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# Assessing sustainability competencies present in class proposals developed by prospective mathematics teachers

## *Evaluando competencias en sostenibilidad presentes en propuestas de aula elaboradas por futuros profesores de matemáticas*

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**Abstract ∞** The recent crises make it more important than ever to focus on training teachers to develop competencies in sustainability. This paper analyses the impact of a mathematics training program that promotes the design of tasks on mathematics and sustainability, with a focus on Education for Sustainable Development. Using an evaluation rubric, five sustainability competencies were analised in the classroom proposals. Overall, an improvement in the level of achievement of all sustainability competencies was observed after the training. Additionally, the rubric serves as a tool not only to measure the level of achievement in each sustainability competence, but also to identify the aspects that need to be integrated in the proposal to achieve its advanced level, in connection with mathematical knowledge.

**Keywords ∞** Sustainability; Mathematics; Prospective Teachers; Rubric; Competencies

**Resumen ∞** Las crisis recientes hacen más necesario que nunca centrarnos en la formación del profesorado hacia el desarrollo de las competencias en sostenibilidad. En este trabajo se analiza el impacto que provoca en el diseño de propuestas de aula de una formación matemática que fomenta el diseño de tareas matemáticas y tareas en sostenibilidad, orientada a la Educación para el Desarrollo Sostenible. Se analizarán cinco competencias en sostenibilidad mediante una rúbrica de evaluación. En general, se observó una mejora en el nivel de logro de todas las competencias en sostenibilidad analizadas después de recibir la formación. Además, la rúbrica es una herramienta que no sólo señala el nivel de logro alcanzado en cada competencia en sostenibilidad, sino que permite conocer qué aspectos de la competencia es necesario integrar en la propuesta para así lograr su nivel Avanzado, en conexión con el conocimiento matemático.

**Palabras clave ∞** Sostenibilidad; Matemáticas; Futuros profesores; Rúbrica; Competencias

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## 1. Introduction

Throughout the 21st century, several crisis events have occurred (economic, environmental, health, etc.) that threaten the survival of humanity. To address this critical situation, the 17 Sustainable Development Goals (SDGs) of the 2030 Agenda (UNESCO, 2015) indicate how to meet the needs of our generation without jeopardizing the needs of future generations. Achieving this, will be everyone's responsibility and, therefore, the aim is not only to reach political agreements, economic incentives and technological solutions (Albareda-Tiana et al., 2018), but to get all future citizens to think and act critically and thus contribute to achieve a sustainable future (UNESCO, 2017). For this reason, Education for Sustainable Development (ESD) emerges, which is not only about transferring knowledge, but also about holistic, inclusive and it is transformative teaching that "creates interactive, learner-centered teaching and learning contexts. It seeks a transformative and action-oriented pedagogy, and is characterized by aspects such as self-directed learning, participation and collaboration, problem-orientation, inter- and transdisciplinarity, and the creation of links between formal and informal learning" (UNESCO, 2017, p. 7).

However, the crises in recent years and "their complex interactions impact on all the SDGs and develop serious consequences for food and nutrition, health, education, the environment, and peace and security" (UNESCO, 2022a, p. 3), slowing down or even reversing the progress made so far.

For its part, the university is a fundamental institution in the training of committed citizens to a sustainable world (Vilches and Gil, 2012), as it trains professionals who will develop positions of responsibility in our society. However, having high levels of education is no guarantee of a greater awareness of sustainability (Orr, 2004) since, even though many world leaders are university graduates, sustainability is not their main policy (Sibbel, 2009). In this sense, the initial training of future teachers is particularly critical (Geli, 2002) as they will be responsible for the sustainability awareness of future citizens (Cardeñoso et al., 2013).

## 2. Competencies in Sustainability and Mathematics Education

The term competence is widely used in the field of training and coaching. The literature calls competence a dynamic combination of knowledge, skills, attitudes and values that influence decision-making and task performance (Gajparia et al., 2021; QAA, 2020; Rieckmann, 2012; Wiek et al., 2015). In this sense, ESD promotes sustainability competencies, which will be key to achieving sustainable development (de Haan, 2010; Rieckmann, 2012; Wiek et al., 2011), bearing in mind that these do not replace the already existing core academic competencies necessary for an "academic education for sustainability" (Wiek et al., 2011, p. 211-212).

UNESCO (2017) identifies eight key competencies in sustainability: *Systemic Thinking competence*; *Anticipatory competence*; *Normative competence*; *Strategic competence*; *Collaborative competence*; *Critical Thinking competence*; *Self-Awareness competence*; *and Integrated Problem-Solving competence.* These are transversal, multifunctional and independent competencies that should be developed in all citizens at different levels according to their age (UNESCO, 2017). And although their achievement is the responsibility of all citizens, teachers have a greater challenge, as they are the real agents of change, responsible for ensuring that their students achieve the competencies, attitudes and behaviors aimed at promoting more sustainable societies (Alperovitz, 2014; UNESCO, 2018; Vásquez y García-Alonso, 2020). In addition, teachers have "their knowledge and competencies, essential to restructure educational processes and institutions towards sustainability" (UNESCO, 2017, p. 51), through "teaching, learning and assessing activities aligned and designed to meet key sustainability competencies and learning outcomes" (QAA, 2020). On the other hand, teachers, in turn, will need to acquire sustainability competencies, as without them they will hardly be able to promote ESD in their classrooms (Ull Solís, 2015; Vega-Marcote et al., 2015). Therefore, we must think about initial and continuous teacher training that, in parallel, builds sustainability competencies in students and suggests didactic strategies that facilitate the integration of sustainability competencies in their classrooms (Unece, 2016; UNESCO, 2017). Even more so when science teachers consider their teaching to be far removed from the challenges of sustainability, and only address activities in the ecological or socio-cultural fields (Uitto & Saloranta, 2017). This means that future mathematics teachers need to be aware of their role as builders of sustainability competencies (Vásquez & Alsina, 2021).

Mathematical competence is mathematical knowledge aimed at building critical thinking, decision-making and problem solving in different contexts (Alsina, 2022; NCTM, 2000; Niss, 2002). Among the strategies to foster mathematical competence, the use of active, participatory and experimental learning methods is suggested (Sterling, 2011, p. 36) that favor integration in the classroom, analysis in complex environments and the promotion of systemic thinking (Lozano et al., 2013). In this sense, Project Based Learning (PBL) is presented as a teaching model that facilitates transdisciplinarity and allows working on the resolution of real problems contextualized in their social, environmental and economic dimensions (UNESCO, 2022b), which ESD aims to achieve.

But how do we know if a classroom proposal (CP) promotes sustainability competencies in students? There is a growing number of studies assessing sustainability competencies (Redman et al., 2021) but research remains to be developed to guide practitioners and researchers on how to assess sustainability competencies (Farioli et al., 2022) because they either provide data on one type of pedagogical innovation or address very specific outcomes in ESD (Farioli et al., 2022). It has also been observed that the literature consulted does not always address the sustainability competencies given by UNESCO (Albareda-Tiana et al., 2018; Álvarez-García et al., 2017; Gajparia et al., 2021; Sandri et al., 2018). These authors use different assessment tools, in which the rubric presents the advantage of making explicit the different levels of development of the competence studied and constitutes a contribution for both the learner and the teacher (Goodrich, 2000), indicating which elements are key to both processes. In this sense, the rubric indicates the path to progress in the development of the competency or knowledge being assessed. It provides guidance on which aspects can be incorporated in the development process.

In this study we analyze the impact of training future mathematics teachers through PBL methodology that incorporates both mathematical tasks and sustainability tasks. We investigate the sustainability competencies promoted by the CPs developed by future mathematics teachers and how the training received affects their development.

We propose the following specific objectives:

a) Design a rubric for assessing competencies in sustainability in connection with the mathematical knowledge promoted by the mathematical CPs (M-CP) developed by future teachers.

b) Apply this rubric to the M-CP and its modifications, and thus analyze the impact of the training.

## 3. Methodology

We conducted a mixed-method, descriptive and exploratory approach (McMillan & Schumacher, 2005) using content analysis as our research methodology (Stemler, 2001), to investigate the sustainability competencies promoted by M-CPs oriented towards ESD, through contexts linked to sustainable development in which mathematical knowledge is promoted.

### 3.1. Participants and context

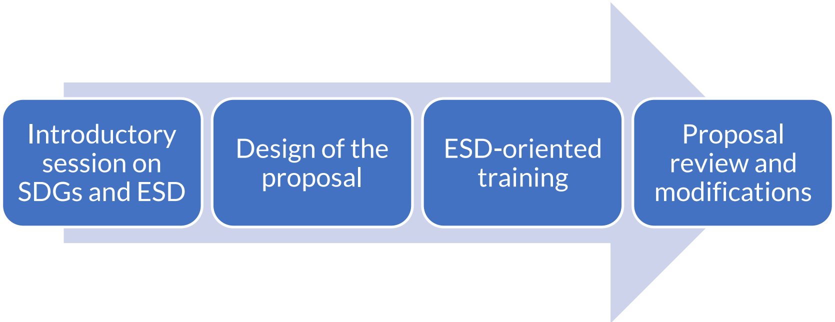
This study involved 15 students of the master's degree in Teacher Training for Secondary Education in the specialty of Mathematics at University of La Laguna, who were taking the subject *Curriculum and Complements for Disciplinary Training in the Specialty of Mathematics* during the 2022-23 academic year. This is a subject of 3 ECTS credits in the first term of the master's degree, 1.5 credits of which are devoted to the study of the mathematics curriculum for Secondary Education in Canary Islands. Students were given a 30-minute introductory session on the SDGs and were presented with the ESD document, which provides examples of contexts to develop in the classroom (UNESCO, 2017). After that, they had to design, in pairs, an M-CP incorporating SDG work for the first year of Compulsory Secondary Education (11-12 years), following a script developed during the master's course (Table 1).

Subsequently, the students received a 2-hour ESD-oriented training in which different exemplary tasks combining mathematical knowledge and sustainability knowledge were offered. From this training, the students had to take back their proposal, analyze its strengths and weaknesses, and propose modifications they considered (Figure 1).

**Table 1**. Guide for the elaboration of the classroom proposal

| | |
|---|---|
| 1. Descripción general de la propuesta de aula<br>2. ODS<br>3. Fundamentación curricular<br>4. Fundamentación metodológica<br>5. Secuencia de actividades de la propuesta<br>• Descripción general de las tareas previstas que componen la PA<br>• Objetivos didácticos de la Pa<br>• Actividades concretas que componen las distintas tareas<br>• Instrumentos y herramientas de evaluación<br>• Agrupamientos<br>• Recursos y espacios | 1. General description of the classroom proposal<br>2. SDGs<br>3. Curricular foundation<br>4. Mthedological foundation<br>5. Activities of the proposal<br>• General description of the planned tasks that make up the CP<br>• Didactic objectives of the CP<br>• Activities selected of the different tasks<br>• Assessment instrument and tools<br>• Grouping<br>• Resources and spaces |

**Figure 1**. Diagram of the process followed by the study participants

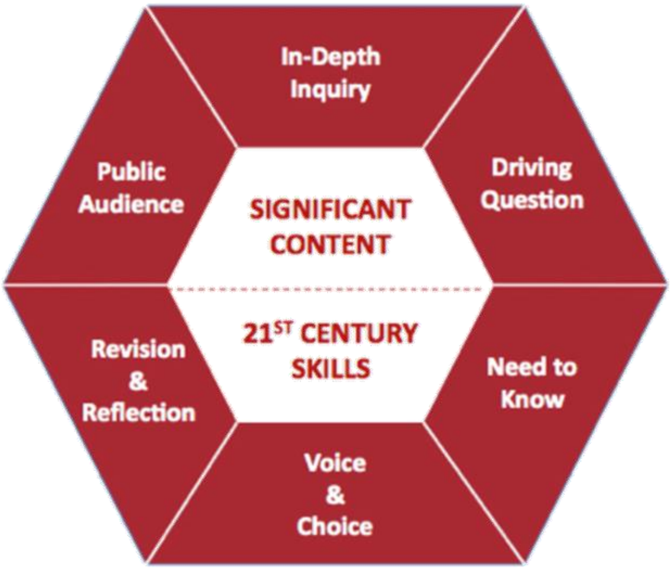



## 3.2. ESD-focused training in connection with mathematics

The training that was carried exemplifies a classroom proposal built according to the methodological model of PBL, that is, different types of tasks are shown according to the characteristics that PBL possesses (Figure 2): guiding question, deepening and inquiry, reflection, and presentation. An ESD-oriented project is developed in the context of SDG-4 (Quality Education), in which, based on data on the global schooling of students between 6 and 11 years of age, it explores this issue in depth, the reasons that lead us to the point we are at and how we can tackle it, using mathematical tools to do so.

As it is aimed at teachers, it makes explicit the tasks that address aspects of mathematics or sustainable development. In addition, throughout the project it is shown how mathematical tasks help to deepen the complexity of the context analyzed and how sustainability competencies are addressed. As an example, Table 2 shows situations, tasks and related competencies.

**Figure 2.** Characteristics of Project Based Learning.




**Source:** What Does Project Based Learning Look Like? - Center for Project Based Learning (PBL) - Sam Houston State University. (s. f.).

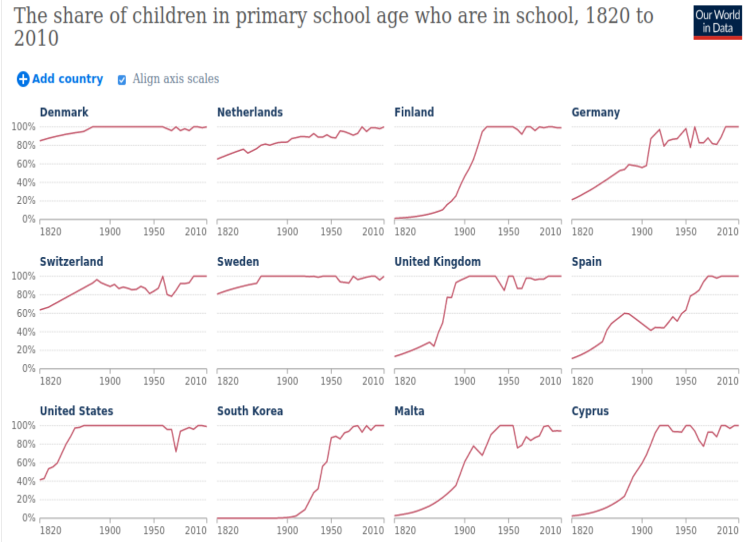
**Table 2.** Mathematical and sustainability situations and tasks [Sustainability competence]

| Situation | |
|---|---|
| *Globally, 262 million or 18% of all children, adolescents and youth age 6 to 17 years were out of school in 2017. Based on current trends, these numbers will drop only slightly to 225 million or 14% by 2030. Among **children** of primary school age (typically 6-11 years), 64 million or 9% between 2000 and 2008, but has not changed in subsequent years.* | |
| **Mathematical Task (MT)**. Determine the global numbers of schoolchildren, adolescents and young people. | **Sustainability Task (ST):** Do you think the situation has changed in 2022 **[Self-awareness]**? |
| **Situation** | |

Children out of school (Primary, by years)

| | |
|---|---|
| **MT.** What function do you identify in the graph?<br>**MT.** Build a predictive model with the indicated functions so that we can appreciate the real trend change produced. | **TS.** What historical events do you think had a relevant influence on these two periods [1979, 1997] and [1997, 2007]? **[Systemic Thinking].**<br>**TS.** Which initiative marks the greatest decline in history? **[Systemic Thinking]**<br>**TS.** What are the implications of this trend for our environment? **[Anticipation]** |

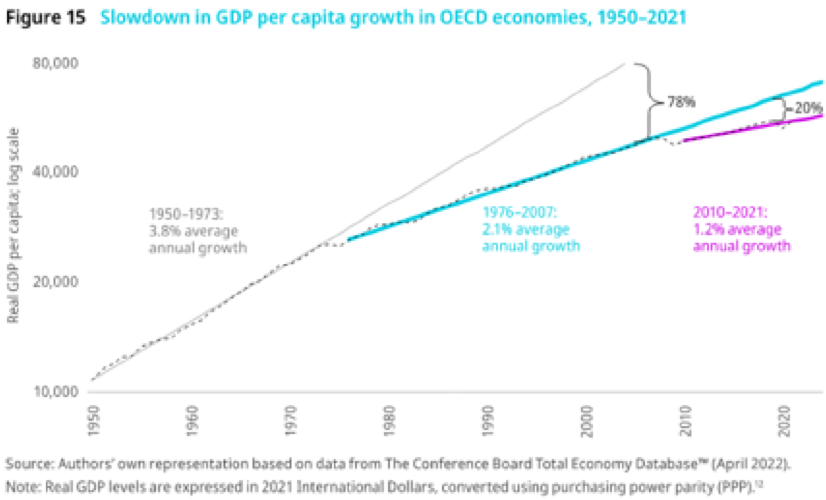
**Situation**




School enrolment by country from 1820 to 2010

| | |
|---|---|
| **MT:** Which country achieves the highest school enrolment rate, which one earlier and which one later **[Problem solving]?** | **TS.** What characteristics connect all these countries? **[Critical Thinking and Anticipation]**. |

**Situation**




Income per capita in the OECD, evolution and prediction

| | |
|---|---|
| **MT.** Growth is linear, what characteristics do you see in its behaviour? | **TS.** What role does education play in the income per capita? What can you do as a teacher? **[Self-awareness]** |

**Source:** Graphics taken from https://data.worldbank.org/indicator/SE.PRM.UNER

### 3.3. Tool for the analysis of the Sustainability Competence developed through Mathematical Knowledge

A rubric to ass the sustainability competencies as well as the degree of achievement developed in the CPs was created and validated. This rubric establishes different levels of achievement for the five out of eight sustainability competencies given by UNESCO. In order to do so, a prior analysis was carried out on the competencies that the training develops and demonstrates, which will be the ones promoted in future teachers. After this analysis, it was observed that the *Normative, Strategic and Collaboration* competencies are not demonstrated throughout the proposal. Therefore, we focused the analysis on the changes observed in the other five sustainability competences: *Systemic Thinking, Anticipation, Critical Thinking, Self-Awareness and Integrated Problem Solving.*

For each of these selected competencies, it was described by competence unit(s) (CU), i.e., a description of the competence connecting mathematical knowledge and its contribution to the development of the sustainability competence, as it is shown next.

*Systemic Thinking Competence* allows us to observe the relationships between the variables of the problem or of these with the information offered in the situation posed (CU1.1.) and how mathematical knowledge is presented as a tool that helps to achieve a global vision of the problem posed.

*Critical Thinking Competence* is aimed at reflecting on students' lifestyles in terms of sustainable development, investigating and creating new questions to position themselves regarding the issue under analysis.

*Self-Awareness Competence* will address reflection on the problem and how to modify their behavioral habits.

*Anticipation Competence* will entail the analysis of future scenarios in the context of the SDGs regarding the possible consequences and actions to be taken.

Finally, *Integrated Problem-Solving Competence* will be divided into two CUs, one related to the depth with which the sustainability problem is dealt with, and the other referring to the use of the mathematical tools proposed for searching solutions in the context provided.

In the rubric there are three levels of competence acquisition, for each competence unit, that sequentially describe how the sustainable development aspects and mathematical knowledge are interrelated in an activity aimed at developing the sustainability competence.

In the process of the validation of the rubric, there were consulted four experts in Mathematics Education and Education for Sustainable Development from different national and international universities, selected for their knowledge of the subject. In order to issue the assessment, they were sent a letter of request and a guideline to carry out the validation, in which they had to analyze the competency units and the indicators of the different levels of achievement, assessing clarity (explained in concise, exact and direct language), accuracy (adequate to explain the category) and relevance (necessary to explain the category). After receiving the opinion of the experts consulted, the adjustments were made, resulting in the rubric presented here (Table 3).

**Table 3.** Assessment rubric for selected sustainability competencies

| | | |
|---|---|---|
| **Systems thinking competency:** The ability to recognize and understand relationships, to analyze complex systems, to perceive the ways in which systems are embedded within different domains and different scales, and to deal with uncertainty | | |
| **1.1** It proposes activities and/or tasks that, through mathematical knowledge, identify and deepen the understanding of the problem posed, through the study of new variables, not initially explicit in the problem, with which to reinterpret and address some novel aspect, thus evidencing the complexity of the problem that arises. | | |
| **Basic** | **Integrated** | **Advanced** |
| M-CP identifies or enumerates the relationships between the variables, as well as the information offered by the problem posed. Mathematical knowledge does not contribute to achieving the global vision of the problematic situation. | M-CP relates the variables and information offered by the problem posed and incorporates new variables or new information to the suggested problem. Mathematical knowledge helps to achieve the global vision of the problematic situation. | M-CP relates the variables and information offered by the problem posed and incorporates new variables or new information to the suggested problem. Mathematical knowledge helps to achieve the global vision of the problematic situation. |
| **Critical thinking competence:** The ability to question norms, practices and opinions; reflect on one's values, perceptions and actions; and take a position in the sustainability discourse. | | |
| **2.1** It proposes activities and/or tasks aimed at reflecting on the impact of their lifestyle with the problem posed, asking other questions inquiring about their position on sustainability, as well as the reasons and origin of the problematic situation in connection with mathematical knowledge. | | |
| **Basic** | **Integrated** | **Advanced** |
| M-CP promotes the study of the sustainability-related questions given in the original problem. Mathematical knowledge is directed at the same time. | M-CP promotes the construction of new questions that address the questioning of their lifestyle in relation to sustainability. Mathematical knowledge is directed at the same time. | M-CP promotes the investigation and construction of new questions that question and require a position on the issue of sustainability and may question the origin of the information. As a consequence, different mathematical knowledge is mobilized. |
| **Self-awareness competency:** The ability to reflect on one's role in the local community and (global) society, continually evaluate and further motivate one's actions, and deal with one's feelings and desires. | | |
| **3.1** It proposes activities and/or tasks that allow the student to reflect on the responsibility they have in the face of the problem posed and offers the opportunity to modify habits or behaviors determined by personal feelings and/or desires in order to contribute to the achievement of the selected SDG. | | |
| **Basic** | **Integrated** | **Advanced** |
| M-CP presents the problem of sustainability and encourages reflection on responsibility in general. The student is not the center of reflection. | M-CP presents the problem of sustainability and encourages reflection on the responsibility of students, aimed at the development of concrete actions that do not involve modification of their habits. | M-CP presents the problem of sustainability and encourages reflection on the responsibility of students, aimed at the development of concrete actions that involve the modification of their habits. |

| | | |
|---|---|---|
| **Anticipatory Competency:** The ability to understand and evaluate multiple future –possible, probable and desirable – and to create one's own visions for the future, to apply the precautionary principle, to assess the consequences of actions, and to deal with risks and changes. | | |
| **4.1** It proposes activities and/or tasks that promote the analysis of future scenarios, analyzes possible consequences and, in coherence, proposes different actions to be carried out within the selected SDG. | | |
| **Basic** | **Integrated** | **Advanced** |
| M-CP presents the problem of sustainability and encourages the analysis of future scenarios. | M-CP presents the problem of sustainability and encourages the analysis of future scenarios and their consequences. | M-CP presents the problem of sustainability and encourages the analysis of future scenarios and their consequences, providing possible actions. |
| **Integrated problem-solving competency:** The overarching ability to apply different problem-solving frameworks to complex sustainability problems and develop viable, inclusive and equitable solution that promote sustainable development - integrating the above-mentioned competencies. | | |
| **5.1** It proposes the analysis and in-depth understanding of a sustainability problem, from a local and/or global perspective. | | |
| **Basic** | **Integrated** | **Advanced** |
| M-CP presents a problem with context in sustainability in which its local or global study is not deepened. | M-CP presents a problem with context in sustainability in which its given local and/or global study is deepened. | M-CP presents a problem in sustainability and offers the opportunity to investigate and deepen its local and global study. |
| **5.2** It proposes the use of appropriate mathematical tools to analyze and understand a sustainability problem whose mathematical solution is aimed at a positive and equitable transformation of the context in which the problem is framed. | | |
| **Basic** | **Integrated** | **Advanced** |
| M-CP presents isolated mathematical tasks, which address the sustainability problem posed. | M-CP presents the mathematical tasks connected to the problem in sustainability, which do not promote transformative or equitable solutions in the proposed context. | M-CP presents the mathematical tasks connected to the problem in sustainability and these promote transformative and equitable solutions in the proposed context. |

### 3.4. Analysis procedure

The proposals elaborated by the students were coded according to the levels of achievement identified in the assessment rubric constructed for this purpose. The coding was performed by the authors and, to guarantee reliability, a calibration process was carried out that included joint coding sessions and discussion of disagreements, followed by a process of individual coding. For this process it was design a Google form where the codification was registered. Once categorized, the results were pooled and a consensus was reached on the categories developed, obtaining the results shown in the next section.

## 4. Results and discussion

This section presents the results obtained by applying the sustainability competencies assessment rubric to each of the M-CP elaborated by the participants in the experience, both in their initial and revised proposals, with the aim of identifying the impact of the training received.

## 4.1. Analysis of pre-training proposals

Each M-CP corresponds to a pair of prospective teachers. Table 4 shows the different SDGs addressed in each of the proposals, as well as the mathematical knowledge developed.

**Table 4**. SDG and Mathematical knowledge for each M-CP

| Code | SDG | Mathematical Knowledge |
|---|---|---|
| 1A | 12 - Responsible production and consumption | Numbers and operations |
| 1B | 4 - Quality education | Statistics: tables and graphs |
| 2 | 12 - Responsible production and consumption | Numbers: proportionality and measurement |
| 3A | 3 - Health and well-being | Numbers and operations |
| 3B | 6 - Clean water and sanitation | Numbers and operations |
| 4A | 3 - Health and well-being | Statistics: tables, graphs and parameters |
| 4B | 13 - Climate action | Statistics: tables, graphs and parameters |

After the application of the rubric, the results (Table 5) show that, overall, the M-CPs address all five competencies in sustainability, although not with the same level of achievement. While, looking at each M-PC individually, not all address all competencies (blank in Table 5).

**Table 5.** Levels of achievement of the sustainability competencies for each of the M-CPs developed by prospective mathematics teachers

| | CU1.1 | CU2.1 | CU3.1 | CU4.1 | CU5.1 | CU5.2 |
|---|---|---|---|---|---|---|
| 1A | | | | | Basic | Basic |
| 1B | | | Basic | Basic | Basic | Basic |
| 2 | Basic | | Basic | | Integrated | Integrated |
| 3A | Integrated | Integrated | Advanced | | Integrated | Advanced |
| 3B | Integrated | | | | Basic | Integrated |
| 4A | Integrated | Integrated | | | Advanced | Integrated |
| 4B | Integrated | Basic | | | Basic | Basic |

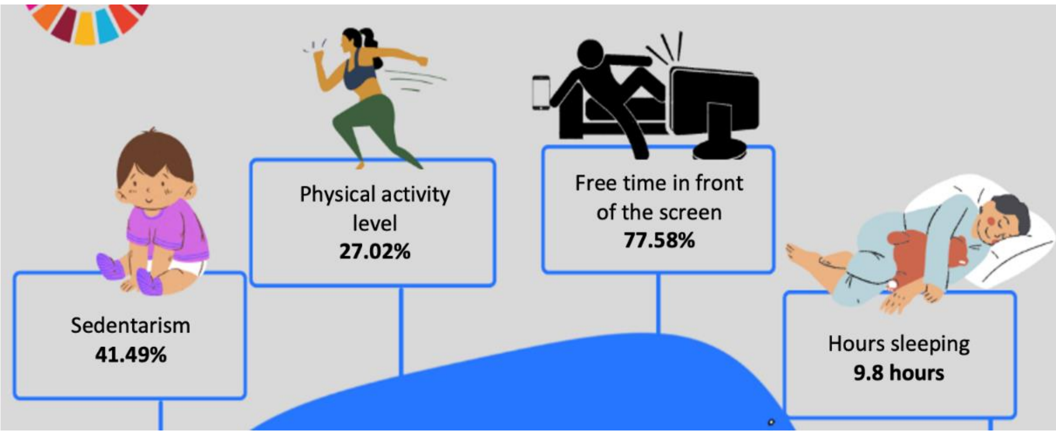
Note: The range of grays is associated with the level of achievement attained, from basic (light) to advanced (dark).

Also, we can observe (Table 5) that *Integrated Problem-Solving Competence* (CU5.1, CU5.2) is worked on in all the M-CP, in both competence units, while *Anticipation Competence* (CU4.1) appears in a "Basic" level only in one M-CP, and *Critical Thinking* (CU2.1) *and Self-Awareness* (CU3.1) competencies are demonstrated in three M-CPs. *Systems Thinking Competence* (CU1.1) is shown in its "Integrated" level in four of the five M-CPs, although two do not address it.

Analyzing the table 5 longitudinally, we can observe that M-CP-3A develops the most competencies in sustainability, while M-CP-1A only develops the *Integrated Problem-Solving* competence in its two CUs (5.1, 5.2).

Thus, for example, M-CP-4A, which addresses SDG3 (Health and Well-being), has been placed at the Integrated level in the *systems thinking* competence (CU1.1) because it presents the study of sedentary lifestyles both at regional and national point of view, analyzing different variables that may affect this issue, such as time spent in front of a screen or physical activity (Figure 3). In contrast, there are two proposals (M-CP-1A and M-CP-1B) which do not establish relationships or attempt to carry out a global analysis of the situation. Another M-CP carries out a Basic level study (M-CP-2), as the mathematics is focused on the analysis of the data collected, with no other projection or interest.

**Figure 3**. Extract from the initial M-CP-4A in relation to CU1.1. Source: M-CP-4A.




Both, *Critical Thinking Competence* (CU2.1) and the *Self-Awareness Competence* (CU3.1), have been observed in only three of the M-CPs, although only one of them addresses both competencies (M-CP-3A). Thus, M-CP-3A studies obesity (SDG3 - Health and Wellbeing) and promotes the study of interrelated variables such as ultra-processed foods and macronutrients, which it will use to help students develop a balanced weekly menu (Figure 4).

**Figure 4**. Extracts from the initial M-CP-3A in relation to CU2.1. and CU3.1

Una vez finalizada, realizaremos un debate en clase que iniciaremos con las siguientes preguntas.

- ¿Eran tan buenas y tan malas las comidas como creímos en un principio?
- ¿Deberíamos cambiar nuestra alimentación?

*Descripción*. La tercera tarea constará de una única actividad en la que el alumnado tendrá que crear de manera grupal un menú semanal atendiendo a los diferentes conocimientos adquiridos de las tareas anteriores así como del cálculo de las kilocalorías diarias que requiere cada alumno y cada alumna atendiendo a su género biológico, a su nivel de sedentarismo y a los porcentajes de los macronutrientes en una dieta equilibrada.

*Once finished, we will hold a class discussion that we will start with the following questions:*

*- Were the meals as good and as bad as we thought at first?*

*- Should we change our diet?*

*<u>Description.</u> The third task will consist of a single activity in which the students will have to create a weekly menu as a group based on the different knowledge acquired from the previous tasks as well as the calculation of the daily kilocalories required by each student according to their biological gender, their level of sedentary lifestyle and the percentages of macronutrients in a balanced diet.*

**Source:** M-CP-3A.

As we have pointed out, *Anticipation Competence* (CU4.1) is only addressed in M-CP-1B, at the "Basic" level, when it deals with a prediction of the evolution of the variable under study, although without studying consequences neither action (Figure 5).

**Figure 5**. Excerpt from the initial M-CP-1B in relation to the Anticipation competency

Asimismo, la reflexión deberá incluir aspectos que los estudiantes destaquen sobre la evolución de la tasa de AET, sobre si seguirá disminuyendo o si, por el contrario, aumentará y comentar el porqué de las respuestas que proporcionan. El interés de dicha reflexión radica

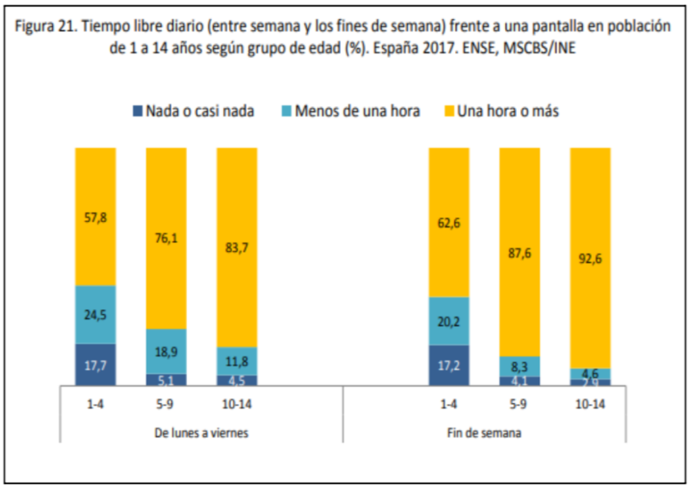
*So, the reflection must include aspects that the students highlight about the evolution of the Early School Dropout rate, about whether it will continue to decrease or if, on the contrary, it will increase, and comment on the reasons for the answers they provide.*

**Source:** M-CP-1B

With respect to *Integrated Problem-Solving Competence*, we observe that CU5.2 has obtained a result with a slightly higher level of development than CU5.1. Furthermore, we find that M-CP-4A is at the Advanced level in CU5.1, as throughout its proposal it promotes local study, by analyzing healthy habits, and global, by means of the statistical study by autonomous communities (Figure 6). For its part, M-CP-3A obtains an Advanced level for CU5.2, as its proposal contributes to the development of a healthy menu as a solution to the problem posed (Figure 7).

If we analyze every M-CP, the rubric also allows us to observe the depth with which each of the M-CP promotes the competencies in sustainability in connection with mathematical knowledge, as well as to indicate the opportunities for improvement in the proposals. As we indicated above, none of them promotes the five sustainability competencies, being M-CP-3A the one that develops more than the others, with four sustainability competencies at the "Integrated" and "Advanced" levels, although with no one task for *Anticipation* (CU4.1). M-CP-4A is in a similar situation, but in this case, apart from the *Anticipation* competence, the *Self-awareness* competence (CU3.1) is not addressed either. And M-CP-1A and M-CP-1B only address all the competencies at the "Basic" level. The other three proposals are at the "Basic" and "Integrated" levels.

**Figure 6**. Extract of two tasks from the initial M-CP-4A with global and local study of leisure time habits




A. ¿Qué representa este gráfico? ¿A qué franja de edad pertenecen los datos representados? ¿Qué tipo de gráfico se ha utilizado para su representación?
B. ¿Los datos presentados son frecuencias absolutas?
C. ¿Cuáles son los niveles de sedentarismo representados?
D. Si nos centramos en la población de 10 a 14 años, ¿qué porcentaje gasta una hora o más diaria frente a una pantalla? Valóralo.
E. Compara estos datos con el presentado en Canarias.

Figure 21. Daily tme watching a screen (weekdays and weedends). From 1 to 14 years old, according to age group (5). Spain 2017.
A. What does this graph represent? What age range does the data represented belong to? What type of graph has been used for its representation?
B. Are data presented absolute frequencies?
C. Which are the levels of walking represented?
D. If we focus on the population between 10 and 14 years old, what percentage spends an hour or more daily in front of a screen? Give your opinion.
E. Compare these data with that presented in the Canary Islands.

**ENCUESTA HÁBITOS SEDENTARIOS Y DESCANSO**

**Pregunta 1**. ¿Cómo te identificas?
☐ Hombre ☐ Mujer ☐ No binario ☐ Otro/Prefiero no indicarlo

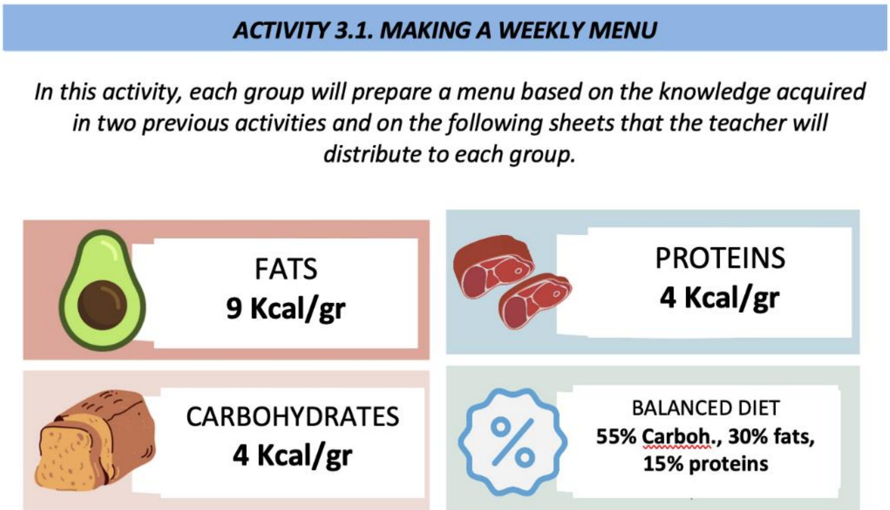
**Pregunta 2.** Aproximadamente, ¿cuánto tiempo sueles pasar en un día lectivo frente a una pantalla, incluyendo el ordenador, la tablet, la televisión, los vídeos, los videojuegos o la pantalla del teléfono móvil?
☐ Nada o casi nada ☐ Menos de una hora ☐ Entre 1 y 2 horas ☐ Entre 2 y 3 horas
☐ Entre 3 y 4 horas ☐ Entre 4 y 5 horas ☐ Más de 5 horas ☐ No sabe/No Contesta

**Pregunta 3.** ¿Y en un día de fin de semana?
☐ Nada o casi nada ☐ Menos de una hora ☐ Entre 1 y 2 horas ☐ Entre 2 y 3 horas
☐ Entre 3 y 4 horas ☐ Entre 4 y 5 horas ☐ Más de 5 horas ☐ No sabe/No Contesta

*Survey of sedentary habits and spare time*
*Question 1. How do you identify?*
*Question 2. Approximately, how much time do you usually spende in a school day in front of the screen? (Including computer, tables, television, videos, videogames or mobile screen)*
*Question 3. And, on weekend days?*

**Source:** M-CP-4A.

**Figure 7**. Excerpt from the initial task of M-CP-3A, which proposes the transformative mathematics-based solution.




**Source:** M-CP-3A

## 4.2. Analysis of proposals after ESD training

Once the students received the ESD-focused training, they reviewed their M-CP and made any modifications they considered appropriate to refocus the M-CP towards ESD. The results obtained after applying the sustainability competencies assessment rubric are shown in Table 6. Here we highlight the new achievements obtained for each CU after training, as observed through the evaluation rubric of selected sustainability competencies. The shading refers to the results shown in Table 5.

**Table 6.** Levels of achievement of the sustainability competencies for each of the modified M-CPs by prospective mathematics teachers after training

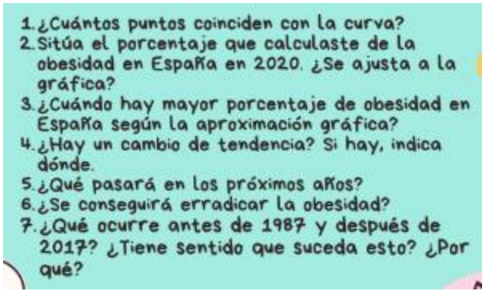
| Code | CU 1.1. | CU 2.1. | CU 3.1. | CU 4.1. | CU 5.1. | CU 5.2. |
|---|---|---|---|---|---|---|
| 1A | Basic | | | | | |
| 1B | Basic | Basic | | | Integrated | Integrated |
| 2 | | Basic | | | | |
| 3A | Advanced | | | Integrated | | |
| 3B | | Integrated | | | Integrated | Advanced |
| 4A | | | | | | |
| 4B | | | Basic | Basic | Integrated | Integrated |

Note: The range of grays represents the level of achievement attained in the first version of the CP (Table 5).

Comparing these results (Table 6) to the ones in the initial version (Table 5), there is better achievement in each sustainable competencies for every M-CP, except for M-CP-4A, which did not modify its level of achievement in any of the CUs. Thus, we find that eight UCs that were not observed in the first M-CP, in the modification made are shown in their "Basic" (6) or "Integrated" (2) level. In addition, four of the six competency units (1.1., 2.1., 5.1. and 5.2.) have modified their level of achievement after the revision of three M-CPs, while the competency units that were less developed in the first M-CP (*Anticipatory Competence*, CU4.1, and *Self-Awareness*, CU3.1), have been modified in two and one M-CP, respectively.

Analyzing the results for each competence, we observe that *Competence in Systemic Thinking* (CU1.1) moves to "Basic" level in M-CP-1A and M-CP-2, while M-CP-3A moves forward to the "Advanced" level (Figure 8). In those three cases, the tasks incorporated looks for a deeper understanding of the problem posed through mathematical knowledge.

**Figure 8.** Excerpt from the modified M-CP-3A


1. ¿Cuántos puntos coinciden con la curva?
2. Sitúa el porcentaje que calculaste de la obesidad en España en 2020. ¿Se ajusta a la gráfica?
3. ¿Cuándo hay mayor porcentaje de obesidad en España según la aproximación gráfica?
4. ¿Hay un cambio de tendencia? Si hay, indica dónde.
5. ¿Qué pasará en los próximos años?
6. ¿Se conseguirá erradicar la obesidad?
7. ¿Qué ocurre antes de 1987 y después de 2017? ¿Tiene sentido que suceda esto? ¿Por qué?

*1. How many points coincide with the curve?*
*2. Locate the percentage you calculated for obesity in Spain in 2020. Does it fit the graph?*
*3. When is there a higher percentage of obesity in Spain according to the graph approach?*
*4. Is there a change in trend? If there is, indicate where it is.*
*5. What will happen in the next few years?*
*6. Will obesity disappear?*
*7. What happens before 1987 and after 2017? Does it make any sense for these results? Why?*

**Source:** M-CP-3A

With regard to *Critical Thinking Competence* (CU2.1) we observe that two M-CPs move to "Basic" level (M-CP-1B and M-CP-2), while M-CP-3B goes directly to the "Integrated" level. It is relevant that M-CP-3B proposes modifications in students' weekly menu to reduce their water footprint, which will entail a change in their lifestyle in relation to the sustainability problem studied (Figure 9).

**Figure 9.** Extract from the modified M-CP-3B where the menu should be modified to reduce the water footprint

Una vez tengan el menú cooperativo, deberán hallar qué ingredientes son los que más aportan a la huella hídrica del menú. Calculando la proporción porcentual que representa en la comida. Finalmente, deberán modificar algunos de los platos del menú para conseguir disminuir la huella hídrica total de la semana, mostrando el cambio porcentual de huella hídrica que se consigue con cada cambio.

Once they have the cooperative menu, they will have to find which ingredients contribute the most to the water footprint of the menu. Calculate the percentage that it represents in the food. Finally, they shoud modify some of the dishes on the menu to reduce the total water footprint of the week, showing the percentage change in water footprint that is achieved with each change.

**Source:** M-CP-3B

Once they have the cooperative menu, they will have to find which ingredients contribute the most to the water footprint of the menu. Calculate the percentage that it represents in the food. Finally, they shoud modify some of the dishes on the menu to reduce the total water footprint of the week, showing the percentage change in water footprint that is achieved with each change.

Only M-CP-4B incorporates *Self-Awareness Competence* (CU4.1) at the "Basic" level, i.e. by generating reflection questions on the students' opinion about the subject matter, but without elaborating on the responsibility involved (Figure 10).

**Figure 10.** Excerpt from the modified M-CP-4B asking new questions about the student's opinion

Una vez recogidos los datos correspondientes al cuestionario se les pide que representen los datos gráficamente. A continuación se les preguntará lo siguiente generando un pequeño debate:

¿Qué opinan de las respuestas obtenidas?¿Creen que se podría mejorar las emisiones de $CO_2$?¿Cómo?¿Qué creen que ocurre a nivel global?

Once the data corresponding to the questionnaire have been collected, they should present the data in a graph. Then, they should answer the following questions, generating a small debate: What do you think of the answers obtained? Do you think $CO_2$ emissions could be reduced? How? What do you think is happening globally?

**Source:** M-CP-4B

With regard to *Anticipation Competence*, it can be observed that M-CP-3A, in its initial version, did not propose the analysis of future scenarios (level not observed in CU4.1), whereas in the modification, both the analysis and the consequences of future scenarios are encouraged ("Integrated" level in CU4.1), although they do not address the study of actions to be implemented (Figure 8). In addition, M-CP-4B, in which this competence had not been observed in its initial version, has included a new task in which the analysis of future scenarios is encouraged, achieving the "Basic" level.

Finally, *Integrated Problem-Solving Competence*, in its two CU (5.1, 5.2), is the most developed in the proposals analyzed, as only one of them (M-CP-1A) offers this competence at a "Basic" level and the rest at its "Integrated" or "Advanced" level.

It is worth noting that only M-CP-4A did not carry out modifications that involved changes in the levels of achievement for the sustainability competencies. Students only considered improvements in the statistical content they were developing, as they evaluated their proposal as "coherent and appropriate" as they pointed out that "small individual actions have a significant result as the students themselves are the object of the study in some areas of action along this SDG" (M-CP-4A, p. 3). Modifications in the mathematical content focused on adding more explanation of the statistical concepts working on.

## 5. Conclusions

This study analyzed the impact of an ESD-focused training for future mathematical teachers. This training is based on exemplifying a proposal developed to work on mathematics and sustainable development, following the PBL model, in which strategies are identified and exemplified to develop mathematical and sustainability tasks in the context of SDG-4 (Quality Education) for the development of ESD-focused M-CPs.

The impact of this training was analyzed through the study of the sustainability competencies promoted by the proposals drawn up by the future teachers. For this, a rubric that describes the levels of achievement of the sustainability competencies worked on in the training was constructed and validated. This rubric assess five sustainable competencies: *Systemic Thinking, Critical Thinking, Self-Awareness, Anticipation and Integrated Problem Solving.* The levels of achievement indicate the depth with which the competence is addressed in the M-CP and provide guidance on how to develop a better sustainability competence linked to mathematical knowledge.

In the analysis of the M-CP prior to the training developed, it has been detected that *Integrated Competence in Problem-Solving* is present in all the M-CPs. Although this is not surprising, since Problem Solving is a basic process in Mathematics, not all of them develop it with equal depth, since in some cases only "Basic" level is achieved. The competence *Anticipatory Skills* is the least developed, followed by *Critical Thinking* (CU2.1) *and Self-Awareness* (CU3.1) competencies. The analysis of future scenarios is not usually addressed in the construction of M-CP, nor are studied their consequences or actions to be developed. This is significant because, if there is one thing that defines ESD, it is that it should be a transformative education and, in this sense, action and the positive transformation of our environment, having control over the repercussions of these actions, should be an inherent activity of this teaching model.

It should be noted that the proposals do not easily integrate *Critical Thinking* (CU2.1), even though Mathematics promotes this type of thinking. This is evidence of a teaching model that prioritizes learning that is more procedural and not very reflective or interpretative. Education for Sustainability is an opportunity to reflect on the role of Mathematics in the construction of critical thinking, contextualized in the students' social and cultural environment and in which they understand the scope of their decisions (*Self-awareness*).

After the implementation of the training, the modifications suggested by the teachers develop *Systemic Thinking Competence* (CU1.1) in all M-CPs, and in almost all of them improves *Critical Thinking Competence* (CU2.1). In addition, it is observed a higher level of achievement in the *Anticipation* (CU3.1) and *Self-Awareness* (CU4.1) competencies.

The assessment rubric helps us to observe that, after the training, there was a reflection on the proposal that contribute to redirect the proposal towards ESD.

This was because either appears new CU that were not present in the first proposal, or a greater level of achievement on sustainability competence.

Therefore, we can affirm that the impact of the training received by future Secondary Mathematics teachers has promoted reflection and awareness of how to work on the SDGs and sustainability competencies in an integrated way with mathematical knowledge in their classroom proposals.

Project-based learning, studied in the training, has promoted awareness-raising among prospective teachers and has helped them to know how to develop proposals that address aspects related to sustainable development, thus advancing the integration of sustainability competencies (Cebrián, 2018; Lambrechts et al., 2013) in their future students.

Proposals analyzed here suggest that addressing the initial training of future mathematics teachers by exemplifying classroom proposals that show how to develop in the classroom a connection between mathematical knowledge and sustainability competencies is necessary to build M-CPs with a focus on ESD, and thus, promote initial teacher training towards ESD. The implementation of training sessions for teachers that promote these connections contributes decisively to holistic and systematic teaching, who also develop their sustainability competencies and learn strategies to implement them in their classrooms. Last but not least, the assessment rubric has provided insight into the level of depth offered by the proposals, while pointing out how to move towards a proposal that develops sustainability competencies in connection with mathematics. It is necessary to continue to address this challenge for teacher training to integrate ESD into their usual teaching strategy.

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## Evaluando competencias en sostenibilidad presentes en propuestas de aula elaboradas por futuros profesores de matemáticas

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Las crisis recientes hacen más necesario que nunca centrarnos en la formación del profesorado hacia el desarrollo de las competencias en sostenibilidad. La Unesco (2017) señala ocho competencias clave competencias clave en sostenibilidad que son transversales, multifuncionales e independientes a desarrollar en todos los ciudadanos en distinto nivel según su edad: *competencia en Pensamiento Sistémico*; *competencia en Anticipación*; *competencia Normativa*; *competencia Estratégica*; *competencia de Colaboración*; *competencia de Pensamiento Crítico*; *competencia de Autoconciencia*; *y competencia Integrada de Resolución de Problemas.* Y, aunque su logro compete a todos los ciudadanos, los docentes tienen un reto mayor, pues son los verdaderos agentes del cambio, responsables de que sus estudiantes logren las competencias, actitudes y conductas encaminadas a promover sociedades más sostenibles.

En este estudio analizamos cómo los futuros profesores de matemáticas movilizan cinco competencias en sostenibilidad a través de las propuestas matemáticas que elaboran para trabajar la educación para el desarrollo sostenible. Y estudiamos cómo modifican estas propuestas y las competencias abordadas, tras recibir una formación dirigida a construir propuestas matemáticas que combinas tareas matemáticas y tareas en sostenibilidad que siguen el Aprendizaje Basado en Proyectos. Para este análisis se ha construido y validado una rúbrica que establece niveles de logro para las competencias seleccionadas: *de Pensamiento Sistémico, de Anticipación, de Pensamiento Crítico, de Autoconciencia e Integrada de Resolución de Problemas.*

Los resultados muestran que las propuestas matemáticas de aula elaboradas por los futuros profesores incluyen, incluso antes de recibir la formación, la *Competencia Integrada en Resolución de Problemas*, mientras que la competencia *de Pensamiento Sistémico* estará presente en todas las propuestas una vez han recibido la citada formación.

Con respecto a la competencia del *Pensamiento Crítico,* llama la atención que no se promueva en las propuestas, aun siendo objetivo fundamental de la enseñanza de las Matemáticas. Lo mismo sucede con las competencias de *Anticipación* y de *Autoconciencia*, que en las versiones iniciales no abordan el análisis de escenarios futuros, o de consecuencias y acciones a desarrollar.

Observamos que es necesario ofrecer una formación orientada a promover la Educación para el Desarrollo Sostenible a través de la enseñanza de las matemáticas, lo que constituye una oportunidad para reflexionar sobre el papel que posee la Matemática en la construcción del pensamiento crítico, contextualizado en el entorno social y cultural de los estudiantes y en el que el estudiante comprenda el alcance de sus decisiones. Implementar sesiones formativas para docentes que promuevan estas conexiones contribuye de forma decidida a lograr una enseñanza holística y sistemática en la que, además, se desarrollen sus competencias en sostenibilidad y construyan estrategias que faciliten la implementación en sus aulas. Y, no menos importante, la rúbrica de evaluación permite conocer el nivel de profundidad que ofrece la propuesta, a la vez que señala cómo avanzar hacia una propuesta que desarrolle las competencias en sostenibilidad en conexión con la matemática.