methods are not enough for the in-depth interpretation that this work proposes.

Thus, it is characterized by showing the use of lexical analysis tools supported by the software *Iramuteq 0.7 alpha 2*. In this, there is the use of descriptive statistic elements and multivariate analysis with predominance of qualitative interpretation.

In adition to the lexical analysis provided by the software, we also performed a content analysis of the PPs, which indicates to us a triangulation of the data already pointed as possible by Nascimento and Menandro (2006).

In regards to the methodological procedures, fifteen Biological Sciences Undergraduate programs were chosen through the following criteria: availability of the Pedagogical Project on the program's website, selecting three programs for each region of Brazil, and one program by institution type (Federal University, State University and Federal Institute). Exclusion criteria were to not select two programs from the same state, as well as two programs from the same type of institution on each region.

Thus, we investigated the programs of the following institutions detailed on Table 1.

Table 1: Teaching Institutions and their Regions

INSTITUTION	REGION
IFRN	Northeast
UNEAL	Northeast
UFPE	Northeast
UFTM	Southeast
Unesp	Southeast

IFES	Southeast
IFB	Central-West
UEMS	Central-West
UFMT	Central-West
IFPA	North
UERR	North
UFT	North
IFSul	South
UDESC	South
UTFPR	South

Source: Research data (2022)

Once the PPs that make up the sample were chosen, we proceeded with the creation of the *corpus* for the first analysis. Thus, we extracted from the Projects the goals and formation profiles, which were coded and analyzed by *Iramuteq*, generating similarity graphs, word clouds and Descendent Hierarchical Classifications.

After the lexical analysis, we proceeded with a manual content analysis, searching for emerging categories and triangulating the results with the ones obtained by the software.

At this point in the text, by being an unusual software for research on the teaching of Sciences and Mathematical Education, the role of the software is one of organizing the data in an intelligible way in order for the researcher to make their own inference, and not confusing with the analysis itself. We leaned on previous studies (SOUZA; NUNES; OLIVEIRA, 2020; CAMARGO; JUSTO, 2008; SOUZA *et al.,* 2018) that reaffirm the role of the analyst and the possibility for a qualitative interpretation of the graphs and dendrograms generated by the application.

In theoretical terms, our analysis categories were thought of from the axes elaborated by Sasserson and Carvalho (2011), already reported in this work's introduction.

3 RESULTS AND DISCUSSIONS

As explained in the methodological process, the goals, competences and habilities of the Biological Sciences undergraduate programs were coded and analyzed with the aid of the software *Iramuteq*.

As can be seen on Figure 1, the results show that the texts analyzed heavily mention the professional education of the Biological Sciences undergraduate student. Noticed from the size of

the font of the mottos “professional”, “knowledge”, “formation”. Likewise, the mention of Biology itself is also high, perceived through the mottos “Science” and “biological”. Other mottos worth highlighting due to their frequence on the corpus are “teaching”, “practical”, “competence”, “research”, “education”, “development”, “social” and “pedagogical”.

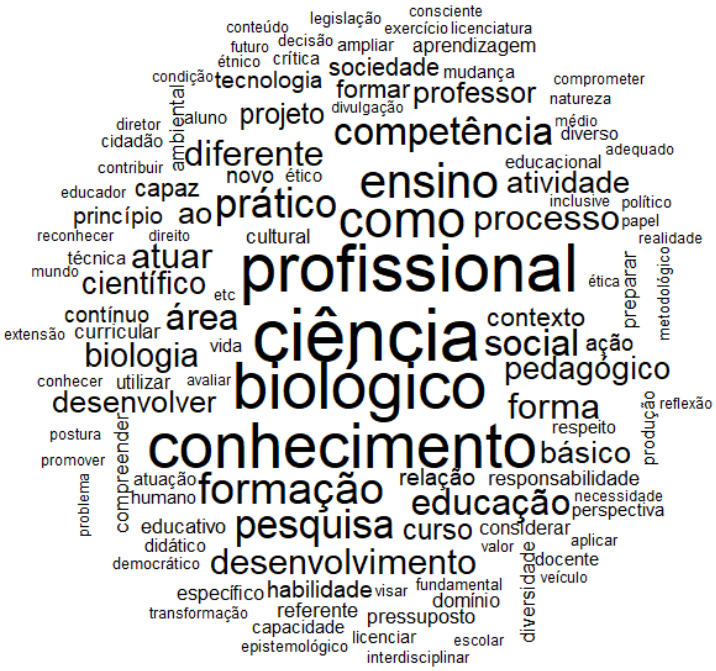

Figure 1: Word cloud depicting the programs’ objectives.

It is necessary to highlight the mottos that that are shown on the second level. Since we are discussing programs that graduate educators, it would be expected that words that relate to the pedagogical aspect would appear on the first level. What can be deduced at first is that each institution uses different terms to reffer to questions of teaching, education and pedagogical practice. Altough, our objectives and the teacher formation are contemplated. About the other mottos, we highlight the perspective that the future teachers must be prepared for research, and they must contribute to social development.

At this point, it is necessary to emphasize that the interpretation of a word cloud brings with it some uncertainty, once it is the result only of the frequency of the mottos from the corpus analyzed. In this context, Tournier’s consideration is valid, that “the computer cannot directly treat the content of a political discourse, but, when analyzing the words that make it up, It uncovers many choices, habits and preconceived ideas” (TOURNIER, 1986 *aput* BARDIN, 2011, p. 185).

In order to deepen the understanding of the relationship between the mottos, we will use the similarity graph shown next on Figure 2. In it, we can notice, beyond the frequency of the words expressed by its font size, the relationship stablished in terms of co-occurrence of mottos, which graphic representation resides over the width of the connection line between the mottos.

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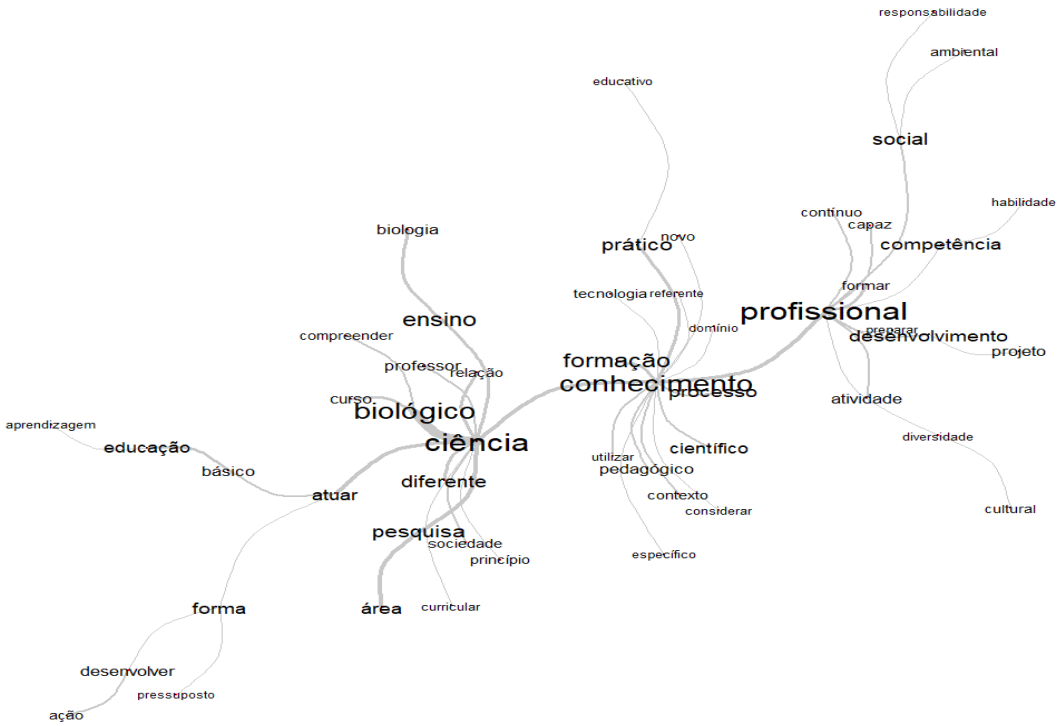

Figure 2: Similarity graph of the objectives.

At this stage, we need to evaluate which additional information the similarity graph brings us. The initial impression that matters of teaching are sidelined on the objectives of the programs is confirmed when we notice that the words “education”, “teaching” and “pedagogical” have few connections, smaller size (mening less frequency) and thinner connections.

The main axes of the objectives seem to be the professional formation and the biological Science itself, not so much linked to matters of teaching. Here, it is necessary to resort to classical content analysis in order to understand this matter.

The attentive reading of the objectives, competences, and skills leads us to deduce that the writing of the objectives is done in three categories for most of the analyzed programs: a) Biological knowledge; b) Pedagogical knowledge; c) Pedagogical knowledge of the Content. As seen next on Table 2:

Table 2: Professional knowledge categories in the objectives

CATEGORY	UNITY OF DIRECTION
	“To apply the scientific method for planning, managing and execution of processes and techniques aiming for the development of projects, assessments, reports, technical advices etc., in different contexts. To

Biological knowledge	uuse the knowledge of Biological Sciences to understand and transform the sociopolitical context and the relationships in which the professional practice in inserted, knowing the relevant legislation." (UTFPR) "To enbable the understanding of the role of research as a tool for investigating, building and rebuilding of knowledge towards the adressing of socioenvironmental demands." (UNEAL)
Pedagogical knowledge	"To promote the discussion about education in human rights as a strategic necessity in the formation of education professionals and in the educative action in consonance with the National Guidelines for Education in Human Rights." (IFRN) "To participate colectively and cooperatively of the elaboration, management and evaluation of the educational and curricular project of the school, acting in different contexts of professional practice, beyond the classroom."(UEMS)
Pedagogical knowledge of the content	"To plan and develop different didactic experiences in Sciences and Biology teaching, recognizing the relevant elements to the adequate strategies; to elaborate and/or adapt didactic materials of different natures, identifying their formative objectives of educational learning; to participate on the elaboration and development of activities in Sciences and Biology teaching."(IFES) "To facilitate the production of knowledge in the specific and didactic-pedagogical areas in an integrated and multidisciplonary way." (IFRN)

Source: Research data (2022)

Thus, we understand that the pedagogical matters not being central in the texts is due not to a lack of them in the objectives and competences, but to a greater focus on matters of biological knowledge and didactic knowledge of the content in the texts, with wide variety in the nomenclature used about the educational knowledge (teaching, education, pedagogical, didactic…).

But what about the relationship with Scientific and Technological Literacy? Considering the axes elaborated by Sasseron and Carvalho (2011), we notice that the objectives and competences clearly approach the need of formation towards biological knowledge (First axis), and there are few mentions about the nature of science, and even fewer mentions to the Science-Technology-Society relationships. It is worth to mention that some programs do bring these perspectives, even though they are a minority, and the objectives and competences aimed towards the formation of the biologist are clearly the main goal of these programs.

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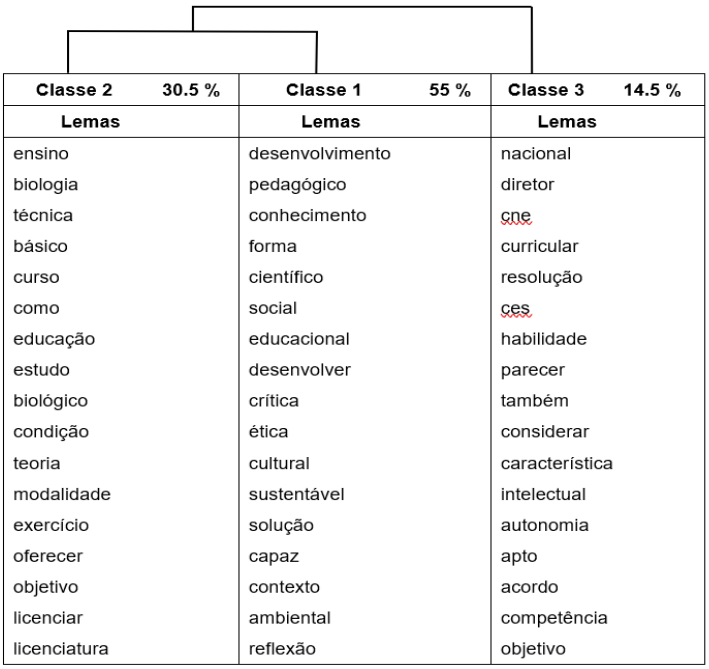
Later, we searched in the curricula for classes that could bring elements both from the second and third axes, and we noticed the most of the programs have a Philosophy of Science/Epistemiology class, and there were almost no classes that approach the Science-Technology-Society relationships.

At this point, it must be asked: how can the objectives and competences not show something related to the nature of the science, if it is present in the curriculum? How to approach the intricate STS relationships in teaching, if the primary formation does not point in that direction?

As additional elements, we also bring the Descendent Hierarchical Classification (DHC) of the same section on Figure 3.



Classe 2 30.5 %	Classe 1 55 %	Classe 3 14.5 %
Lemas	Lemas	Lemas
ensino	desenvolvimento	nacional
biologia	pedagógico	diretor
técnica	conhecimento	cne
básico	forma	curricular
curso	científico	resolução
como	social	ces
educação	educacional	habilidade
estudo	desenvolver	parecer
biológico	crítica	também
condição	ética	considerar
teoria	cultural	característica
modalidade	sustentável	intelectual
exercício	solução	autonomia
oferecer	capaz	apto
objetivo	contexto	acordo
licenciar	ambiental	competência
licenciatura	reflexão	objetivo

Figure 3: DHC of objectives and competences

In the DHC, we analyzed 15 texts, which generated 207 text segments with a proportion of 151 ranked text segments (~73%). As can be inferred, it is noticeable the formation of three classes which we associate with three categories on the following Table 3.

Table 3: emerging categories of DHC of objectives and competencies

CLASS	PERCENTAGE	CATEGORY
Class 1	55%	Social and pedagogical development
Class 2	30,5%	Formation towards teaching in Biological Sciences

Class 2	14,5%	Regulation of the profession

Source: Research data (2022)

As the first and most representative mottos of the category, we have “development” and “pedagogical”, indicating that in the PPs is noticeable a link between the role of the teacher and the socioenvironmental development of the communities where this future teacher will work. Mottos like “cultural”, “social”, “sustainability” are found in this class, indicating that, even though there is no direct mention to the STS relationships, they are in some way indicated as objectives within the Biological Sciences undergraduate program.

The second category, which most statistically significant motto is “teaching”, is related to the formation towards teaching, in terms of methodology and content, highlighting previous understanding that there are (as expected), a strong enphasis in questions of content of Biology itself, and teaching questions. At last, the third category speaks about matters of legislation for the formation of the professional.

To better illustrate the categories, we selected the two main mottos of the first class: development and pedagogical. We bring next portions of the text containing them:

> *“(...) to strenghten the relationship between the technical-scientific knowledge and a formation capable of boosting the social development of marginalized populations from a work proposal that focuses in a sistemic way on prevention and conservation strategies of the natural resources and life in general (…)” (UNEAL)*

> *“(...) to contribute to the improvement of basic education and professional education through the development of competences inherent to the teaching activity that surpass the scientific knowledge and adance to the formation of professional competences of pedagogical character relative to the knowledge of investigation and reflection processes about day-to-day practice (…)” (IFB)*

> *“(...) to the mastery of pedagogical knowledge to understand investigation processes that make possible the perfecting of pedagogical practice and to the management of the professional development itself (…)” (IFSUL)*

> *“(...) to contribute to the development in terms of nature conservation, economic growth and improvement of quality of life of the populations, to interact with the modern approaches and principles of sustainable development linking the pedagogical with the biological knowledge (…)” (IFPA)*

We see from the excerpts that the word “development” appears in two contexts: the professional development of skills, and the socioenvironmental development of which the student

must be one of the promoters. Another very representative motto from the first class is "pedagogical".

> *"The economic growth and the improvement of quality of life of the population, appropriating modern approaches and principles of sustainable development linking them to the specific and didactic knowledges" pedagogicals (IFRN)*

> *"to practice teaching with a mastery of knowledges from the field of scientific knowledge of the natural sciences the education sciences and the pedagogical practices with social and democratic commitment to be guided by principles of democratic ethic" (IFSUL)*

> *"the internalization of knowledges from the specific area of pedagogical knowledges and of the experiential knowledges to provide the formation of teachers focusing on the conscience of diverstity respecting the differences of environmental ecological ethic racial nature" (IFRN)*

Once again, it is noticeable that there is a link between the pedagogical practice and the socioenvironmental commitment in the objectives of the Biological Sciences programs. Which brungs us back the the Scientific and Technological Literacy in a broad perspective of Auler and Delizoicov (2001). Here, the future Science teachers should be trained not only for a bureaucratic and restrictive education, but for the comprehension and acting towards sustainability.

4 FINAL CONSIDERATIONS

The analysis of the objectives, competences and skills of the Pedagogical Projects of the Biological Sciences undergraduate programs of Brazil show that the three axes of Scientific Literacy must be worked in the mentioned programs. However, it is clearly noticeable an enphasis on the scientific formation, in a sense of concepts/procedures of the Biological Sciences field itself. It stays implied the formation of the other axes, even though a later analysis shows the existence of Philosophy of Science/Epistemology classes, and almost no existence of classes the approach the STS relationships properly.

The results of this research indicate that it is necessary to perform a further, deeper stage of analysis about the programs in order to understand how Scientific and Technological Literacy happens in the hidden curriculum, once the formal curriculum does not approach this theme in a more in-depth way in some aspects. This further stage could be done by interviews with the professors and the students, as well as the observation of the teaching spaces. We highlight that these procedures may need more time, may constitute the object of theses and dissertations in the field.

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SOBRE OS AUTORES

A.O. NUNES
Professor de Ensino Básico, Técnico e Tecnológico - IFRN/Campus Mossoró. Licenciado em Química – UERN. Docente do Programa de Pós-Graduação em Ensino. Mestre em Ensino de Ciências – UFRN. Doutor em Química/ Ensino de Química –UFRN. E-mail: albino.nunes@ifrn.edu.br
ORCID ID: https://orcid.org/0000-0002-3585-2137

R. F. LEITE
Universidade Estadual do Oeste do Paraná - UNIOESTE. E-mail: rosana.leite@unioeste.br
ORCID ID: https://orcid.org/0000-0002-0471-337X

L.A. DELLA JUSTINA
Universidade Estadual do Oeste do Paraná - UNIOESTE. E-mail: lourdesjustina@gmail.com
ORCID ID: https://orcid.org/0000-0001-6013-7234

M.F. RODRIGUES
Universidade do Estado do Rio Grande do Norte/UERN. E-mail: manoelfabio@uern.br
ORCID ID: https://orcid.org/0000-0003-0722-7526

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