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Physics Education and Sustainable Development: A Study of Energy in a Glocal Perspective in an Angolan Initial Teacher Education School

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Education is a key element to address sustainable development goals (SDG). This is particularly relevant in developing countries (e.g., Angola) where politicians signed agendas (2030 and 2063), but their commitment is far from expected. One issue of these agendas is the sustainable production and use of energy, where Angola faces a serious situation given the strong petroleum dependence and the weak use of alternative energy resources. Despite recent national policies, physics education in Angola is characterized by traditional practices. Therefore, this study questions how electric energy may be taught in a physics course of an initial teacher education program to develop teacher educators' conceptions and practices. Empirically, the study included a case study (CS) in a physics course for future physics teachers in an Angolan school and an exploratory study (ES) 1 year later. Data collection used a variety of techniques and instruments in the CS (e.g., documental analysis, questionnaire, and physics teachers' documents produced in an intervention action where a didactic sequence about energy was negotiated) and, in the ES, a focus group with physics teachers involved in the CS. Data were treated by statistics and content analysis. Although the results cannot be statistically generalized, they suggest that: with the traditional approach, the future teachers learned academic concepts, but do not know/nor see the importance of local energy resources and do not value their role as active citizens; the teacher educators agreed with the didactic sequence to improve their teaching; 1 year later, teachers referred to have changed their practices. Recommendations pointed to promoting teacher professional development in order to contribute to the SDG and educational research as a collaborative process to support and sustain new practices.

Keywords: education for sustainable development, physics teaching, energy resources and uses, initial teacher education, glocal educational perspective

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INTRODUCTION

This study results mainly from the first author's Master's dissertation (Malavoloneque, 2020), under supervision of the second author, although the second part of the empirical study (the exploratory stage) took place subsequently. Both parts of the study were carried out in the context of an Initial Teacher Education (ITEd) school in Angola.

The research question addressed in the master's thesis was: How the energy topic, included in the electricity curricular thematic, may be taught in a physics course of an ITEd program, having in mind the development of future teachers' knowledge and attitudes so they can become critical and active citizens and professionals? Methodologically, our research involves a case study (CS) approach with one class of 12th grade physics students in a school for future physics and mathematics teachers for the first cycle of secondary education (seventh to ninth grade). The CS was carried out during the academic year 2019, involving all the students of the class ($N = 39$), four physics teachers, and the coordinator of the physics teachers group. The four teachers and the coordinator were all teaching, or had taught, the 12th grade physics course. One year later, and despite the pandemic crisis, the authors contacted the teachers who had been involved in the CS and set up a focus group in order to answer the second research question of this article: What impact the innovative approach had on teachers' practices in the academic year 2020?

The choice to carry out the research in an ITEd program, and in a physics course, in Angola was based in the following four reasons: (a) ITEd is the first step for teachers' professional development, and so it should have a crucial role in developing future teachers' competences for education for sustainable development (ESD), as referred by Albareda-Tiana et al. (2019), even when teaching is seen as a "profession placed within the context of lifelong learning" (European Commission [EC], 2005). Furthermore, and despite educational research in Angola being still scarce, there is some evidence that ITEd does not yet integrate the perspectives of ESD, which takes on board the sustainable development goals (SDG), neither in future teachers' pedagogical projects nor by teacher educators (Chissingui and Costa, 2020); (b) there is still a lack of initiatives in Angola in the context of continuous teacher education, namely for physics teachers (Breganha et al., 2019a), which highlights the need for initiatives toward educational change in ITEd program; (c) research carried out in the country shows that physics teaching, namely in secondary education, is still based on a transmissive model, mainly centered on scholarly knowledge, which does not highlight the social role of physics teaching (Breganha et al., 2019a); and (d) the first author's professional experience as a physics teacher, and as the coordinator of the subject for 7 years, in the school where the study was carried out. Furthermore, his experience also shows worries from his physics students (future teachers) about the irrelevance of the physics they were taught. In other words, students did not seem to recognize the social dimension of physics education (Júnior, 2002).

The option to focus our study on teaching the energy topic lies in two main reasons. The first reason refers to the situation in Angola concerning challenges to energy supply and use. As concerns the first of these reasons, it should be noted that Angola depends mainly on petroleum products to produce energy, notably its electricity. As is well known, petroleum is not a clean energy and so causes many environmental problems. Furthermore, Angola's overall dependence on petroleum (and not just for energy purposes) has been a main contributor to the economic crisis in which the country finds itself. In addition, the popular use of electric energy has contributed to frequent electrical power cuts (Dombaxe, 2011), namely due to an increasing adoption of the consumerist model and lack of information about its use (e.g., in Angola, the use of incandescent lamps is still very common despite their lower efficiency when compared with other lamps, such as fluorescent). Nevertheless, there have been political efforts, namely by the Ministry of Energy and Water [MEA] (2014), toward defining principles and strategies aiming for the promotion of renewable energies, in particular the use of solar and biomass. In fact, according to the Ministry of Energy and Water [MEA] (2014), solar energy should be very important for Angola, which benefits from abundant solar irradiation throughout its territory and for most of the year. This is particularly so in the south part of the country, including in Ondgiva, the capital of Cunene Province, where the study was developed (Welborn et al., 2020). Considering its many rural areas, energy supplied by biomass is another option to facing Angola's energetic problems. Due to Angola's characteristics, but also of other African countries, Lopes (2020) calls for the implementation of a green economy in the continent and questions whether African countries should make similar options to those of the so-called western countries, namely with respect to the sustainability of the continent and the planet.

The second reason relates to the relevance of the energy topic for sustainable development and the fact that educational systems are increasingly regulated by international agendas, such as Agenda 2030 (UNESCO, 2016) and Agenda 2063 for the African continent (African Union Commission [AUC], 2015). One of the goals of Agenda 2030 is dedicated to education (SDG 4: "Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all"). However, education is important to all of the 17 SDG because "(. . .) sustainability in essence poses an educational challenge for humankind" (Bell, 2016, p. 51). Here, we highlight the seventh SDG: "Ensure access to affordable, reliable, sustainable, and modern energy for all." However, despite the fact that these international agendas have been signed, in particular by the Angolan government, the literature shows that the attainment of such goals are far from being reached (Addaney, 2018) and that education plays an important role to change this situation.

Even if education, as Nelson Mandela [1918–2013; President of South Africa (1994–1999) and winner of the Nobel Peace Prize in 1993] once said, is a "powerful weapon to change the world," Paulo Freire (1921–1997; a famous Brazilian educator and philosopher best known for his work on the *Pedagogy of the Oppressed*) also added that "Education is not enough to change the world, but it can change people, and people can change the world." However, this can only happen if education has a transformative approach, aiming not only to transmit knowledge but also to change students' attitudes. Although, as mentioned above, it seems that Angolan education practices are still far from this scenario, a process of curricular revision is currently underway (Afonso, 2019), which aims to develop in students what is designated by the acronym CHAVE (meaning "key" in Portuguese), that is, knowledge (C), abilities (H), attitudes (A), values (V), and ethical principles (E). Furthermore, despite the centralized functioning of the educational system, a recent governmental decree calls for the need to give schools and

teachers pedagogical autonomy (Julião, 2019) so that they can combine universal knowledge with local knowledge. Thus, in this study, we talk of a glocal (global–local) perspective (Robertson, 2012). According to John et al. (2017), a glocal curricular perspective.

> "[. . .] captures the importance of integrating both local and global considerations when addressing the pressing real-world sustainability problems of our time. (. . .) A glocal teaching-learning environment organizes spaces, places, and people so as to allow students to learn how to address real-world sustainability problems in local and global contexts." (p. 31).

In summary, the challenges that the Angolan society in general, and the educational system and practices in particular, face today demand highly qualified teachers, and this qualification must come namely from ITEd programs.

MATERIALS AND METHODS

In order to answer the two research questions presented above, a CS approach was carried out in the academic year 2019 and then combined with an exploratory study (ES) 1 year later. As referred by Yin (1981), a CS is the adequate research approach when the researcher aims to understand deeply a unique phenomenon in a given context, and therefore it should use a variety of research techniques and instruments to collect data. As the CS concerns a unique phenomenon in a given context, the results cannot be statistically generalized; however, they can contribute to theory and applied in similar contexts. In our study, the phenomenon to be studied was how the curricular topic Energy, included in the electricity thematic, was planned and taught in a 12th grade physics subject in an ITEd program and how it could be innovated taking into account the social relevance of physics education in general and, in particular, as concerns the topic of electrical energy (energy resources to produce it and their uses) in a glocal perspective. The context of the CS was the school "Magistério de Ondjiva," which has, among others, an ITEd program for physics and mathematics teachers for the first cycle of secondary education (seventh to ninth grade), and its surroundings (Province of Cunene). It should be noted that, and unlike what happens in other countries, namely in Europe (European Commission [EC], 2005), the school is not a higher education institution, but belongs to the previous educational level (secondary school). The ITEd program for physics and mathematics teachers, as all other programs in the school, has a duration of 3 years (from the 10th to the 13th grade).

As in all CS, the context of the study (the school and its surroundings) should be characterized. As referred above, the school is located in Ondgiva (the capital of the Province of Cunene), in the south of Angola. Cunene is a rural region, although, due to its dry and semi-desert tropical climate, the soil does not have the best conditions in which to develop many agricultural activities, although corn, beans, tobacco, sugarcane, wheat, and citrus fruits are cultivated. The main economic incomes come from the exploitation of wood and livestock, mainly goats and cattle. It should be highlighted that Cunene has very high levels of solar energy radiation and, due to its agricultural activities, is rich in biomass. Therefore, solar energy and biomass can be clean alternatives to produce electrical energy, especially when compared with petroleum. One interesting information about the context of our CS is that the Board of Renewable Energies of the Ministry of Energy and Water [MEA] (2014) produced the "Mapping the Wind and Solar Energy in Angola Project" (MINEA, 2017), with the main aim of identifying the Angolan regions with potentialities to apply new energy resources to produce electrical energy. In fact, Cunene has been identified as one of them, namely due, as referred, to the high solar radiation during the whole year and, as a consequence, in 2018, the first power plant using solar energy to produce electricity being inaugurated in the Province, in the village of Xangongo, about 100 km from Ondgiva (Agency Angola Press [ANGOP], 2018), and therefore could be a location for an outdoor school activity, as suggested in the intervention action.

Table 1 presents a summary of the techniques and instruments used to collect data in both empirical studies (CS and ES), and, for each, the specific questions to be answered. As **Table 1** indicates, in the CS, five techniques/instruments were used: documental analysis of the (a) official curricular program used in 12th grade physics; (b) didactical materials produced by the physics teachers for their classes; and (c) four written physics tests produced by the physics teachers. All these aimed to characterize physics teaching in the 12th grade. The second instrument was a questionnaire applied to all 12th grade physics students about knowledge and reported attitudes concerning energy resources and their use in a glocal perspective, in the academic year before the work done by the researcher with the physics teachers, with the aim to characterize students' previous knowledge and attitudes. The third were physics teachers' reports collected during the action intervention, aiming to understand the relevance of the innovative plan previously developed by the researcher. The fourth was the researcher's written diary that included his thoughts about the research process in general and during the planning and the work developed with the physics teachers in particular, aiming to complement the description and interpretation of the study carried out. The fifth was an interview conducted by the researcher with the physics coordinator of the school, which aimed to evaluate his perception about the action intervention and its possible impact on physics teachers' future practices. In the ES, a focus group was carried out with teachers who participated in the action intervention 1 year later, aiming to understand the impact the intervention had on their practices.

The data collected were treated, as referred previously, by descriptive statistics (the open questions of the questionnaire) and content analysis (Bardin, 2011).

RESULTS AND DISCUSSION

Following **Table 1**, this section presents and discusses the main results achieved, first with respect to each question in the table and then by triangulating all the results.

- What is planned, officially and at the national level, for the 12th grade of the physics subject for future physics and mathematics teachers for the first cycle of secondary education?

The curricular program for the 12th grade physics subject for future physics and mathematics teachers for the first cycle of secondary education is an official document developed by the National Institute of Research and Educational Development (INIDE) of the Angolan Ministry of Education and constitutes Annex V of the whole program for physics and mathematics ITEd (Physics Official Programme for 12^{th} grade Subject, 2013). The annex is 12 pages long and includes an introduction framing the physics subject, the general objectives of the subject, the general objectives for the 12th grade, the contents, methodological suggestions, assessment, and bibliography. The instrument developed by the authors to analyze this document included the following main dimensions: (a) the presence of the social role of physics education (in the introduction and objectives), namely with respect to the role of the future teacher; (b) the contents proposed with regard to the topic Electricity and Energy; and (c) the proposed teaching, learning, and assessment methodologies.

The analysis showed explicit references, in the introduction and general objectives sections, to the social role of physics, in particular concerning the training of future teachers {for example, "[The subject] (. . .) aims to provide to the future teacher (. . .) necessary competences towards a global training (. . .) making them informed professionals and capable of acting in a responsible way in problem solving (. . .)."—Introduction, p. 105}. From the eight general objectives defined for the 12th grade, two seem to express the social role of education ("To develop initiative, creativity, rigor, responsibility, tolerance and solidarity," Objective 5, p. 106, and "To understand the implications of scientific and technological knowledge about social problems," Objective 6, p. 106). However, the 13 objectives defined for the physics subject are mostly related to the acquisition of academic knowledge (for example, "To know the electrical field," Objective 2, p. 107, and "To understand the dual behavior of Light, namely as a particle and a wave," Objective 10, p. 107). Only two objectives refer to the articulation between physics and society ["To apply Radioactivity knowledge in Technology and Medicine (. . .)," Objective 12, p. 107, and "To understand the fusion and friction of atomic nuclei as a possibility to solve world energy problems," Objective 13, p. 107]. It should also be noted that the last objective is the only one which refers to the energy concept, and certainly not in a local perspective, as nuclear energy is not a solution in use in Angola.

Regarding the contents of the subject, the four pages (pp. 108–111) dedicated to this present seven topics, the first three in the field of electricity. However, all the contents are presented in an academic format, that is, specifying only the topics to be learnt, such as concepts and laws (for example, electrical charge and Coulomb law, p. 108) without any contextualization. The only reference to electrical energy is as a subtopic of topic 2 ("Electrical

TABLE 1 | Data collection techniques and instruments used in both empirical studies and specific questions to be answered.

CASE STUDY	
Data collection techniques and instruments	**Questions to be answered**
Documental analysis of:	
The official national curricular programme of the 12th grade physics subject (2013)	What is planned, officially and at national level, for the 12th grade of the physics subject for future physics and mathematics teachers for the 1st cycle of secondary education (general and specific aims, contents and teaching-learning, and assessment methodologies)?
The didactical materials produced by the teachers to prepare their 12th Physics classes about the topic Electricity in 2019 (p. 41)	What was planned by the 12th grade physics teachers for their classes in the school year 2019, about Electricity (aims, content, and methodologies)?
4 written tests produced by the physics teachers (2 from the school year 2016, 1 from 2017, and 1 from 2018)	What aspects were valued by the physics teachers in summative written tests?
Questionnaire to 12th grade physics students	What was the knowledge and reported attitudes of the 12^{th} grade physics students (N = 39), after they had been taught Electricity in the school year 2019, namely about Energy resources and their use and, in particular with respect to Angola/Province of Cunene?
Teacher reports produced during an action intervention (of around 10 h) lead by the researcher (1st author of this study) on: (a) how they teach the Electricity topic; (b) their opinions about an innovative teaching plan previously developed by the researcher, and discussed with the teachers during the intervention action; and (c) their evaluation of the intervention action and possible effects on their practice	How do the physics teachers (N = 4) with experience in teaching the 12th grade, including the physics coordinator, analyse (evaluate and propose changes) the relevance of the innovative plan previously developed by the researcher, namely when compared with (a) their previous methodology for teaching the electricity topic and (b) the results of the students' questionnaire on energy resources for electricity production and their uses, in a glocal perspective?
Research diary	What was reported by the researcher in their written diary throughout the research process, mainly with respect to the design of the innovative teaching sequence and the intervention action with the physics teachers?
Interview to the physics coordinator	How does the physics coordinator evaluate the action intervention, and the possible effect on the physics teachers' future practices?
EXPLORATORY STUDY	
Data collection technique and instrument	**Questions to be answered**
Focus group, with a semi-structured format, with three of the physics teachers involved in the case study, one year later	One year later, how did the physics teachers who participated in the Case Study describe and justify the effect of the intervention action on their practices?

Field," p. 108), and again in an academic format ("Electric Field Energy," p. 108).

The teaching, learning, and assessment methodologies are, in general, aligned with up-to-date educational perspectives (Guisasola et al., 2017); that is, they include active ways of teaching and learning (for example, individual search and study visits, p. 113) and assessment (for example, the use of the three assessment approaches: diagnostic, formative, and summative, p. 113).

As to the recommended biography (p. 113), this includes nine sources corresponding to traditional physics books (three) and textbooks for secondary physics education in Portugal, this most probably due to the influence of Portugal in Angola, which was under Portuguese occupation until 1975. Therefore, it may be observed that the suggested physics books do not present physics concepts in a daily life perspective (as, for example, Bueche, 1981, does) and the physics textbooks are certainly not related to the Angolan context as they belong to the Portuguese educational system.

In summary, and despite some alignments with the current physics education perspectives for ITEd programs, in particular regarding teaching, learning, and assessment approaches, and a few references to its social role (mainly in the introduction), the other components of the program do not seem to guide physics teacher educators as to what is expected nowadays, namely by exploring contents in a contextualized way.

- What was planned by the 12th grade physics teachers for their classes in the school year 2019 about electricity?

When the physics teachers were asked to present the material produced to prepare their 12th grade classes about electricity, a 41-page document was provided. The analysis of this document showed that they are mostly concerned with the description of the contents to be taught (for example, the definition of concepts, laws, and their respective mathematical equations), including some examples of exercises and their resolutions, mainly centered in the mathematical dimension of physics (for example, the application of the Kirchhoff laws for particular electrical circuits). There were occasional references to the history of physics [for example, the introduction of the field concept by Michael Faraday (1791–1867), p. 4], but only as historical facts, without contextualizing the evolution of scientific knowledge as suggested in the literature (Lu, 2020). There is only one reference to electrical energy, when the concept of capacitors is developed and defined ["The property of these devices is to store electrical energy in the form of an electrostatic field (. . .)," p. 13]. Nowhere in the document are the learning outcomes specified, nor the teaching, learning, and assessment approaches discussed, nor even any contextualization to daily life and society provided.

In summary, the materials produced by the physics teachers to prepare their classes differ significantly from what are proposed as lesson plans/sequences (Eylon and Bagno, 2006). More importantly, the materials do not discuss the social relevance of physics and its glocal contextualization, which does not foster an approach toward ESD, as suggested, for example, by Albareda-Tiana et al. (2019).

- What aspects were valued by the physics teachers in summative written tests?

The answer to this specific question emerged from the analysis of four written tests produced by the 12th grade physics teachers, two from the academic year 2016 and one each from 2017 and 2018. The instrument used to analyze these tests was adapted from the grid developed by Breganha et al. (2019b). Similarly to the that study, which refers to the first cycle of a secondary school (seventh to ninth grade) in Lubango (Angola), the results indicated that the tests, in general, included short questions (e.g., to define a physical concept) and questions where students have to use mathematical equations to find the value of certain physical variables (e.g., the intensity of the electrical current in a given electrical circuit), but none of the questions refer to daily situations nor are locally contextualized. An exception could be found in only one question (in the written test of 2018) where the introduction of the first question refers to the electric rheostat device used in electrical lamp switches. However, the question asks for an answer about the value of electrical variables not related to electrical lamp circuits. The same type of situation was also found in Breganha et al. (2019b), as it is designated by the authors as "pseudo-contextualization."

Although the materials produced by the teacher do not identify students' learning outcomes, the written tests value students' knowledge acquisition about the conceptual and mathematical dimensions of physics without considering its social role and its importance in promoting glocal knowledge. This seems to be aligned with what the physics teachers did with the didactical materials for the preparation of their classes.

- What was the knowledge and reported attitudes of the 12th grade physics students after they had been taught electricity in the school year 2019, namely about energy resources and their uses, in particular with respect to Angola/Province of Cunene?

A questionnaire developed by the first author of this study, piloted with 12th grade students of another ITEd school with a physics and mathematics program, was applied to the 12th grade students ($N = 39$) of this study at the end of the academic year 2019. The questionnaire consisted of two main sections: the first contained 15 sentences about energy, in general (eight) and in the Angola/Cunene context (seven), which the students had to assess in a Likert-type scale of five values (from complete agreement to complete disagreement and with a last value for "no opinion"); the second section with two open-ended questions: the first asking students to refer two attitudes they consider important to have toward electrical energy consumption and the second asking for one suggestion concerning the management of electrical energy resources in the Province of Cunene.

The closed questions (first section) were analyzed using simple descriptive statistics (percentage calculation) and the open questions through content analysis. **Table 2** indicates

the results of the first section of the questionnaire. We distinguish the generic sentences from the sentences about energy in the Angolan/Cunene context by showing the latter in italics.

The results from the questionnaire, as shown in **Table 2**, indicated that the majority of generic sentences (five out of eight) are correctly answered by the students, which suggests that they have acquired some knowledge about energy [e.g., what is petroleum as a source of energy (S2) and the classification of energy resources as renewable and non-renewable (S14)] and also that students seem to be aware of the danger to the planet from the use of non-renewable sources of energy (S13 and S15). However, their position on other sentences, for example in S5 ("Non-renewable energy resources are limitless because nature can replace them") where a considerable percentage of students do not have an opinion, may raise questions about the consistency and depth of their knowledge. Also, the results suggest some lack of knowledge about alternative and clean energy resources, such as plastic and waste.

Regarding the seven sentences about energy in the Angolan/Cunene context, only one sentence (S6) was answered correctly by the majority of students agreeing that petroleum is the most used electrical energy resource in Angola. In relation to the other six sentences, either the majority of students answered wrongly [e.g., by saying that the energy resources used in Angola are mainly renewable (S9)] or show some lack of knowledge about local energy resources and uses (such as plastics, waste, and biofuels) or even the use of solar energy. Interestingly, a considerable percentage of students express their awareness about the fact that their (lack of) knowledge about energy resources prevents them from participating actively in the conservation of electrical energy.

With respect to the first open-ended question (second section of the questionnaire), the results indicated that the majority of students gave answers that were classified as "Correct uses of electrical energy," e.g., by avoiding consumption in certain situations, such as to switch off electrical lamps during the day or electrical devices when they are not in use.

In the second open-ended question, concerning students' opinions about the management of electrical energy resources in the Province of Cunene, around 42% of the responses were classified as "Concrete proposals for energy resource management in the Province" (e.g., to build hydroelectric dams to avoid dependence on the Province of Namibe or to expand the electrical energy distribution grid), followed by "General proposals," accounting for around 28% of students' answers. This latter category of answers, although highlighting the need to improve the electrical energy resource management in the province, does not make explicit how to do so (for example, "It is very important to manage the electrical energy resources of the province as energy is fundamental for the development of society"). Only a small percentage of responses (around 3%) were classified as "Personal responsibility," i.e., answers referring that management of electrical energy resources could depend on the citizens (for example, "People may propose to the Town Hall ways of better managing electrical energy resources"). A positive aspect concerning the results of these two open questions was the very reduced number of "No replies" or "Non-classified replies"

TABLE 2 | Students' positions toward sentences from the questionnaire about energy in general and in the Angolan/Cunene context.

Statements in which the majority of students (more than 70.0%) agree, in decreasing percentage of agreement
S2 – Petroleum is an energy resource consisting of a fossil ore that, when processed, gives rise to several by-products (for example, gasoline, diesel, and electricity in thermoelectric plants) (92.0%)
S1 – Energy can be obtained from different resources (87.0%)
S6 – *The most used electrical energy resource in Angola is petroleum* (84.0%)
S14 – Energy resources are classified as renewable and non-renewable (77.0%)
S13 – The increasing use of renewable and non-polluting energy sources represents one of the main hopes for the reduction of environmental impacts on the planet (77.0%)
S9 – *In Angola, energy sources used are primarily renewable, such as wind, solar and hydroelectric energy* (74.0%)
S15 – A good use of electrical energy reduces waste and investments in the construction of petroleum-based energy generating plants, preserving the environment for future generations (74.0%)
Statements with a relative balance between agreement and disagreement (the percentages for each of these positions is greater than 30.0% and less than 60.0%), in decreasing order of the difference of these percentages
S12 – *The energy sources currently used in Angola contribute to the increase of environment pollution* (20.5%)
S3 – Materials such as plastic and waste are energy resources (18.0%)
S14 – By saving electrical energy we are postponing the need to build more petroleum-based energy generating plants (11.0%)
S11 – *My own lack of knowledge about energy resources and their importance prevents me from participating actively in the conservation of electrical energy* (5.1%)
S10 – The energy resource most used in your Province is the Sun (2.0%)
Statements in which there is a considerable number of students who expressed not having an opinion (percentage higher than 15%), in decreasing order
S8 – *The production of electrical energy from biomass is part of the government policies of several countries, including Angola* (22.0%)
S7 – *In addition to petroleum, in Angola other energy resources are also used (for example, biofuels)* (22.0%)
S5 – Non-renewable energy resources are limitless because nature can replace them (21.0%)

Sentences about energy from the Angolan/Cunene context are shown in italics.

(less than 5%), which seems to indicate students' commitment to participation in the study.

- How did the physics teachers (N = 4) with experience in teaching the 12th graders who participated in the intervention action, including the physics coordinator, analyze the relevance of the innovative plan previously developed by the researcher?

As referred above, the CS included an intervention action, developed in three sessions (October 18, November 29, and December 20, 2019, for a total of 10 h), with all the physics teachers with experience in teaching the 12th grade (N = 4), including the physics coordinator, with the aim to analyze an alternative teaching plan focused on the topic of electrical energy resources and uses in a glocal perspective. At the end of each of the three sessions, an individual written reflection was requested of each participant, aiming to evaluate the action. Although the teachers did not elaborate much on their answers, may be due to a lack of reflective practice among Angolan teachers (Breganha et al., 2019a), they highlighted three main ideas: (a) the need for a different approach from what they had done so far in teaching the topic of electricity by including the topic of electrical energy resources and uses in a glocal perspective in order to develop the social role of physics; (b) the approach used by the researcher during the sessions should provide a participative environment, and the topics approached with an alternative teaching, learning, and assessment about energy resources and their uses should be integrated in the topic Electricity (see an example in **Table 3** below); and (c) the format used in the alternative teaching sequence, namely the clarification and articulation between the learning outcomes, the contents, and the teaching, learning, and assessment activities. This last result may be seen as the teachers having found more usefulness in this approach than in what they used to do in preparing their lessons, which included, as referred above, mainly the development of scientific knowledge about electricity.

- What was reported by the researcher in their written diary throughout the research process, mainly with respect to the design of the innovative teaching sequence and the intervention action with the physics teachers?

The researcher, the first author of this article, kept a diary on what he thought as more important in the research process, namely while developing the alternative teaching sequence and during the intervention action with the teachers.

Regarding the development of the alternative teaching sequence, and based on the literature review carried out, the researcher systematized the following five principles to be considered in it: (a) to focus the teaching process on the students, namely on their previous knowledge, on the ways they may acquire meaningful learning, and on their interests; (b) to promote students' learning toward the development of knowledge, abilities, and attitudes based on scientific knowledge with a social dimension and in a glocal perspective; (c) to promote collaborative learning among students; (d) to define expected learning standards and develop educational materials to contribute to their achievement; and (e) to promote assessment as a way of learning, namely through continuous formative assessment.

The diary then presents the alternative teaching sequence designed by the researcher, which included the plans of three physics lessons. As an example, the first lesson plan is presented in **Table 3**.

The other two lesson plan proposals have a similar format. For example, in the second lesson, the teacher, in collaboration with the students (future teachers), plans and implements the construction of a solar oven with low-cost materials; as an extra classroom activity, the teacher plans a visit to the first solar energy power plant in the village of Xangongo.

Regarding the preparation of the intervention action with the physics teachers, in order to present and negotiate the alternative teaching sequence, the researcher wrote and justified the options taken. These were as follows:

(a) To take on board the professional experience of each participant, in particular how they taught the topic Electricity in previous years, given the importance of the social constructivist approach (McLeod, 2019);
(b) To present and discuss with the teachers the main results that emerged from the students' questionnaire due to the potentialities that this information may have in changing teachers' previous practices; and
(c) To present and discuss the proposed alternative teaching sequence only after the previous steps, given the constructive perspective which refers the importance for learning, namely in the context of teachers' professional knowledge, the motivational dimensions, and what the teachers already know.

Regarding the intervention action itself, the researcher reports some critical events, such as: "Teachers were very interested in understanding the results presented to the students' questionnaire" (regarding the first session of the intervention, October 18); "After teachers reflections about the way they used to teach electricity, and confronted with the questionnaire results, they seemed to realize the need to change the teaching practice" (regarding the first session of the intervention, October 18); "Despite my expectations, teachers did not propose changes to the lesson plans, and only seemed to agree with them, although they present some doubts about the feasibility of the extra class activity, that is, the visit to the energy power plant in the village of Xangongo."

- How did the physics coordinator evaluate the action intervention and the possible effects on physics teachers' future practices?

At the end of the intervention action, the researchers conducted a semi-structured interview with the physics coordinator of the school. **Table 4** summarizes the main questions asked and the answers provided, with some examples of the interviewee's speech.

Given the results to the seven research questions just presented, it may be stated that the CS showed that it is possible to design an alternative sequence to teaching the topic of Electricity in the 12th grade, namely by introducing the topic of electrical

TABLE 3 | Proposal of the first lesson plan of the alternative teaching sequence.

LESSON PLAN N. 1				
School: "Magistério de Ondgiva"				
Speciality: Physics and Mathematics			**Subject:** Physics (12th grade)	
Date: xxx			**Duration:** 45 min	
Topic: Most common energy resources, namely to produce electricity, in Angola and in the region				
Learning outcomes	**Contents**	**Teaching and learning activities**	**Resources**	**Assessment**
To become aware of the need to develop knowledge and attitudes toward energy to their students (future teachers)	Main results of the questionnaire applied previously to the students	Teacher presentation and discussion with the students about the main questionnaire results	Overhead projector	Grid to register students' participation in the class by the teacher Worksheet to be filled in by the students on (a) the main aspects learned in the class, and (b) the formulation of two questions students would like to learn more about the topic
To characterize the most common energy sources and possible uses in Angola and the region	Most common energy resources in Angola and the region, and possible uses	Teacher presentation, and dialogue with students, about the topic of the lesson Questions to students to interpret the images about energy resources in Angola and in the region, and possible uses Synthesis of the topics discussed in the lesson, done by the teacher in collaboration with the students	Images with graphics about (a) solar radiation in Angola and in the region, (b) percentage of other existing resources in Angola and in the region (for example, biomass, plastic and waste)	

energy resources and uses in a glocal perspective. Both the physics teachers and the physics coordinator agree that this possibility may be implemented in their classrooms, given the curricular flexibility existing in the school and, we may also add, due to the increasing pedagogical autonomy given to schools that is present in a recent Angolan decree-law (Julião, 2019). However, some constraints in such an implementation may be foreseen given its novelty when compared with the official physics program, which is not very explicit in guiding teacher educators on to use this kind of approach, and also due to teachers' previous practices, particularly with regard to their teaching materials and written tests. Thus, continuous support should be given to teachers in this transformative process. The alternative approach implementation may influence physics teachers' future students, making them more aware and knowledgeable of the topic of electrical energy resources and uses in a glocal perspective. The development of such an alternative approach may also prepare future physics teachers better to teach toward ESD and, therefore, contribute to the goals of Agendas 2030 and 2063. However, this may be enhanced if incorporated in other subjects of the ITEd program (for instance, in the subject of physics methodology and teaching practice).

Finally, the ES which took place 1 year later, complementing the CS, addressed the following question:

- One year later, how did the physics teachers who participated in the CS describe and justify the effect of the intervention action on their practices?

To answer this question, a focus group was set up with three of the physics teachers involved in the CS, that is, teachers with experience in teaching physics in the 12th grade in an ITEd program. The fourth teacher could not participate due to health problems. The results indicated that all three teachers, and despite the pandemic situation which forced Angolan schools to close down for a period of about 2 months, answered that their practices have been influenced by the work done, namely the intervention action where the new teaching proposal was presented and discussed. As examples of such effects, teachers refer mainly the new way of lesson planning, by specifying learning outcomes and in alignment with them; the contents to be taught; the teaching, learning, and assessment activities; the inclusion of more practical activities, in contrast to the transmissive model centered on uncontextualized scenarios; and not including the social role of physics, as they have previously done. One teacher gave the example of the construction of a solar oven with low-cost materials with his students, as previewed in the alternative teaching sequence discussed during the intervention action. The visit to the solar energy power plant in the village of Xangongo could not be carried out, now also due to the constraints imposed by the pandemic.

FINAL CONSIDERATIONS

This study has highlighted the importance of conceiving new teaching, learning, and assessment practices in physics classes for future teachers with the aim to contribute to the achievement of an ESD, as other researchers have been suggesting (Nurfaradilla et al., 2020). Using a CS about energy resources and uses to produce electricity, a new teaching sequence was developed in an attempt to provide teachers with new knowledge about local problems, such as how electrical energy is produced and used in their surroundings, in the country, and in other countries (glocal perspective), how it affects the country/regional environment and economy, and the different ways to produce electrical energy using cleaner and existing local resources (such as solar and biomass). This approach also aims to change students' (future teachers') attitudes, giving them more responsibilities in order to increase critical citizenship, which is certainly important for their future teaching practices. Doing this in an ITEd program, namely in physics classes, aims, therefore, to contribute to students' new practices in their future professional contexts toward an ESD in a glocal perspective. The results show that the manner in which physics was taught to them (according to the course program, teacher materials, written tests, and what they express in the first session of the intervention action) did not include the social role of physics teaching with respect to the topic of electricity. This means that students, who are the future physics teachers, did not acquire knowledge on the different ways of producing electrical energy using local and cleaner resources (solar and biomass), preventing them from taking on social responsibilities regarding this topic. The results also show that it is possible to

TABLE 4 | Main questions asked and answers provided by the physics coordinator, with examples of the interviewee's speech.

Question to the physics coordinator (as the coordinator of the physics subject. . .)	**Synthesis of the main answers and illustrative interview transcriptions**
Q1 – . . . do you consider that the intervention with the teachers was an enriching moment for their professional development?	Yes, because "(. . .) the approach used was very good (. . .) and it will contribute to the improvement of the teaching of the physics subject in the school (. . .)"
Q2 – . . . how do you evaluate the proposed alternative teaching sequence?	The proposal will enhance the Physics teaching, learning, and assessment process of the 12th grade: "(. . .) yes, certainly the topic and the way it can be developed will contribute to the improvement of students' learning in 12th grade."
Q3 – . . . what intentions, if any, do you have to continue to work with the alternative sequence in the next academic year?	The alternative sequence should be used by the 12th grade physics teachers in the academic year 2020, considering all that has been learned. This is possible due to the curricular flexibility of the physics programme in the school: "(. . .) taking into account what we have learned, we intend to apply the didactical sequence according to the curriculum flexibility (. . .) new content will be introduced to enrich students' learning in the next academic year "

plan innovative ways of teaching the energy topic and that, when this is done in collaboration between researchers and teachers, it seems to affect teacher educators' practices.

Since the study was carried only in an ITEd school in a physics course, and with respect to the electrical energy topic, some recommendations for ITEd emerge. These are: (a) to carry out more actions to promote physics teacher educators' professional knowledge, also in other curricular topics, and (b) to include in such actions other teacher educators, for example those responsible for physics methodology subjects and for teaching practices, so that the whole pedagogical project of the ITEd program, and teachers' education practices, could be articulated toward supporting ESD. This would contribute to the achievement of the goals of Agendas 2030 and 2063.

This study has not included the supervision of teacher educators' practices nor of future teachers, namely in their teaching practices, which is in the actual schools where they will continue to develop their knowledge. Thus, another way to pursue research would be to develop action-research participative projects in collaboration between teachers and educational researchers, as also referred by Hines et al. (2016). If the collaboration between teachers and educational researchers is to be relevant, it should attempt to develop teachers' ownership (Valdmann et al., 2020), that is, making teachers competent and responsible to pursue their educational practices, making them authors of their professional knowledge construction and development.

DATA AVAILABILITY STATEMENT

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by the Direção da Escola do Magistério Primário de Ondgiva. The patients/participants provided their written informed consent to participate in this study.

AUTHOR CONTRIBUTIONS

GM was responsible for the case study and exploratory study approach, and for the revision of the proposal. NC was responsible for the scientific supervision of the research conducted by GM and for the writing of the 1st version of the proposal. Both authors contributed to the article and approved the submitted version.

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