Una metodologia educativa a distancia para abordar el desarrollo sostenible basado en el método científico: un relato de caso en el Instituto Federal de Educación, Ciencia y Tecnología de Rio Grande do Norte

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Resumen

En este artículo reportamos el diseño y la aplicación de una metodología innovadora e interdisciplinaria en línea para abordar el desarrollo sostenible basado en el método científico en el Instituto Federal de Educación, Ciencia y Tecnología de Rio Grande do Norte (IFRN). Esta metodología educativa se basó en los principios del pensamiento complejo de Edgar Morin, la perspectiva problematizadora y dialógica de la educación contextualizada de Paulo Freire y el aprendizaje transgresor de Arjen Wals. Se aplicó a treinta y ocho estudiantes de la clase de 3er año de Electromecánica del IFRN Campus Canguaretama, inscritos en las disciplinas de Seminario de Iniciación a la Investigación y Proyecto Integrador, que se impartieron en el año 2021 en formato online con actividades sincrónicas y asincrónicas. Siguiendo una guía de instrucción previamente elaborada y con la ayuda de herramientas en línea, se definieron ocho proyectos diferentes que abordan temas locales y que están alineados con los objetivos de desarrollo sostenible de las Naciones Unidas y que fueron realizados por los estudiantes. Los resultados muestran que este enfoque estimula el pensamiento crítico-reflexivo y proporciona una oportunidad para el aprendizaje efectivo al estimular a los estudiantes a utilizar sus conocimientos de forma integrada y contextualizada a su entorno. Finalmente, anticipamos que esta metodología educativa puede ser fácilmente aplicada y adaptada para ser utilizada a una gran escala en otras escuelas de todos los niveles educativos, especialmente como un proyecto escolar anual interdisciplinario que involucre a toda la comunidad.

Palabras clave: Metodología educativa. Educación profesional. Desarrollo sostenible. Aprendizaje crítico-reflexivo.

Uma metodologia educacional online para abordar o desenvolvimento sustentável baseado no método científico: Um relato de experiência no Instituto Federal de Educação, Ciência e Tecnología do Rio Grande do Norte

Resumo

Neste artigo relatamos a concepção e aplicação de uma metodologia online inovadora e interdisciplinar para abordar o desenvolvimento sustentável baseado no método científico em uma turma de ensino médio profissional do Instituto Federal de Educação, Ciência e Tecnologia do Rio Grande do Norte (IFRN). Esta metodologia educacional foi baseada nos princípios do pensamento complexo de Edgar Morin, na perspectiva problemática e

dialógica da educação contextualizada de Paulo Freire e no aprendizado transgressivo de Arjen Wals. Ela foi aplicada a trinta e oito alunos da turma do 3º ano do curso Curso Técnico de Nível Médio em Eletromecânica do Campus Canguaretama do IFRN, matriculados nas disciplinas de Seminário de Iniciação à Pesquisa e Projeto Integrador, que foram ministrados no ano de 2021 em formato on-line, com atividades síncronas e assíncronas. Seguindo um guia de instrução previamente elaborado e com a ajuda de ferramentas on-line, foram definidos e realizados pelos estudantes oito diferentes projetos que tratavam de questões locais e alinhados com as metas de desenvolvimento sustentável das Nações Unidas. Os resultados mostram que esta abordagem estimula o pensamento crítico-reflexivo e oferece uma oportunidade de aprendizado eficaz, estimulando os estudantes a usar seus conhecimentos de forma integrada e contextualizada à sua realidade. Finalmente, antecipamos que esta metodologia educacional pode ser facilmente aplicada e adaptada para o uso em larga escala em outras escolas em todos os níveis de ensino, especialmente como um projeto escolar anual envolvendo toda a comunidade.
Palavras-chave: Metodologia educacional. Educação profissional. Desenvolvimento sustentável. aprendizado crítico-reflexivo.

An online educational methodology to approach sustainable development based on the scientific method: A case report from the Federal Institution of Education, Science and Technology of Rio Grande do Norte

Abstract

This paper reports on designing and applying an innovative and interdisciplinary online methodology to approach sustainable development based on the scientific method in the Federal Institution of Education, Science and Technology of Rio Grande do Norte (IFRN). This educational methodology was based on Edgar Morin's complex thought, Paulo Freire's problematizing and dialogical perspective of contextualized education, and Arjen Wals' transgressive learning. It was applied to thirty-eight students from the 3rd-year class of the Integrated Vocational High School Course in Electromechanical of IFRN, campus Canguaretama, enrolled in the disciplines of Research Initiation Seminar and Integrative Project, which were taught in the year 2021 in an online format with synchronous and asynchronous activities. Following a previously elaborated instruction guide and with the help of online tools, eight different projects addressing local issues and aligned with the sustainable development goals of the United Nations were defined and carried out by the students. The results show that this approach stimulates critical-reflexive thinking and provides an opportunity for effective learning by stimulating students to use their knowledge in an integrated way and contextualize their world. Finally, we anticipate that this educational methodology can be easily applied and adapted to use on a large scale in other schools at all levels of education, especially as an annual interdisciplinary school project involving the whole community.
Keywords: Educational methodology. Professional education. Sustainable development. Critical-reflexive learning.

Introduction

In recent decades, the increasingly recurring global scenario of social exclusion and environmental degradation has stimulated various segments of society to question the sustainability of our current model of social organization and discuss the urgency of

advancing on issues that strengthen a more equitable distribution of resources, environmental respect, cultural diversity, and the recognition of people as social actors and political agents (BARBARINI; MARIO, 2020; MOFIJUR et al., 2021; STEFANAKIS; CALHEIROS; NIKOLAOU, 2021).

Recently, continuing the global discussions about a sustainable development model, the United Nations and its member countries published the document "Transforming Our World: The 2030 Agenda for Sustainable Development", which is a global action plan that lists 17 Sustainable Development Goals (SDGs), and 169 interconnected targets that must be put into practice by the year 2030 (UNITED NATIONS, 2015).

However, despite the recognized importance of the SDGs to ensure the sustainable future of the planet and its population, there has been minimal progress on this issue in most countries. This context led to the implementation of an action plan in which SDG 4 (Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all) is a crucial component for social engagement and compliance with the 2030 agenda in progress, especially regarding its goal 4.7, which proposes:

> "By 2030, ensure that all learners acquire the knowledge and skills needed to promote sustainable development, including, among others, through education for sustainable development and sustainable lifestyles, human rights, gender equality, promotion of a culture of peace and non-violence, global citizenship, and appreciation of cultural diversity and of culture's contribution to sustainable development (United Nations, 2015)".

Within this scenario, it is a challenge for countries and educational systems to implement sustainable development education in schools at all levels of learning. This demand becomes even more crucial in the ongoing context of the Covid-19 pandemic affecting our society, which emerged as a public health problem and quickly turned into an unprecedented educational crisis in global history. In Latin America and the Caribbean, recent data shows that one hundred seventy million students were directly affected by school closures at all levels of education (WORLD BANK, 2020).

Consequently, because of the challenges that global education currently faces, especially in Brazil, where some schools are still operating in a remote model, learning strategies that enable the development of pedagogical practices while contributing to the achievement of the goals proposed in the 2030 agenda become necessary.

Therefore, in this brief context, this article aims to report the development and application of an innovative and interdisciplinary online methodology to approach sustainable development based on the scientific method in a class of the Integrated

Vocational High School Course in Electromechanical of the Federal Institution of Education, Science and Technology of Rio Grande do Norte (IFRN, acronym in Portuguese).

Theoretical Referential

To facilitate understanding of the context in which this methodology was applied, this section will briefly present the IFRN context and discuss the foundational bases that have inspired the designing of this online and interdisciplinary methodology for sustainable development based on the scientific method.

Federal Institution of Education, Science, and Technology of Rio Grande do Norte

IFRN is part of the Federal Network of Professional, Scientific and Technological Education (RFEPT, acronym in Portuguese), also known as the Federal Network, which is a set of institutions of professional education whose origins date back to the beginning of the last century. The RFEBT, currently composed of more than 600 school units spread throughout the country, acts in all levels and modalities of professional and vocational education, with a deep commitment to the integral student development and the articulation of technical and scientific knowledge (LEMOS, 2020; NASCIMENTO; CAVALCANTI; OSTERMANN, 2020; ROSA, 2017).

The IFRN has over 28,000 students enrolled in its 21 campuses distributed throughout all regions of Rio Grande do Norte. The Canguaretama campus, about 80 kilometers from the state capital, was inaugurated in 2015 and operated at different levels of education, emphasizing the provision of Integrated Vocational High School Courses over four years (NETA; SOUZA, 2020). Among these courses is the Integrated Vocational High School Course in Electromechanical, where the students, besides the basic disciplines of a high school curriculum, learn about technical skills such as analog and digital electronics, machine elements, principles of refrigeration and air conditioning, hydraulics and pneumatics, low voltage electrical installations, electrical projects, manufacturing processes, and microcontroller automation (IFRN-CONSEPEX, 2017).

During the course, a set of complementary disciplines is included, such as the "Research Initiation Seminar" discipline and the "Integrative Project" discipline, which have general objectives to introduce the basic principles of scientific research to the students and stimulating them to develop projects by integrating the whole course contents. It is essential to highlight that despite the curricular proposal of disciplinary integration of these

disciplines, there is practically no interdisciplinarity, especially between the vocational disciplines and those of the high school curriculum, making learning quite fragmented and ineffective.

The foundational bases of the applied online methodology

The globalized world and the rapid technological and scientific development have brought unprecedented challenges for educational systems around the planet. In this context, schools must be prepared to provide their students with a set of new skills to cope with uncertainties and a world in constant change - curiosity, imagination, resilience, self-knowledge, problem-solving, and teamwork skills, among others (BARBOSA; PINHEIRO, 2012; OECD, 2018; THIBAUT et al., 2018).

In this context, this proposed methodology aims to integrate different subjects and promote contextualized and critical-reflective thinking directed toward solving social and environmental problems in disadvantaged contexts. Then, the pillars used here are the most considerable known Edgar Morin's complex thought (MORIN, 1999; MORIN; MONTUORI, 2008), Paulo Freire's problematizing and dialogical perspective of contextualized education (BRAUER; FREIRE, 2021; FREIRE, 1974; LEWIS, 2012) and the more recent Arjen Wals' transgressive learning (LOTZ-SISITKA et al., 2015; WALS, 2007).

Paulo Freire, patron of Brazilian Education and a world-renowned educator for publications such as "the pedagogy of the oppressed," brings in his philosophical basis the recreation of social relations from the perspective of emancipation and freedom of the subject. Moreover, Freire distinguished in his literacy practices the student-centered and contextualized teaching-learning process, where the student becomes an active actor in his educational trajectory (FREIRE, 1974).

Edgar Morin, a critic of the "increasingly broader, deeper, and more serious inadequacy of separate, fragmented, and compartmentalized knowledge among disciplines," has proposed the complex thought. This educational approach allows overcoming the current realities or problems that are increasingly "multidisciplinary, transversal, multidimensional, transnational, global, and planetary" (Morin & Montuori, 2008, pag.35). According to Morin, only the complex thought, and the profound reorganization of the educational systems could promote adequate human development consistent with the current demands of our society.

Arjen Wals has been pursuing the development of learning that allows a rupture with dominant and resistant unsustainable routines and systems, leading to continuous reflection on values and ways of understanding the world. Thus, as addressed by Walls, the teaching and learning process within the context of social-ecological sustainability needs to be relational, critical, ethical, and political. Thus, teaching sustainability becomes an educational tool where teachers can create environments that lead to exploring sustainability issues (LOTZ-SISITKA et al., 2015).

These pedagogical principles have been widely used to support an active interdisciplinary methodology student-centered, emphasizing scientific research in the classroom. This methodology, named "Classroom research as a pedagogical practice, innovation, and social transformation," has been designed and implemented in public school classrooms by professor Leandro Costa, one of the authors of this article, and recently received an award from the Brazilian Ministry of Education as the best high school practice in the Brazilian Northeast and one of the five best practices in the country in the year 2018 (COSTA et al., 2019; COSTA & FREIRE, 2022).

In this regard, the scientific method teaching appears to be highly relevant since, to develop a research project, it is necessary to carry out a planned investigative process based on rigorous pre-established methods to search for existing knowledge in the area. Also, it is essential to focus on problem formulation and the way to address it, collect and analyze data, and draw conclusions (INKINEN et al., 2020). Because of classroom scientific research, students learn to deal with the unknown and find new knowledge. The students also learn to think logically about everyday facts and learn to solve practical and straightforward problems. Still, this is the only opportunity they must explore their environment logically and systematically for many students.

Therefore, given the pandemic conjuncture associated with the increased current demand for the implementation of interdisciplinary and contextualized approaches to achieve the goals of sustainable development, as well as the importance and the experience of the teacher-authors of this article in the teaching and dissemination of scientific research in the classroom, this online interdisciplinary methodology of education for sustainable development based on the scientific method arises as an essential tool to improve the teaching-learning process.

Methodological course

This educational study was carried out at the IFRN Campus Canguaretama, located in the city of Canguaretama in Rio Grande do Norte, during the year 2021. The municipality and the Institute's region have a pretty flawed education system, with unsatisfactory educational indices. According to the latest score of the Basic Education Development Index (IDEB), the main index used to value Brazilian schools, in 2017, the Canguaretama's schools in the final years of elementary education had a score of 3.0, a classification well below the goal 4.4 stipulated by local administrators (QEDU, 2019).

The educational methodology designed by the authors of this article was applied to thirty-eight students from the 3rd-year class of the Integrated Vocational High School Course in Electromechanical. Two groups of schoolteachers have participated in this study: The first one was the two authors of this article, who have been responsible for the disciplines, and named here as the *manager teachers.* The second one was those teachers from other disciplines nominated by the students to act as research project supervisors, called here as *mentor teachers.*

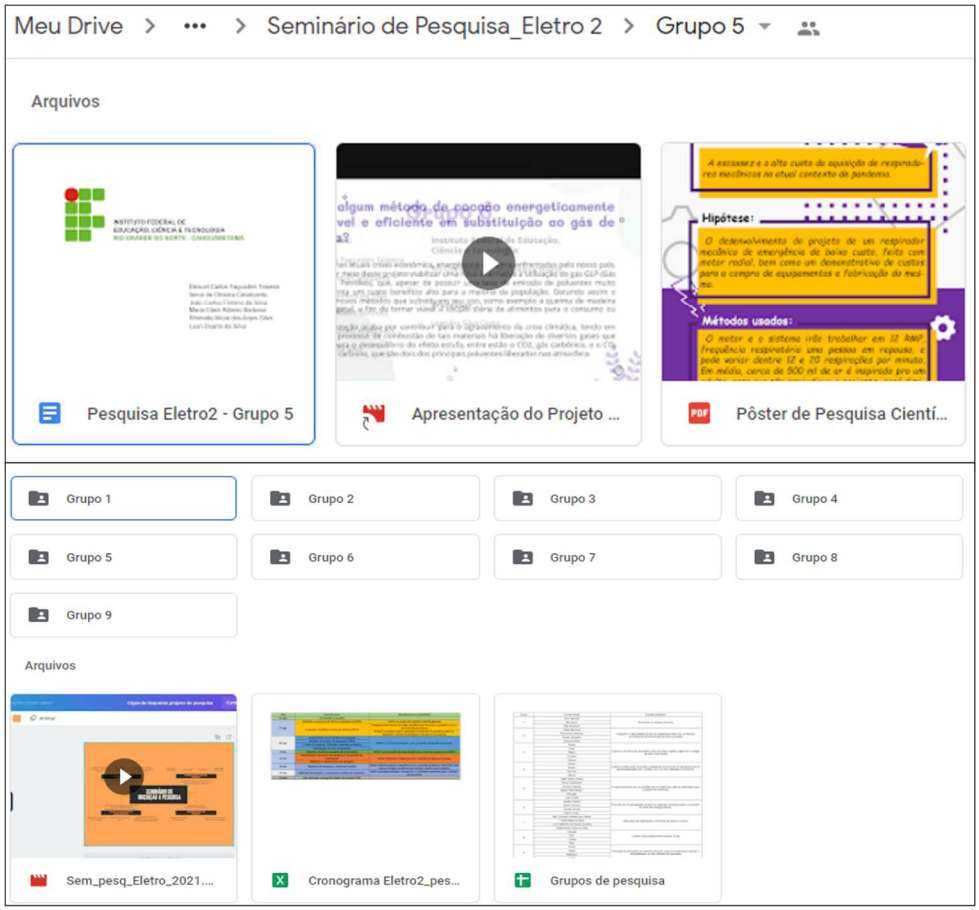
The students had initially enrolled in the discipline of "Research Initiation Seminar," with a course load of 30 hours, divided into synchronous (10 hours) and asynchronous (20 hours) online activities. It is essential to mention that attendance at synchronous activities was mandatory, but the classes were recorded and made available to those students who could not attend them.

By the end of the first discipline, thirty-three students had completed the activities. Then, they could enroll in the "Integrative Project" discipline, with 60 hours of activities, 15 hours synchronous, and forty-five hours asynchronous. Overall, a workload of ninety hours was necessary to develop this methodology, with most of it dedicated to asynchronous activities.

In order to support the online learning process, three tools were used for the development of the course: Google Class, Google Meet, and Google Drive. The first one was primarily used as an online classroom to transmit information to the students, provide subject planning, publish the activities, and store documents and recordings of the classes. The google meet tool was used for the synchronous meetings and the mentoring meetings with the mentor and manager teachers. Moreover, Google Drive was used to support students in managing the projects and facilitating the monitoring of the development of the projects. Also, using this last tool, one folder was created for each student group, and they had to

register in a Google document all information about the progress of the projects (Figure 1). In this way, Google Drive allows suggestions and corrections in real-time.

Figure 1 - Google Drive as a tool to support the activities of the disciplines. Upper image: Subfolder of one of the student groups. All information about the project and the progress of the activities was fed into the folder by the students; Bottom image: Discipline's main folder in Google Drive. A subfolder has been created for each group of students.



Source: Authors, 2022

Based on the authors' previous experiences with similar methodologies and on what was planned before the beginning of the disciplines, in the first lessons, students were introduced to a guide containing instructions about the content and objectives of each meeting, as well as details about what should be delivered by the students as the final product of the course. The main guidelines introduced to the students are presented in Box 1.

Box 1 - Guidelines for project development by the students.

General instructions
1. In the first class, students should organize themselves into groups of no more than five components. 2. Each group will be responsible for a subfolder on the discipline's google drive and must keep it updated with information about the projects and activities. 3. Based on their critical analysis of the community, each group should choose a problem question for the research project. a) The problem question must be related to any local problem (family, street, neighborhood, nearby communities) b) The problem question must address some social, educational, or environmental issue. c) The issues must be aligned with at least one of the seventeen UN Sustainable Development Goals. 4. The project must contain an intervention proposal to be put into practice by the end of the activity. a) The intervention proposal must be some possible solution to the problem question. b) The intervention proposal must obligatorily include at least one technology or knowledge learned by the students in the technical disciplines (Analog and digital electronics, machine elements, refrigeration, and air conditioning, hydraulics and pneumatics, low voltage electrical installations, electrical projects, manufacturing processes, and microcontroller automation) c) The intervention proposal must include some communication plan or strategy for disseminating the project to the community or target audience (presentations, awareness campaigns, shared educational materials, and events, among others) 5. The project must include at least one vocational discipline teacher and one high school subject teacher.

Source: Authors, 2022

Due to the pandemic context and to overcome the challenges regarding student access to live classes, the course activities were divided into synchronous classes (live classes for

general course orientations and theoretical lessons) and asynchronous classes (intended for project design). Also, the two disciplines were planned to have total integration between them since the final product of the "Research Initiation Seminar" discipline was going to be used in the "Integrative Project" discipline by the student groups. The detailed planning of the disciplines, containing the different stages, activities, and contents, and synchronous and asynchronous workload is shown in box 2.

Box 2 - Detailed planning of the courses containing stages, activities, content, and each lesson's time load.

Discipline	Stages	Activities	Workload
Scientific research initiation seminar (30 hours)	Synchronous lessons (10 hours)	Discussing concepts and principles of scientific methodology	2h
		Introducing the concepts of sustainable development	2h
		Researching for online articles approaching scientific research focused on technologies and sustainable development	1h
		Analyzing and discussing local problems (environmental, social, and economic) in groups	2h
		Discussing the steps in the designing and development of a research project	3h
	Asynchronous lessons (20 hours)	Defining the research groups	1h
		Defining a problem question based on local issues	5h
		Designing an intervention proposal based on technologies	5h
		Defining disciplines involved in the project and mentoring teachers	1h

		Elaborating hypothesis and objectives for the chosen project	3h
		Elaborating a skeleton of a chronogram for the execution of the project	3h
		Producing a video presentation of the project sketch	2h
Integrative project (60 hours)	Theoretical Classes (Synchronous activities - 10 hours)	Introducing the bibliographic search in scientific article databases	1h
		Designing the methodology of a research project	2h
		Writing the abstract, introduction, results, and conclusions of a research project	2h
		Presenting the research projects to the academic community	5h
	Project designing (Asynchronous activities - 50 hours)	Mentoring activities with the supervising professors	20h
		Setting up experiments, simulations, and intervention proposals	20h
		Data Collection and Analysis	10h

Source: Authors, 2022

Results and development

Thirty-eight students enrolled for the initial "Research Initiation Seminar" discipline. They were divided into nine groups with up to five members. However, with the withdrawal for personal reasons of five students during the beginning of the activities, the class was rearranged into eight groups, which remained until the end of the activities.

Following the schedule of activities presented in box 2, the students defined eight different projects addressing local issues and aligned with the UN SDGs. During the ten hours of synchronous activities in the "Research Initiation Seminar" discipline, the students

had the opportunity to delve into essential topics such as the scientific method and sustainable development and receive some tutoring on their problem questions and the design of project stages. All groups were able to define a topic of interest and progress with the project design, specifically the intervention proposal, hypotheses, objectives, and implementation schedule. Details are shown in box 3.

Box 3 - Details of the projects designed by the students.

Project title	Issue	Intervention proposed	Subjects involved	Student (n)	ODS
Development of an intelligent prototype for hydroponic vegetable gardens	High cost of hydroponic gardens and their difficult access by poor populations in the region	Development of a prototype of a hydroponics system automated by Arduino and powered by renewable energy sources	Biology and Microcontrollers and automation	4	2, 7, 10, 12 and 13
Development of orthosis for wrist, hand, and fingers	No access to orthotics in economically vulnerable populations	Production of a low-cost wrist, hand, and finger orthosis that is easily accessible to the local population	Physical education, Hydraulics and Pneumatics, and Manufacturing Processes	5	3 and 10
Electrophoresis Laboratory	Lack of science labs in local public schools and poor student performance in physics, chemistry, and biology	Development of a didactic prototype of an electrophoresis system for use in practical classes in community schools	Chemistry, physics, biology, and analog and digital electronics	5	4
Biogas production through the construction of a biodigester	The high price of domestic gas and the lack of access to this energy source	Development of a safe, low-cost stove powered by methane gas from a home	Chemistry and Manufacturing Processes	3	1, 2, 7, 11 and 13

	for the region's poor populations	biodigester			
Democratization of proper disposal and recycling of electronic waste	A large amount of electronic waste without proper treatment in the city	Establishment of an e-waste collection station at the school and society's awareness campaigns on the electronic waste issue	Biology, physics, and electronics maintenance	5	3, 4, 10 and 11
Development of a more efficient and viable solar oven	The high price of domestic gas and the lack of access to this energy source for the region's poor populations	Development of a prototype solar stove to harness sunlight and heat for cooking	Physics and Manufacturing Processes	5	1, 2, 3 and 10
Irrigation and dynamic monitoring system based on irrigas and microcontrollers	Impact of electricity and water costs for small farmers during the irrigation process	Development of a low-cost prototype of an automated, solar-powered irrigation system	Biology, physics, Microcontrollers , and automation	3	1, 2, 7, 10 and 13
Reuse of High-density polyethylene (HDPE) in civil engineering	Inadequate disposal of High-density polyethylene (HDPE) and its impact on environmental and human health	Mapping the use of HDPE in civil engineering and raising public awareness about the health and environmental impacts	Geography and manufacturing processes	3	3 and 13

According to what was proposed in the general guidelines, the problems addressed were quite varied, ranging from educational problems to socioeconomic problems. It is

worth mentioning that the region where IFRN Canguaretama is located has low human development indexes (0.579), even below the national average for 2010 (0,724), according to data from the Brazilian Institute of Geography and Statistics (IBGE) (IBGE, 2022). The city presents high inequality and poverty in many communities, which requires a more significant commitment from the government and local institutions to solve these problems.

This is the first positive point of this methodology. Students with a more critical-reflective look can understand their reality and seek appropriate solutions. Secondly, it can be said that the proposed methodology contributed to learning contextualized to the students' reality.

Another positive point was the stimulus to interdisciplinarity since all projects succeeded in approaching knowledge from vocational disciplines and the primary curriculum of high school. In all, thirteen teachers from ten different disciplines were involved in the projects at the beginning of the "Integrative project" discipline by appointment of the students. The disciplines involved were five vocational disciplines (Microcontrollers and automation, Hydraulics and Pneumatics, Manufacturing Processes, analog and digital electronics, and electronics maintenance) and five basic disciplines (biology, physics, chemistry, physical education, and geography).

Concerning the sustainable development goals, nine of the seventeen were reported as having alignment with the projects developed by the students. The most reported were goals 2 (End hunger, achieve food security and improved nutrition, and promote sustainable agriculture), 10 (Reduce inequality within and among countries), and 13 (Take urgent action to combat climate change and its impacts), with four mentions each. Also mentioned three times each were objectives 1(End poverty in all its forms everywhere), 3 (Ensure healthy lives and promote well-being for all at all ages), and 7 (Ensure access to affordable, reliable, sustainable, and modern energy for all). Objectives 4 (Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all), 11 (Make cities and human settlements inclusive, safe, resilient, and sustainable), and 12 (Ensure sustainable consumption and production patterns) also were mentioned.

On the other hand, only eight sustainable development goals were not mentioned, or at least found no relation by the students to the projects in development. They are goals 5 (Gender Equality), 6 (Clean Water and Sanitation), 8 (Decent Work and Economic Growth), 9 (Industry, Innovation, and Infrastructure), 14 (Life Below Water), 15 (Life on Land), 16 (Peace and Justice Strong Institutions) and 17 (Partnerships to achieve the Goal).

Finally, at the end of the "Integrative Project" discipline, all groups presented their projects to the community in online activity and received feedback and evaluations of the work by teachers involved (manager and mentor teachers), which ranged from 87.5 to 100 (maximum score), with a final average of 92.5, suggesting a good performance of all thirty-three students regarding the aspect of writing the report and the progress of the stages of project development.

Challenges and difficulties

Many were the challenges faced during the application of this teaching methodology. The first, and perhaps most impactful, was the pandemic context, where face-to-face classes were suspended, and students have come to depend on internet access and tools such as computers and cell phones to attend classes (ADNAN; ANWAR, 2020; CHANDASIRI, 2020). In addition, the situation brought issues beyond the control of the classroom and school contexts, such as severe health and psychological problems (BROOKS et al., 2020; OPPENAUER et al., 2021).

These problems were relatively minimized by school policies that ensured students' access to the Internet and by donating computers and notebooks for those in a situation of socioeconomic vulnerability. In the discipline context, the alternatives found were to prioritize part of the course workload with asynchronous activities and make available all the recorded synchronous classes for later access by those students who did not participate in the live moment.

Another challenge was the students' difficulty, at the beginning of the activities, to understand the teaching methodology and its objectives and what they should accomplish throughout the disciplines. This difficulty was already expected, so the instructional guide and the detailed schedule of the courses (Box 1 and 2, respectively) were created to facilitate the understanding of everything that was planned and, for this reason, were delivered and introduced in the first meeting. We believe that the remaining doubts, especially those present in the stages of research project development, can be solved in the future through better communication between all the teachers involved in the discipline, including the mentors, to fully understand their role and better assist in the supervising process.

Two other difficulties that arose along the process deserve to be highlighted, perhaps because these are the biggest challenges for teachers and educators in the possible dissemination and application of this methodology in their schools. After defining the problem, it was difficult for some groups of students to elaborate on a project with the

intervention proposal. Also, due to inexperience with scientific research, many students faced problems when writing the project, especially about what should be addressed in each of the parts of the project (Abstract, introduction, justification, objectives, methodology, conclusions, and others).

In this sense, some actions were taken to minimize these difficulties. First, due to their experience and knowledge of the key contents (scientific method and sustainable development), the manager teachers used synchronous meetings to guide the students in the groups with difficulties and stimulate them to achieve the activities goals. Also, in some cases, the manager teachers searched for scientific articles related to the themes of the projects and shared them with the students to visualize how the idea could be put into practice more efficiently.

Secondly, a manual entitled "How to write your research project" was produced to assist in the students' writing, with simple tips and models for writing a scientific project (unpublished material). The mentor teachers also helped the students during the writing process of the project during the mentoring activities in the "integrative project" discipline.

For future moments, some ideas emerged intending to inspire and facilitate other students' understanding of this educational methodology, such as creating and sharing a bank of all scientific projects developed by the students. We believe that this bank of projects will serve as a reference base for other students and an accessible portfolio for the community and other interested parties.

Finally, other important questions still need to be addressed to improve this teaching methodology. For example, it is necessary to pursue strategies to engage a more significant number of teachers and disciplines, especially those from the high school curriculum, since, at this first moment, five teachers actively participated (Biology, Physics, Chemistry, Physical Education, and Geography). It is also essential to have more adequate tools to evaluate the student’s performance, especially when we think of adopting this methodology to regular high schools as an annual interdisciplinary school project. Also, the community around the school needs to be more engaged in this kind of activity, and the results of the project need to be widely shared to make people more aware of these issues and thus adopt a more sustainable behavior. Finally, it is essential to contemplate as many sustainable development goals as possible within the projects since eight goals were not even mentioned. It will be a great challenge to improve the methodology to expand the list of SDGs worked on and contribute to meeting the 2030 Agenda for Sustainable Development.

Final considerations and future perspectives

This online educational approach based on the scientific method aimed to stimulate critical-reflexive thinking in students based on scientific research as an intervention proposal for local problems aligned with sustainable development objectives.

In this sense, it is interesting to review the foundational bases of this methodology, Edgar Morin's complex thinking, Paulo Freire's problematic and dialogical perspective of contextualized education, and Arjen Wals' transgressive learning. From this, it is possible to infer that this methodology provides an opportunity for effective learning by stimulating students to use their knowledge in an integrated way, or at least in an interdisciplinary way, contextualized to their world. Also, following what Wals talks about transgressiveness, students can understand that they can transform the reality around them, promoting effective sustainable and social development and being a protagonist, contributing to the improvement in the quality of life of their community.

Also highly relevant, this methodology has been serving as inspiration for other projects aimed at sustainable development and the social transformation of the community. The first idea is to create a space in the school to function as a sustainable home teaching laboratory, where students and teachers from other schools in the region can visit the projects developed and learn skills related to sustainable development and interdisciplinarity, and contextualized learning. The second idea is to work together with the public schools in the region to implement this teaching methodology in their spaces and to qualify and empower teachers, school managers, and the academic community. We seek to contribute to improving the quality of local education and the creation of a more sustainable culture aimed at overcoming social inequalities.

We are aware that much still needs to be learned before this methodology can be implemented on a large scale in the region; many gaps still need to be filled, such as how to adapt it to the reality of other elementary and high schools with less structure and how to better involve the whole community. However, the initial results are encouraging and indicate that this educational methodology can be easily applied on a large scale. Still, it is feasible to adopt this educational methodology to be replicated in other schools in the region and at all levels of education, especially as an annual interdisciplinary school project involving all school sectors.

Finally, we hope to improve and share this innovative methodology and contribute to society to pursue contextualized, interdisciplinary, and transgressive teaching.

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