LEARNING SITUATIONS THAT COMBINE SUSTAINABLE DEVELOPMENT GOALS AND UNIVERSAL DESIGN IN MATHEMATICS TEACHING

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Abstract

In this paper, we explain the content and development of a series of learning situations proposed to university students for the introduction of various mathematical concepts in numerical calculus (integral, differential, and ordinary differential equations), and statistics. Each of these learning situations involved the planning of a set of sequenced activities around a problem related to sustainable development goals. We considered curriculum concretization (choice of theme, specific competencies, and basic knowledge), didactic sequencing (set of techniques, tasks, and resources), and the evaluation system.

It is crucial to incorporate SDGs into university education to promote global sustainability and sustainable development [1], while recognizing the uniqueness of each student and the need to provide a learning environment that responds to the diversity of preferences, experiences, and particularities, a paradigm addressed in Universal Design for Learning (UDL) [2].

Students have increased their motivation for mathematics by seeing its connection with SDGs and have also positively considered having information represented in different ways, using computer tools as resources to manage this information, and facilitating strategies that foster motivation.

Keywords: Mathematics Teaching, Sustainable Development Goals (SDG), Universal Design for Learning (UDL).

1 INTRODUCTION

In this work, we explain the design of a series of learning situations whose activities have been planned and sequenced around a problem related to the Sustainable Development Goals, to which students must respond. Thus, these problems are inspired by issues of public interest and are related to environmental sustainability, democratic coexistence, citizen participation, gender equality, and social justice. The goal of these learning situations is for students to learn, through the planned activities, the concepts of numerical calculation and statistics that integrate the content of the Mathematics and Statistics course in the Chemistry degree at Jaume I University in Castelló.

The learning situations are composed of different elements, including [3]:

- Curricular concretization: selection of the theme, specific competencies, evaluation criteria, and basic knowledge to be addressed during the learning situation.
- Didactic sequencing: a set of techniques, tasks, and resources designed to respond to the proposed challenge or problem.
- Evaluation system: a set of indicators and evaluation tools that allow assessing the students' competency development during and at the end of the learning situation.

The motivations behind the choice of problems related to the Sustainable Development Goals (SDGs) are both ethical and pedagogical. Mathematics should not be perceived as a neutral science but rather as having the capacity to contribute to making informed judgments and decisions [4]. Therefore, in addition to focusing on mathematical knowledge, it is also important to integrate mathematics into aspects of social and environmental justice. Moreover, the mathematics and statistics course considered in this study is designed for chemistry students; therefore, their primary focus is not on mathematics. Understanding mathematics through the resolution of real-world problems can enhance their motivation and engagement with the subject [5]. However, for learning situations to be successful, they must also be structured taking into account the uniqueness of each student. One approach that is gaining momentum in the educational field to maximize learning opportunities is Universal Design for Learning (UDL). Within this paradigm, the concept of diversity is addressed broadly, recognizing the individuality of each student and the need to provide a learning environment that responds to the diversity of preferences, experiences, and individual characteristics [6]. In this regard, through the University's Diversity and Disability Unit, we receive information and guidance to attempt to flexibilize the teaching process and establish a tailored response to each student's reality.

Therefore, in the design of learning situations, problems related to the Sustainable Development Goals (SDGs) have been taken into account. These problems have guided the students' learning process to consolidate specific skills in numerical calculus and statistics within the chemistry degree. Moreover, in the didactic sequencing and evaluation system of these situations, various means of representation, expression, and motivation have been provided with the idea of personalizing the process for diverse students in a simpler and more effective manner.

2 METHODOLOGY

The subject to which the learning techniques in this work are applied consists of two distinct blocks. The first thematic block focuses on numerical methods, encompassing the approximation of functions, numerical differentiation and integration, and the solution of differential equations with initial values. The second block involves applied statistics, covering hypothesis testing and linear regression. Additionally, the course is organized such that students have 60 contact hours, including 10 hours of theory for the entire group of 60 students (introducing basic concepts and learning situations), 10 hours of problem-solving for two groups of 30 students (addressing questions and assessing students' assimilation of concepts and acquisition of required competencies), and 40 hours of laboratory work for three groups of 20 students (where students engage with learning situations and complete individual and group projects).

The selection of problems that define the learning situations is linked to the 17 Sustainable Development Goals (SDGs), and through them, the learning of techniques in differential and integral calculus [7] and statistics [8] will be introduced. In the numerical calculus block, learning situations have been designed around issues such as the global population growth since 1950, bacterial growth rates, the amount of methane (CH4) and carbon dioxide (CO2) released into the atmosphere, and the reduction of the Arctic sea ice. On the other hand, in the field of statistics, the selected problems involve confidence intervals on the mean years of education for the adult population, gender pay inequality, sustainable energy production, and the relationship between lead consumption and crime rates.

The UDL aims to provide flexibility to meet the needs of students and is guided by three principles [2]. Principle 1): Provide multiple means of representation (including three guidelines: Guideline 1, provide different options for perception; Guideline 2, provide multiple options for language, mathematical expressions, and symbols; and Guideline 3, provide options for comprehension). Principle 2): Provide multiple means of action and expression (this principle includes the guidelines: Guideline 4, provide options for physical interaction; Guideline 5, provide options for expression and communication; and Guideline 6, provide options for executive functions). Lastly, Objective 3): Provide multiple means of engagement (including the guidelines: Guideline 7, provide options to capture interest; Guideline 8, provide options to sustain effort and persistence; and Guideline 9, provide options for self-regulation).

To explain how the learning situations have been planned and developed, following some of the UDL guidelines, we will summarize one of these situations. The problem that will inspire the learning situation is the increase in the average temperature of the planet over the years, starting from the year 1950. This issue is closely related to various Sustainable Development Goals. The information available to the students is the global average temperature of the planet each year since 1950. First, we explain the importance of approximating the data with a polynomial, given that, although from one year to another the temperature may rise or fall, the trend over the years is clearly one of temperature increase. In Figure 1, we have the annual global average of Earth's temperatures and the second-degree polynomial $f(x)$ that best fits the data.

From the polynomial $f(x)$, we will consider questions such as: how much does the temperature change, and in what manner does it change? This will lead us to the introduction of the concept of derivative, which students will learn based on previous concepts and various forms of representation. For example, in Figure 2, we have drawn three triangles with the same base (10 years) and take this opportunity to introduce terms and notations such as the increment of $f(x)$, which we observe depends on the initial value of time.

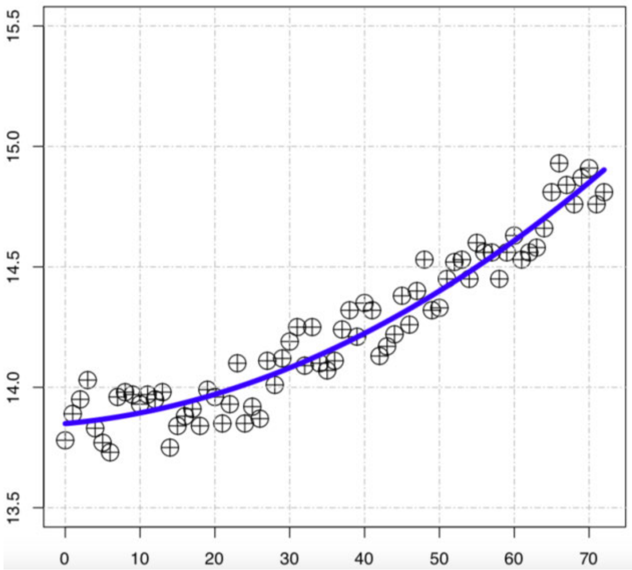

Figure 1. Global average temperature in degrees Celsius since 1950.

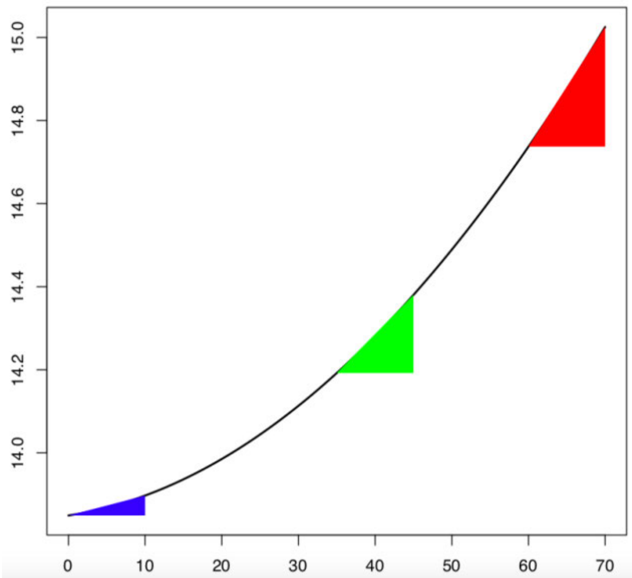

Figure 2. Changes of temperature.

In Table 1, we observe how the temperature varies when the time increment is 10 years, which will help students answer the posed questions.

Table 1. Temperature increase every 10 years.

Years increment	***Decades***	***Temperature increase in degrees Celsius***
From 0 to 10	1950-60	0.048
From 10 to 20	1960-70	0.184
From 20 to 30	1970-80	0.4
From 30 to 40	1980-90	0.696
From 40 to 50	1990-00	1.072
From 50 to 60	2000-10	1.528
From 60 to 70	2010-20	2.064

To observe the transition from average rate of change to instantaneous rate of change, we will fix time (for example, *x=43* (1993)), and examine the behavior of the average rate of change as the time intervals become increasingly smaller. In Tables 2 and 3, we observe what happens as we approach from the left and right to *x=43*, allowing students to relate the results to the concept of limit.

Table 2. Approach to x=43 from the left.

x	23	33	38	40	42	42.5	···→	43
Δf /Δx	0.016	0.018	0.019	0.0194	0.0198	0.0199	···→	0.02

Table 3. Approach to x=43 from the right.

x	63	53	48	46	44	43.5	···→	43
Δf /Δx	0.024	0.022	0.021	0.0206	0.0202	0.0201	···→	0.02

Some of the UDL guidelines applied in this learning situation are as follows. Guidelines 1, 2, and 3: The information provided to students has not only been textual but also audiovisual. Concept maps have been created to help distinguish relevant and important information, and the understanding of concepts has been promoted in three languages (Valencian, Spanish, and English). Guidelines 4, 5, and 6: There were no students needing to present different physical alternatives than the traditional ones, but computer programs such as Mathematica and R were used to assist students in visualizing and managing information. The gradual establishment of achievable and realistic goals based on students' needs has also been proposed, presenting solved example problems and exercises. Guidelines 7, 8, and 9: As the learning situation is designed based on a current real-world problem, it helps capture the students' interest. Alternatives have been presented to students for solving exercises, depending on whether they are more motivated by challenging and difficult exercises or feel more comfortable mastering the topic they are working on. Teamwork has also been fostered to ensure each student feels a common commitment with their peers. Regarding guideline 9, as an option for self-regulation and self-reflection, after each situation, students have been given a questionnaire including questions related to their involvement, commitment, and perseverance, as well as questions about specific competencies necessary for overcoming the course [9].

Providing an assessment centered on Universal Design for Learning involves using different assessment tools. In addition to the final written exam, which is used to verify if students have acquired certain specific competencies and may pose a barrier for some individuals, weekly learning instruments have been employed during laboratory sessions, where there are only 20 students per group. These instruments are used to assess whether each student achieves the clearly defined outcomes set at the beginning of the course [10].

3 RESULTS

As a result of the learning process and methodology outlined in this paper, the following outcomes have been achieved. Students have engaged in learning situations based on problems linked to the Sustainable Development Goals (SDGs), enabling them to incorporate, introduce, and apply the mathematical concepts outlined in the Chemistry degree. Once these concepts were assimilated, a series of problems with real chemical applications [11] were proposed, allowing students to apply the knowledge acquired through learning situations.

In an effort to make learning as inclusive and extensive as possible, collaboration with the Diversity and Disability Unit at Jaume I University was initiated to understand the specific needs of some students. As a significant portion of the teaching was applied to laboratory groups with 20 students, the guidelines of Universal Design for Learning (UDL) were followed, presenting information in a personalized manner. For instance, considering a student with Autism Spectrum Disorder (ASD) in the course, information was presented according to their needs [12].

From the beginning of the course, the learning process and evaluation system were clearly outlined, complementing the final written exam with continuous assessment. Students were informed about individual and group assignments, the use of software when necessary, and evaluation criteria. After each learning situation, a questionnaire was administered to assess students' motivation, work dynamics, and whether they had acquired specific mathematical competencies. The results indicated an increase in motivation to learn mathematics with this innovative learning approach.

4 CONCLUSIONS

In this paper, we present a new methodology for students in the Chemistry degree at Universitat Jaume I in Castelló to assimilate the concepts and specific competencies of numerical calculus and statistics outlined in their studies. In implementing this methodology, we have designed learning situations that students have developed and worked on. Learning situations are scenarios or contexts designed for students to apply theoretical knowledge to practical situations, fostering understanding and the practical application of concepts. Introducing these situations in university teaching provides contextualized and relevant learning experiences. By exposing students to real-world problems, the development of practical skills, problem-solving, and effective application of theoretical knowledge are promoted. This not only enhances information retention but also prepares students to face challenges in the professional world, contributing to a more comprehensive and applied education.

The designed learning situations have been linked to problems related to the Sustainable Development Goals (SDGs). Integrating the Sustainable Development Goals (SDGs) into university teaching is crucial for shaping conscious and engaged citizens. Addressing global challenges such as poverty and climate change provides students with a comprehensive perspective and fosters key competencies such as critical thinking. This approach not only imparts practical knowledge but also drives the social engagement of educational institutions.

Additionally, with the aim of making teaching more inclusive, the guidelines of Universal Design for Learning (UDL) have been taken into account when designing the situations. Following these guidelines in university teaching is important for several reasons. Firstly, UDL promotes accessibility by adapting to diverse needs and learning styles, ensuring all students have equitable opportunities. Furthermore, by integrating multiple forms of representation, action, and expression, UDL maximizes student participation and engagement. This approach also recognizes the diversity of preferences and experiences, contributing to an inclusive educational environment. In this regard, understanding students' needs is crucial.

Although the focus of the work is on teaching a university course, we believe the principles outlined are applicable to mathematics education at all educational levels.

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