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Design and construction of a mini wind turbine for second-year science students: Case study of learning a skills-based approach

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Abstract

The aim of this work is to demonstrate the feasibility of assembling a wind turbine from a 12V coil in the context of secondary education. Through an educational and practical approach, the study shows how students can learn the basic principles of wind energy by building their own wind turbine from simple and accessible materials. This project allows students to develop their skills in DIY, science and technology, while raising awareness of the importance of renewable energies in the energy transition. This work highlights the importance of environmental and technology education from an early age to train tomorrow's citizens who are aware of energy and environmental issues. Our subject raises questions such as: what is a wind turbine made of and how does it work to produce electricity? What is the role of the 12V coil in this process? How can students put these theoretical concepts into practice through assembly and observation experiments? By addressing these concerns, students will be able to gain a thorough understanding of the physical principles involved in generating electricity from a wind turbine, while developing their experimentation, analysis and problem-solving skills. The results of this study provide valuable insights into how wind energy can be used to generate electricity and show how basic physics principles can be applied in practice.

Keywords: Wind energy; 12V coil; Secondary education; Environment; Technology; Physics

1. Introduction

Physical science is a discipline that studies the properties of matter and expresses the laws that make material phenomena observed. It tries to understand, model and explain the natural phenomena of the universe in all its forms, the laws of its variations and their evolution in order to draw predictions and functional applications. For this reason, our dissertation theme entitled: "Study of the physical concept in application of the principle of electrical production from a wind turbine". The choice of this theme is not random because in the national education program of Chad, there are several types of energy that are studied in the first-year classes. As for renewable energies, among others, wind energy by its design and its production of electricity from the wind is not studied but cited only as an example among those studied in the program. Thus, the choice of this theme will allow for practical work on assembling a mini wind turbine, which the first-year student will learn about certain realities, how the wind turbine is designed and how it generates electricity through the movement of the wind. By getting used to it, the student will become interested in it and this will arouse in him the desire to continue his studies in this field in an engineering school.

Renewable energies represent a large part of our energy future. They have their own advantages: they are inexhaustible, environmentally friendly (no waste released into nature) compared to fossil fuels such as coal or oil. They also help to combat the greenhouse effect and air pollution. [1].

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Wind energy is an effective solution to combat global warming and limit our CO2 emissions. Indeed, wind turbines convert wind energy into electricity without producing waste or emitting greenhouse gases. This clean and renewable electricity replaces that of polluting power plants [2].

Wind energy is widely recognized as a clean and renewable source of energy, capable of reducing our dependence on fossil fuels and combating climate change.

Understanding its design, how it works and how it generates electricity is essential to raise awareness among 1st year students about current and future energy issues.

Then, the assembly from a 12V coil allows students to put into practice the theoretical concepts learned in class, such as the notions of magnetic fields, magnetic flux and electromagnetic induction. This allows them to better understand the link between theory and practice and to develop their problem-solving skills.

This study can also arouse students' interest in science and technology, by involving them in concrete and stimulating experiments.

In the national physics curriculum for first-year students in Chad, the chapters on energy are as follows:

- Kinetic energy
- Power and electrical energy
- Potential energy and mechanical energy
- Conservation of energy
- Energy balance.

Among its chapters that talk about energies taught in the first-year class, wind energy which is a form of energy of complex concept is not in the teaching program. Therefore, we propose it in our case study. To do this, we had assembled a mini wind turbine at the AfricLab laboratory

For the assembly of our mini wind turbine, we made it so that, when the blades turn, they turn a generator that converts mechanical energy into electrical energy. This electrical energy is then stored in our 12V coil.[3]

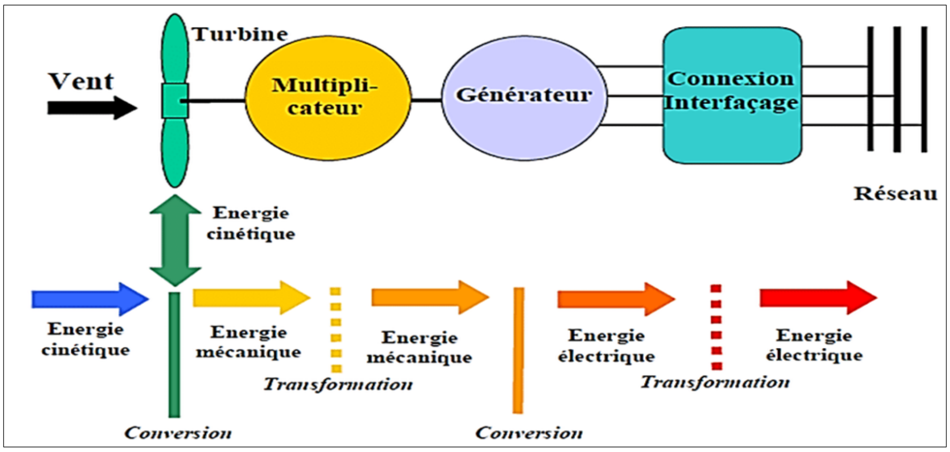

Figure 1 Principle of energy conversion [4]

By connecting the electrical wires to our coil, we can observe the appearance of an electric current that circulates and powers a bulb or LED (light-emitting diode). Our assembly can rotate as long as possible if it is placed in a direction where a wind of sufficient quantity blows and can generate a current with a power of 27.725 W and an intensity of 2.31A. If we go full-scale, the blades are 25 m to 60 m long and make 5 to 25 revolutions per minute. In our case, thanks to this assembly, teachers will be able to illustrate in a concrete and understandable way the different physical phenomena involved in the concept and production of electricity from a wind turbine, which will allow students to better understand the operation of these systems and the advantages of wind energy. We illustrate in the following figure 1 the assembly form, the constitution as well as the principle of energy conversion of a wind turbine.

1.1. This conversion is done in two steps

At the turbine (rotor), which extracts part of the kinetic energy of the available wind to convert it into mechanical energy.

At the generator, which receives the mechanical energy and converts it into electrical energy, then transmitted to the electrical network.

To carry out this assembly, students will need some basic equipment such as a 12V coil, a fan, electrical wires, a multimeter and a support to fix the fan.

The operating principle is as follows: the wind that turns the fan blades generates kinetic energy, which is then transformed into electrical energy by the coil. By rotating in the magnetic field of the coil, the wind generates an electric current that can be measured using a multimeter.

A formula also used in the first-year class was illustrated at the beginning of Betz's law (E = 1/2 mv2) which is the formula for kinetic energy. This experiment will allow students to understand how a wind turbine works, the different forms of energy, as well as the transformation of kinetic energy into electrical energy. They will also be able to learn how to measure and analyze the data collected.

In short, this wind turbine assembly from a 12V coil is an instructive educational activity for first-year students. It will allow them to discover the basic principles of renewable energies, the design of a wind turbine and its conversion into energy, while developing their skills in handling measuring tools.

This is how ADAM MIRECKI worked on: "Comparative study of energy conversion chains dedicated to a small-power wind turbine".

His study compares the architectures and energy management strategies for a wind system based on Savonius-type sails. The introduction of an MPPT device is necessary to maximize energy efficiency. Different control modes are possible, either directly in torque or speed, or indirectly by the current controller on the DC bus side. A fuzzy logic search is considered in case of unknown wing characteristics. Simple energy conversion structures are studied to minimize costs, compared to an assembly based on the MLI rectifier. A dedicated test bench was set up in parallel with the system modeling/simulations, allowing the evaluation of the different structures and control strategies according to the wind speed [5].

MEGHNI BILLEL worked on: "Contribution to improving the performance of a wind energy chain". He says, in variable speed wind turbines, improving energy efficiency requires sophisticated control techniques to obtain optimal conversion of aerodynamic energy. A comparison of the five maximum power point tracking (MPPT) methods showed the superiority of the fuzzy logic (FLC) based technique. This approach allows efficient regulation of the power exchange between the generator and the electrical grid. The simulation results confirmed the efficiency and reliability of this control strategy [6]. ZERARI NAZIHA worked on: "multi-objective modeling and optimization of a horizontal axis wind turbine of a small isolated wind production system". He discusses that the basic principle of installing a small wind turbine on the isolated site is to produce electricity in a simple way. To optimize performance, it is necessary to study various wind parameters. An assessment of the wind resources of the Annaba region in Algeria was carried out to establish a small wind turbine, using a Weibull fitting method. The estimation of the parameters of the Weibull distribution made it possible to determine the wind speed and direction. An aerodynamic study was also carried out to improve the shape of the blades, using two different types. A numerical simulation was carried out to analyze the vibrations of the blades, showing that the simple blade has higher frequencies than a twisted blade.

A numerical simulation was carried out to compare the behavior of simple and twisted blades in an air flow. It is essential to study the wind in a region before installing a wind turbine, but a thorough analysis of the shape and behavior of the blades is also necessary to ensure their profitability [7].

ERIC IMETE NGONDE worked on: "Dimensional study of wind energy for the production of electricity in the city of MBANDAKA". For him, the city of Mbandaka in the DRC has an untapped potential in wind energy for the production of electricity. A study has shown that it is possible to exploit this form of renewable energy in the city, with powers of up to hundreds of KW. It is recommended that local authorities use this resource to meet the energy needs of the population [8].

M. NADJAH, M. KHECHANA, L. LAICHE, T. OUKSEL and C. MAHFOUCLI worked on: "Study of the propeller of a 5 MW wind turbine". They present a logical approach to making the propeller of a low-power wind turbine as part of a research project. They address the essential elements necessary for the design of the propeller, starting from the desired electrical power. They explain the transformation of wind energy into mechanical energy, the Betz formulation, the search for the appropriate blade profile, the propeller diameter and the verification of the blade resistance to different stresses [9].

MEDAH and DJAMILA worked on: "Study of the wind generator for use in the production of electrical energy". Compared to their study, the production of wind energy poses problems of stability of the electrical network and the quality of the energy supplied. Their thesis presents a study on a wind energy conversion chain using a permanent magnet synchronous generator (PMSG). The advantages of this technology are highlighted, in particular its durability, high efficiency and reliability. Models have been developed for the structure and elements of the conversion chain, as well as for the permanent magnet synchronous generator [10].

BENHADJI ABDERRAHMANE worked on: "Study and realization of an emulator of a wind conversion chain based on the DSPACE 1104 card". His work presents an emulator of a wind energy conversion chain based on a DSPACE 1104 card, simulating the dynamic behavior of a wind turbine. It uses a DC motor and a serial chopper to generate the power-speed characteristics. Simulations on MATLAB/SIMULINK and experiments are carried out to validate the emulator, showing its validity [11]. ARNAUD GAILLAR worked on: "Wind system based on a MADA: contribution to the study of the quality of electrical energy and continuity of service". For him, wind turbines must contribute to system services and to the improvement of the quality of electrical energy. A study shows that wind systems based on a doubly fed asynchronous machine can compensate reactive power and harmonic currents without oversizing.

Fault tolerant converter topologies have been studied to ensure continuity of service in the event of faults, with control based on an FPGA component. The results show the effectiveness of these methods [12].

OLIVIER GERGAUD, BERNARD MULTAN and HAMID BENAHMED worked on: "Modeling a small power wind conversion chain". For them, in parallel with the market for high power wind generation, from 100 kW to a few kW, are developing, especially for isolated sites. Energy conversion chains differ from high power ones, often using a three-phase permanent magnet alternator, directly discharging through a diode rectifier to a low voltage electrochemical accumulator (12 to 48V). This article proposes a modelling of this unconventional conversion chain to estimate energy production [13].

MAKHMOUTH GUEYE worked on: "Evaluation of the wind energy potential in Diembéring in Lower Casamance". His work studies the wind potential of Diembéring in Lower Casamance in Senegal. The wind characteristics are analyzed with WASP and MATLAB software, using hourly wind speed and direction data over five years, from a LOSEC weather station. The results identify the windiest periods, in particular the year 2020 and the period from April to June, with respective average speeds of 5.53 m/s and 6.16 m/s. Diurnal variations are observed, with higher speeds during the day. The Weibull parameters indicate an average of 6 m/s for the scale parameter and 2.73 for the shape parameter, corresponding to an average power density of 137W/m2. The power density is higher during the rainy season (147W/m2) than during the dry season (132W/m2). The prevailing winds come from the North and Northwest directions [14].

2. Materials and methods for making a wind turbine

The model proposed here has been modified and adapted according to our objective and the means available. Our mini wind turbine will be assembled and exhibited to allow the students of the first-year class to see and understand the design and operation of it. The photos relating to our assembly will be given in the results section.

2.1. The materials

2.1.1. The electrical circuit

The electrical circuit is used for the assembly of mini wind turbine and is composed of three different elements: the rectifier, the capacitor and the regulator. Together, they allow to transform the alternating current of the motor or the coil into direct current, usable by our accumulator or lamp.

2.1.2. Tools and materials

To make a mini wind turbine, we need the tools and materials to use. Among these tools and materials, some are purchased and others are recovered.

- Wood saw
- Office equipment
- Wire cutters
- Soldering iron and tin
- Screwdriver
- Voltmeter
- Chisel
- Screws
- Blonds
- Nuts
- Glue
- Scotch
- 12V coil
- Wooden board
- Electrical wires
- Fan blades
- Iron wire
- LED bulb

2.2. The manufacturing stages and Proposal for teaching and learning technology in the study programs.

Five activities that take advantage of the approaches proposed in the 2nd cycle of secondary school in Science and Technology.

2.2.1. Reverse engineering of a mini-wind turbine

Technological analysis approach Reverse engineering engages students in a technological analysis approach based on a technical object or a technological system. It allows the development of the second and third disciplinary skills of the program. By learning about various wind turbine prototypes, the questions related to each of them promote the appropriation of scientific and technological principles. We are thinking here of the mechanical and connection functions, the types of energy and movement, the types of force. Students have at their disposal analysis grids, principle or construction diagrams that guide them in answering questions such as:

- Complete the principal diagram as precisely as possible, taking into account the polarity (+ and -), and indicate the direction of rotation of the moving parts.
- Is there a motion transmission mechanism?
- What types of energy do you think are involved here?

In addition to the prototypes provided in class, each team has a fan and a multimeter to measure the voltage produced by each wind turbine prototype. Propeller performance tests are also proposed. Depending on the shape of the propeller (two-bladed, three-bladed, flat, twisted, etc.), students predict which ones will have the best performance. Once the experiment is done, they compare their initial model with the experimental results (reading the voltage at the terminals).

2.2.2. Reverse engineering an electric motor:

We know that the function of the wind turbine is to produce electricity from the wind. In the activities proposed here, the fan simulates the wind and the prototypes are connected to the terminals of a multimeter. Students are thus able to take a voltage reading. But does this "electric machine" act as a motor or a generator? We know that electrical machines include several devices that transform electrical energy and mechanical energy. Machines that transform mechanical energy into electrical energy are generators. Machines that transform electrical energy into mechanical energy are called motors. Thus, the function of the wind turbine is to produce electricity from the wind, so it contains a generator. It is important to emphasize this distinction.

2.2.3. Design a wind turbine:

Students have to design and manufacture, based on the specifications and available materials, an object or technological system. The design of a wind turbine in practical work allows you to develop this skill.

In teams of three or four, students learn about the specifications and safety instructions. [15] A good way to motivate students is to launch a performance competition. The team that has built the prototype producing the most voltage will be the winner!

2.2.4. For or against wind energy:

It is important to take into consideration several elements of the economic, environmental (noise, aesthetics, etc.), technological aspects, as well as the scientific aspects (principles involved, future prospects, etc.) [16]..

2.2.5. practical work of the reproduction of the Wind Turbine in the schoolyard:

An interesting project to put in practical work is the evaluation of the wind potential of a schoolyard using an anemometer. Here are the steps taken from the bibliography by Mr Mohamed Righi who suggests to evaluate the wind potential of a schoolyard:

- Explain the objective of the activity to the students: evaluate the wind potential of their schoolyard using an instrument to measure the wind force, the anemometer.
- Ask the students to draw on a sheet of paper the plan of the school grounds taking into account the main building, neighboring buildings as well as the location of trees and other obstacles that could slow the wind.
- Bring the class into the courtyard or outside the school.
- Ask the students to observe and describe the effects of the wind around them and to identify the dominant wind direction using a compass or a weather vane.
- Ask students to observe the wind force at different locations on the school grounds so that they understand that it is necessary to record observations in order to make comparisons.

For example, around buildings, there is an increase in the resulting wind force (Bernoulli's principle). At the end of this activity, the whole class should reach a consensus on the best location to choose for the possible installation of a wind turbine in their schoolyard.

Wind systems generally consist of the main elements shown in Figure .2

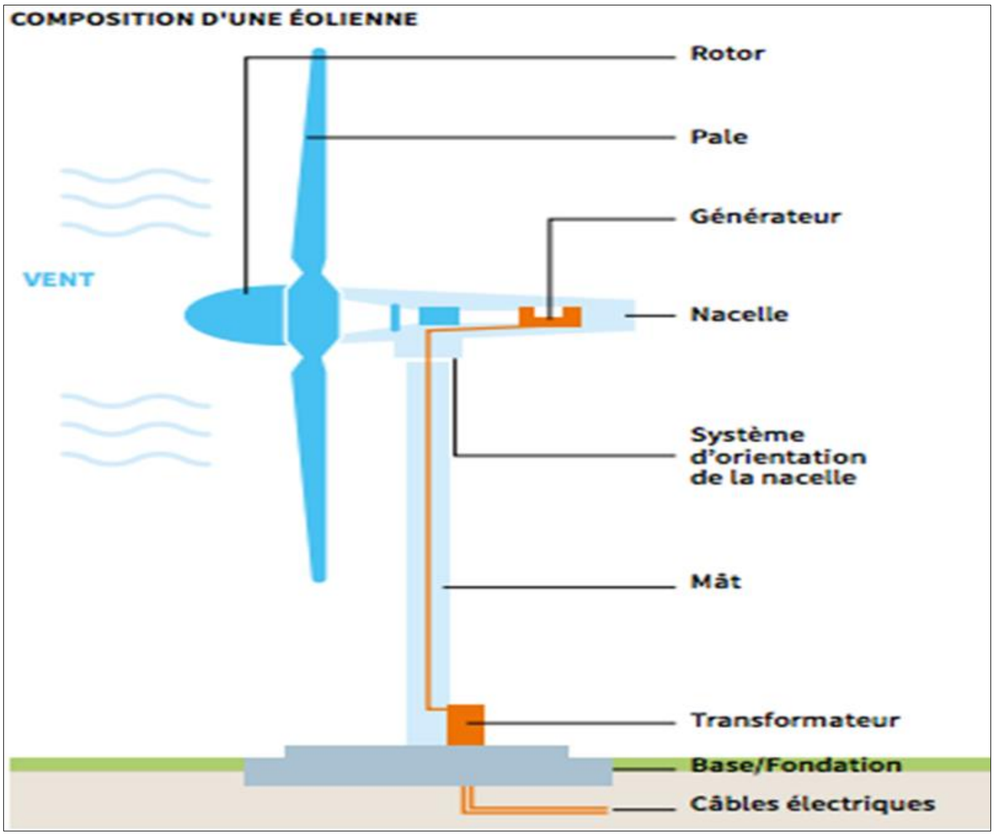

Figure 2 The components of a wind turbine [17].

3. Results and discussion

3.1. Determination of the equations relating to the production of Wind Kinetic Energy and the Conversion into Mechanical Energy

The wind turbine is a complete system for converting the (mechanical) energy of the wind into electrical energy. Three factors determine the ratio between the wind energy and the mechanical energy recovered by the rotor: air density, rotor swept area and wind speed. Air density and wind speed are climatological parameters that depend on the site [18].

3.1.1. Equation of BETZ's Law

The kinetic energy in air of an object of mass m moving with speed v is equal to [18]: E

$$= \frac{1}{2} mv^2 \quad \text{………………..(1.1)}$$

The power of moving air, if we assume constant wind speed, is:

$$Pm = \frac{d}{d} = \frac{1}{2} mv^2 \quad \text{……………..(1.2)}$$

Where m, the rate of flow (flow rate) of mass per second.

When air passes through an area A, such as the swept surface of the rotor blades, the power in the air can be estimated by:

$$Pm = \frac{1}{2}\rho Av^2 \quad \text{……………… (1.3)}$$

Where ρ: the density of the air. It varies with the air pressure and the temperature.

The mechanical energy that is obtained from the converter from the air flow will be equal to the difference of the powers of the air flow before and after the converter:

$$Pm = \frac{1}{2}\rho.A_1.v_1^3 - \frac{1}{2}\rho.A_2.v_2^3 = \frac{1}{2}\rho(A_1.v_1^3 - A_2.v_2^3) \quad \text{………….. (1.4)}$$

Where A1 and A2: the cross sections before and after the converter.

V_1 and V_2: the wind speed before and after the converter.

As the air flow passes through the converter, the wind speed must decrease behind the wind energy converter and the mass flow remains invariable. Therefore,

$$\rho.v_1.A_1 = \rho.v_2.A_2 \quad \text{………………. (1.5)}$$

So,

$$Pm = \frac{1}{2}\rho.A_1.v_1.(v_1^2 - v_2^2) \quad \text{………………………(1.6)}$$

If v2 the output velocity behind the converter is zero, then the input velocity must be zero, which implies that there is no flow through the converter. Using the law of conservation of momentum, the force exerted by the wind on the converter is:

$$F = m.(v_1 - v_2) \quad \text{……………..(1.7)}$$

The extracted mechanical transmission is:

$$Pm = F.v' = m(v_1 - v_2).v' \quad \text{…………..(1.8)}$$

By comparing equation 1.4 and 1.8 we can obtain the relationship for the flow velocity

$$v' = \frac{1}{2}(v_1 - v_2) \quad \ldots\ldots\ldots\ldots\ldots\ldots (1.9)$$

Thus the air flow velocity through the converter is equal to the average of V_1 and V_2. The mechanical power of the converter can then be expressed as:

$$Pm = \frac{1}{2}\rho.A.(v_1^2 - v_2^2).(v_1 + v_2) \quad \ldots\ldots\ldots\ldots (1.10)$$

If we compare this mechanical output power with the power in the air flow that flows through the same cross-sectional area of section A, the ratio between the mechanical power output by the converter and the power contained in the air flow that passes through the same area is called the "power coefficient" CP and can be represented as follows:

$$C_P = \frac{Pm}{Pm} = \frac{1}{2}\rho.A.(v_1^2 - v_2^2).(v_1 - v_2) / \frac{1}{2}\rho.A.v^2 \quad \ldots\ldots\ldots\ldots (1.11)$$

The power coefficient can also be expressed in terms of the speed ratio v1/v2.

$$C_P = \frac{Pm}{Pm} = \frac{1}{2}\left| 1 - (v_2/v_1)^2 \right| . \left| 1 - v_2/v_1 \right| \quad \ldots\ldots\ldots\ldots (1.12)$$

If we plot equation (1.12) we notice that the ideal maximum speed of the power coefficient CP, therefore the maximum power that can be recovered with a wind turbine occurs when :

$$v_2/v_1 = \frac{1}{3}, \text{ so the CP becomes: } C_p = \frac{16}{27} = 0.59$$

The power coefficient is usually given as a function of the propeller blade tip speed ratio λ and the blade angle of attack β. The tip speed ratio of a wind turbine is defined as:

$$\lambda = u/v_1 = \Omega_1.R / v_1 \quad \ldots\ldots\ldots (1.13)$$

Where:
U: the tangential attack speed of the blade;
Ω1: the angular speed of the rotor;
R: the radius of the rotor in meters;
v_1: the wind speed.

3.2. Result of the Assembly of our Wind Turbine for Students

3.2.1. Step 1: the coil

The coil consists of a winding or winding of a conductive wire (stator) possibly around a core made of ferromagnetic material (rotor).

The first step is to prepare and test our coil. It is the main element of our mini wind turbine, without it there is no energy. It is therefore important to make sure that it works properly before using it. Check to see if its two terminals are normal because they are the ones that generate the maximum voltage.

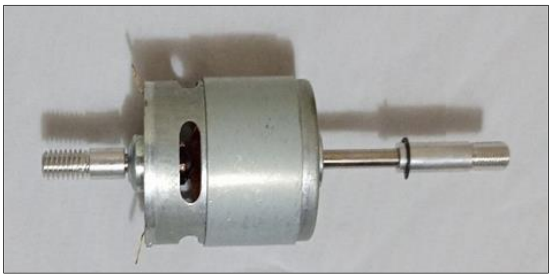

Figure 3 A 12V coil

3.2.2. Step 2: the blades

The blades of our mini wind turbine will capture the energy of the wind, start to turn and thus drive the coil. The shape of the blades is therefore not to be neglected.

In our case study, our blades are part of the blades recovered from a fan whose dimensions are those of its manufacturing house.

Figure 4 The Blades

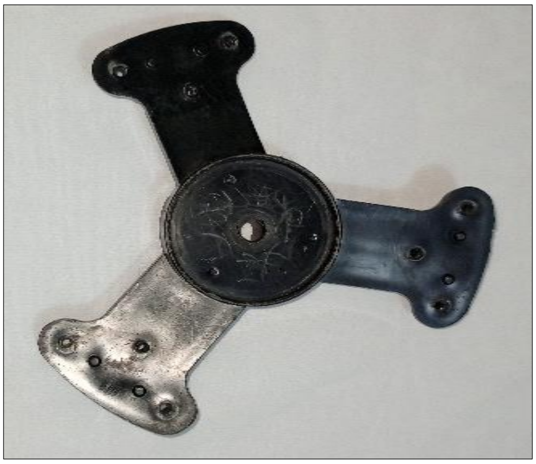

Figure 5 The Ferrule

The power captured is proportional to the surface swept by the blades, the larger they are, the more energy we capture. In our specific case, our coil does not need a high torque to turn, it needs to turn quickly, which is why we use small fan blades that can turn quickly with less strong wind.

For this, we will only use three blades, each 20 cm, which will allow our mini wind turbine to turn fast enough to produce electricity.

3.2.3. Step 3 Assembly and balancing

The main parts of our mini wind turbine are now ready, we will assemble them together and find the balance point of the assembly. This point will determine where we will fix the top of the mast in order to avoid as much as possible any imbalance due to the weight of the parts.

- Assembling the blades: using our screwdriver, fix our blades on the ferrule. They must all be in the same direction and spaced the same distance apart.
- When the blades are correctly fixed, place the part to hold it from the axis to the center of our part that contains the blades, then fix it.
- Assembling the hub: place our assembly on the axis of our coil, then insert the tightening bolt when the assembly is well aligned with the axis.

Figure 6 The blades assembled and balanced

Figure 7 Assembly of the blades and ferrule on the coil axis

3.2.4. Step 4: The mast

Our mini wind turbine will be installed and must be oriented towards the wind or a ventilation system. To do this, we will need to fix it to a sufficiently strong mast, which will itself be fixed to the ground on a flat and solid base (fan base in our case).

	
Figure 8 The mast	**Figure 9** The completed assembly of the mini wind turbine

3.3. Learning a skills-based approach

Renewable energy which is wind turbine, is an energy that has been studied by several people before us and each according to the choice and motive of his theme.

In our secondary education framework, this wind turbine assembly from a 12V coil is an educational experience for students interested in renewable energies and the operation of wind turbines.

3.3.1. Proposal of a framework for the insertion of practical work in the course related to Wind Turbine Technology

The experiment adopted to this concept was taken in integrity and adapted to the Chadian concept.

We propose five activities to be carried out in the second cycle of secondary school in Science and Technology or in Technological and Scientific Applications. Combining the action in the laboratory workshop with a more theoretical reflection, the question of the wind turbine is seen from several aspects: the reverse engineering of wind turbine prototypes, a technological design, a project and a structured controversy. The articulation of these activities promotes the updating of technological education to scientific education in secondary school class.

3.3.2. Why this proposal?

It is following the lack of practical and laboratory work in most general education establishments in Chad that we propose a new course title for teaching science and technology in secondary school: the Science and Technology program.

Currently, given the education reform, we propose for secondary schools in Chad the integration of technological education into the teaching of scientific disciplines.

It is necessary to reflect on certain theoretical considerations before better identifying a teaching practice that is conducive to the integration of technology in science classes. [19]. We therefore propose on this subject that the first disciplinary skill be manifested 70% of the time in scientific investigation (Theoretical Course) and 30% of the time in technological investigation (Practical Course). This scheme should normally be present within the program of the 2nd cycle of secondary school. The study of technology would be oriented towards the design and analysis of the technical object in the first quarter and that of the analysis of technological systems in the second quarter. In relation to the prescribed concepts, they can also be divided into sections. Those related to the study of technology are presented in the Technological Universe: language of lines, engineering, materials, etc. The accompanying guidelines propose a way to approach them by making links with other universes (living, material, earth and space).

The desire to integrate scientific disciplines that are likely to guide the teaching practices of Science and Technology teachers can only be beneficial for tomorrow's students. These reflections will lead us to propose the implementation of activities in the second year of high school on learning a skills-based approach to promote the establishment of links between scientific education and technological education in a context of curriculum reform in Chad.

In an article that raises questions about the possible interrelations between science and technology, Roth (2001)[20] refers to teachers who wondered whether technology-focused activities could support science learning. According to Roth,[20] several studies highlight the interest of using educational activities that guide students towards a design approach or testing of technical objects. These activities would be conducive to the appropriation of the modeling approach and the construction of representations (mental or physical). In addition, they would promote a better critical analysis of the performance of these objects. according to Roth (2001),[20] Roth suggests that instead of emphasizing the differences between science and technology, a teacher should emphasize how representations in science and technology are constructed. In this way, he will be able to argue that the production and translation of representations constructed by students are stabilized by models. In one case, these are mental models and in the other, physical models (technical objects, for example). "The technical objects created exist thanks to their representations which are in turn created by multiple representations of the instruments" (Roth, 2001, p. 770, free translation)[20]. Another promising approach would be to highlight the processes (i.e. the way in which these representations and objects are constructed) rather than the products of each of these fields of knowledge.[21-27]

4. Conclusion

The study of the physical concept in application of the principle of electricity production from a wind turbine, within the framework of secondary education, offers an exciting opportunity to explore the fundamental principles of physics and electronics while raising students' awareness of the challenges of the energy transition and sustainable development.

Thanks to technological advances and ongoing research in the field of wind energy, students have the opportunity to experience the operation and to concretely understand the design, operation of a wind turbine and the process of converting the kinetic energy of the wind into electrical energy. This interactive and practical educational approach allows students to develop their skills in science and technology, while raising their awareness of current environmental and energy issues.

By integrating the study of the physical concept of electricity production from a wind turbine into the framework of secondary education, educators contribute to training a new generation of citizens aware of the challenges related to the energy transition and capable of actively participating in building a more sustainable and environmentally friendly future.

Teaching the physics concept of generating electricity from a wind turbine is essential for several reasons, especially for high school students

Understanding Physical Principles

- Kinetic Energy: Students learn how wind energy (kinetic energy) can be converted into mechanical energy using the blades of the wind turbine.
- Energy Conversion: They explore the principles of energy conversion, including the transformation of mechanical energy into electrical energy using a generator.

Renewable Energy Knowledge

- Sustainability: Wind turbine education helps to raise students' awareness of renewable energy sources and their crucial role in combating climate change and reducing greenhouse gas emissions.
- Environmental Impact: They can analyze the advantages and disadvantages of wind energy compared to traditional energy sources.

Technical and Practical Skills

- Practical Applications: Hands-on projects around wind turbines, such as building models or using simulation software, encourage learning through experimentation.
- Interdisciplinarity: This integrates concepts from physics, engineering, ecology, and technology, promoting an interdisciplinary approach.

Development of Critical Thinking

- Data Analysis: Students can study real-world wind energy production data and evaluate the performance of wind turbines under different weather conditions.
- Problem Solving: They are encouraged to solve problems related to energy efficiency and resource optimization.

Preparation for the Future

- STEM Careers: Understanding concepts related to wind turbines can inspire students to pursue careers in fields such as engineering, environmental sciences, and energy technologies.
- Innovation Awareness: Wind energy represents an important part of future energy innovation, preparing students for the energy challenges of the 21st century.

In short, teaching the concept of electricity production from wind turbines not only provides students with a solid foundation in physics, but also prepares them to become informed and responsible citizens who can contribute to a sustainable future. It inspires them to consider their role in the energy transition and encourages them to think critically about contemporary environmental challenges

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

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