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From knowledge to action: Innovative teaching approaches for energy education at school

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Abstract

This article examines the importance of energy education in schools, in a context of global environmental challenges and the need to shape citizens with environmental awareness and capacity for action. Education for sustainable development is not limited to the transmission of information about energy, but aims at transformative learning, which enhances critical thinking, collaboration and participatory decision-making. The article analyzes the theoretical foundations of environmental and energy education and presents in detail innovative teaching approaches that can be applied in the school environment. Project methods, problem solving, experimental teaching, concept mapping, field study, storytelling, storyline and educational drama are utilized to connect knowledge with students' everyday experience and encourage them to develop skills of investigation and responsible action. Finally, the need to integrate the above approaches into an overall sustainable school framework is underlined, where energy education becomes an element of the school culture and the local community.

Keywords: Energy education; Innovative teaching approaches; Ecology; Environmental Protection; Energy Saving.

1. Introduction

The climate crisis and the strain on natural resources are shifting the educational priority from the sterile transmission of knowledge to the formation of citizens who understand, judge and act responsibly. Environmentally literate citizens are those who make informed decisions about the environment and are willing to actively participate in public life based on these decisions (Holweg et al., 2011). Education for sustainable development provides the content and methods that cultivate critical thinking, values and decision-making skills from an early age, shaping attitudes that serve a sustainable future (Franzen, 2017).

Modern pedagogy must be transformative, based on innovative practices and combining alternative teaching techniques in order to strengthen collaboration and participatory decision-making on the environment (Cebrian et al., 2020), challenge stereotypes and develop new democratic practices of action (Wals, 2010). In this context, energy education in school is a strategic priority: it connects natural sciences with technology and society, bridging knowledge with practice in real problems of energy consumption and climate change.

2. Theoretical framework: environment, sustainability and environmental education

The environment is a complex network of physical, chemical, biological and socio-economic factors that make up the context and conditions of human life. Environmental education aims to make citizens responsible and active, capable of understanding the relationships between humans, civilization and the biophysical environment and of exercising ethical decision-making practices for the quality of the environment (Yiagou & Koumoutsakou, 2015).

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The concept of sustainability, established internationally by the Brutland Report, defines a development that meets the needs of the present without undermining the needs of future generations (Mousiopoulos et al., 2015). Historically, the industrial revolution and the post-war technological explosion brought extensive pressures on resources, leading to increased energy consumption, pollution and climate deregulation. As an educational movement, environmental education began in the 19th century, transformed in the 20th and, influenced by the ecological movement, shifted from simple awareness-raising to a holistic view of the nature-society relationship (Fanioudaki, 2015).

3. Conceptual clarification: approaches, models, methods, forms and strategies

In teaching terminology, the approach denotes the set of theoretical principles that underpin the learning process and guide its design. Teaching models are schematizations of teaching practice that describe processes, roles and objectives at the macro- and micro-level, linking the curriculum to everyday teaching (Styliaras & Dimou, 2015).

The method is an organized system of activities and principles of access to knowledge, broader than the technique, composed of various tools for achieving goals. The teaching form refers to the way of presenting the content and the structure of communication in the classroom. Finally, teaching strategies are deliberate interventions that organize sequences of activities, based on pedagogical principles and oriented towards specific goals (Styliaras & Dimou, 2015). Energy education needs synergies of all of the above: clearly formulated approaches, appropriate models, flexible methods and powerful strategies that allow students to move from understanding concepts such as "energy", "balance", "footprint" and "efficiency", to practical collective decisions in the school and local environment.

4. Energy education in schools: from literacy to capacity for action

Energy education is not the same as simply understanding natural phenomena, nor is it limited to teaching concepts such as energy, power or renewable sources. On the contrary, it concerns the formation of citizens capable of interpreting, evaluating and redefining their energy practices within the social and ecological context in which they live. For this reason, it requires an interdisciplinary approach, as energy is directly linked to physics and chemistry as well as to economics, technology, politics, environmental ethics and social justice (Franzen, 2017).

In schools, energy education acquires meaning when students are asked to work on authentic problems that arise from their everyday lives. Through such situations, students do not learn about energy, but learn with energy: they investigate consumption in the school building, calculate the ecological footprint of the school unit, examine ways to save on heating, cooling, lighting and transportation. At the same time, they learn to seek and evaluate alternative solutions, to take into account the costs and benefits of each option and to understand that behind every energy decision there are socio-economic priorities and value loads.

In addition, energy education cultivates the ability for democratic dialogue and collective decision-making. Students collaborate to create rules for energy use in the school, co-form policies with the local community, participate in school sustainability committees and take on roles that enhance responsibility and active action. The school, in this view, is transformed into a living sustainability laboratory, where theoretical knowledge is linked to practical choices in everyday life.

Learning becomes transformative when it is not limited to the acquisition of knowledge, but when students develop values, attitudes and behaviors that highlight individual and collective responsibility towards the environment. Energy education therefore aims to move from energy literacy (understanding and rational use of energy) to action competence, that is, the ability of the individual to actively participate in shaping solutions for sustainable development (Cebrian et al., 2020; Wals, 2010).

5. Innovative teaching approaches for energy education

The transition from knowledge to practice requires methodologies that activate students as researchers, co-designers and citizens. Below, innovative and alternative approaches that can be orchestrated in a single energy education plan are analyzed in detail.

5.1. Project method and work plans on energy issues

Work plans are open learning and research processes, adapted to the characteristics of the class and the specific issue. In the energy theme, a plan can focus on the energy footprint of the school. The class co-formulates the questions ("Where do we consume more energy?", "Which interventions have the highest efficiency?"), investigates consumption data, records behaviors, analyzes technological solutions and designs an intervention. The approach is experiential, interdisciplinary and critical, leveraging students' previous experiences and gradually building knowledge (Manavi, 2016). The typical process includes selecting and focusing on a topic, defining activities and objectives, implementing in groups, publicly presenting results and, most importantly, evaluating the collaborative and decision-making process, not just the product. In an energy project, children can compare LED/photovoltaic/shading scenarios, propose rules for using devices and suggest to the school community micro-saving policies.

5.2. Teaching through problem solving in real energy issues

The problem solving methodology organizes learning around a real environmental problem, such as wasting electricity in the classroom or increasing energy costs. Students clearly define the goal, collect data (measurements, photographic records, usage diaries), compose alternative solutions, evaluate them using criteria of efficiency, cost and social acceptance, draw up an action plan, implement it and evaluate the results. The method cultivates skills of research, diagnosis, balanced choice and democratic accountability, operating complementary to the project (Douvara & Patrinopoulos, 2019).

5.3. Discussion, brainstorming and democratic argumentation

The energy transition is a social issue; it requires dialogue, listening, argumentation and consensus. The methods of discussion, group discussions, confrontations, public hearings, brainstorming, activate students to explore values and dilemmas: "Individual responsibility or institutional interventions?", "Renewable sources and local resistances?". Brainstorming, especially at the beginning of a unit, highlights previous perceptions, creates a common bank of ideas and stimulates creativity and critical thinking. Confrontation with rules of fair hearing helps in organizing arguments and understanding conflicting positions on energy projects (Georgopoulos, 2014).

5.4. Concept mapping for scaffolding energy concepts

Energy issues are multifaceted. Concept mapping captures relationships between terms such as "energy", "power", "efficiency", "carbon footprint", "life cycle", "user behavior", allowing for the visualization of complex cause-effect relationships. Students build hierarchical or network maps, discuss connections, revise maps after measurements or experiments, and use open source software for co-design. The technique enhances metacognitive awareness, memory, and the ability to transfer knowledge between the natural sciences and social dimensions of energy (Dona & Tsakstaras, 2014).

5.5. Experimental method and small energy labs

Experimentation introduces students to the scientific process: observation, hypothesis, testing, and inference. In energy education, small-scale experiments on thermal insulation, conductivity, photovoltaic power curves, shading and lighting demonstrate how physical principles translate into practical energy-saving solutions. The design should be age-appropriate, control variables and lead to predictions for real-world applications, such as the selection of shading materials in the classroom (Dimitriou, 2009).

5.6. Field study and environmental trails with a focus on local energy

Learning outside the classroom transfers theory to the field: visits to renewable energy centers, industrial plants, waste management plants, energy neighborhoods. Students observe, measure, record and compare data in real-world conditions, developing research skills, empathy and a willingness to act (Douvara & Patrinopoulos, 2019). Energy trails can be repeated seasonally, allowing students to detect changes in energy use or the thermal microclimate of a neighborhood and to document proposals for the local community (Dimitriou, 2009).

5.7. Storytelling to "hear" energy

Storytelling, as a pedagogical method, expands language, activates imagination and offers meaning and emotion that favor learning. In energy thematics, stories can bring the classroom into contact with distant or "invisible" phenomena, such as the effects of energy poverty, the transformations of a city due to transition, the dilemmas of a family choosing heating. The careful selection or creation of stories is crucial to avoid one-sided perspectives and to project valid

knowledge (Dimitriou, 2009). Students can write their own "one kilowatt hour" micro-stories, record podcasts, and share them with the community.

5.8. Storyline: a plot that integrates knowledge and experiences

The storyline, based on social constructivism, organizes activities in a narrative framework that allows students to integrate new concepts into existing mental structures. As an interdisciplinary method, it integrates natural sciences, mathematics, language, social and political education, technology and the arts, serving the principle of interdisciplinary environmental education. In a storyline with the theme "The journey of energy from the sun to our classroom", students map episodes (production, transport, consumption, losses, consequences), integrate experiments, statistics, interviews with local actors and end up with a collective action plan, giving coherence and meaning to learning.

5.9. Educational drama and role play for understanding conflicts

Drama, utilizing theatrical techniques, aims at all-round development and deeper assimilation of knowledge in social contexts. In energy issues, drama and role play make difficult concepts accessible and bring complexity to the fore: students embody residents, mayors, engineers, entrepreneurs, environmental organizations in a public debate about a wind farm or the thermal upgrade of the school. Through dialogues and negotiation, the class explores conflicting interests, ethical dilemmas and decision criteria, translating scientific knowledge into social practice (Everett, 2015). The process often begins with a narrative, utilizes spontaneous play and leads to original dialogues that the students themselves compose, cultivating language, imagination and collective responsibility.

5.10. The role of digital technologies in education

At this point, we must highlight the productive and effective role of digital technologies in the field of education. We have to pump inspiration of the use of digital technologies in all domains of education in order to improve the energy education domain. These technologies and paradigms could be adopted and exploited in energy eduation, which include mobile devices (15-16), a variety of ICTs (17-18), AI & STEM ROBOTICS (19-20), facilitate and improve educational procedures such as assessment, intervention, and instruction. In addition, the use of ICTs in conjunction with theories and models of metacognition, mindfulness, and emotional intelligence cultivation for the environment [21-24], accelerates and enhances educational practices and outcomes, particularly for energy education and environmental issues.

6. Learning and action assessment

The assessment in an innovative energy education focuses on the process: how the groups collaborated, what criteria they used for decisions, how they revised their perceptions, what was the degree of community participation. Before-after mappings, learning diaries, work folders, argumentation rubrics, consumption measurements and micro-indicators of behavioral change constitute a feedback system that enhances metacognitive awareness and accountability to the school and the municipality. Thus, knowledge does not "end" in the classroom, but is folded into cycles of improvement.

7. Implementation suggestions for a multi-day teaching unit

A sample sequence can begin with brainstorming and a conceptual map on "what is energy and where do we find it in our everyday lives". This is followed by small experiments on lighting and thermal insulation, which feed into the choice of problem to solve ("how do we reduce lighting consumption by 30%). The groups design and implement an energy control project for the unit, while composing a storyline "the kilowatt hour in our school" and producing podcasts with narration of energy poverty incidents in the community. The process culminates with a drama/public hearing, where the groups present proposals to a "student council". The field study at a local renewable energy installation links theory with practice. The unit closes with a new conceptual map, comparison with the original, assessment of consumption indicators and a shared commitment to energy use rules.

8. Conclusion

Energy education that aspires to turn knowledge into action needs to be experiential, interdisciplinary, democratic and action-oriented. Project work and problem solving connect scientific understanding with practical change in the school ecosystem. Discussion methods and theatrical pedagogy cultivate citizenship, empathy and the ability to publicly argue in complex energy dilemmas. Conceptual mapping and experimentation build precision and depth in concepts.

Fieldwork and trails open the school to the community, while narrative and storylines add meaning and coherence to the learning experience. When all of this is integrated into a holistic vision of a "sustainable school", the result is a culture that goes beyond the classroom: students and teachers become participants in a collective transformation for energy transition and sustainability. The challenge for schools is not to teach more physics chapters, but to design learning ecosystems where understanding energy leads to participatory decisions, evidence-based interventions, and responsible daily practice.

In addition to the above, it is clear that energy education cannot be limited to fragmented actions or individual programs, but needs to be integrated into the overall school culture. The school unit needs to function as an example of responsible energy behavior through practices that touch everyday life: from the management of material resources and energy consumption, to the transportation choices of the school community and the organization of the school space. The involvement of all members of the educational community, teachers, students, parents and local bodies, strengthens the sense of collective responsibility and makes the school unit a living cell of social change.

In this context, innovative teaching approaches acquire essential importance, as knowledge is linked to action and learning ceases to be a passive process of transmitting information. Experiential inquiry, problem solving, collaborative work and creative forms of expression allow students to understand the causes and consequences of energy choices, to develop a responsible attitude and to assume roles with social impact. Thus, energy education contributes to the development of citizens capable of participating in the design of sustainable solutions and democratically influencing decisions concerning the common future.

Ultimately, the transition to a school that promotes sustainability is not only a matter of teaching, but a matter of vision for the role of the school in the 21st century. Energy education, as the core of Education for Sustainable Development, is one of the most decisive paths for the formation of societies capable of facing environmental challenges with knowledge, responsibility and collectivity.

Compliance with ethical standards

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The Authors proclaim no conflict of interest.

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