Revista Iberoamericana para la Investigación y el Desarrollo Educativo
ISSN 2007 - 7467

https://doi.org/10.23913/ride.v10i20.640

Artículos Científicos

Estequiometría como unidad de aprendizaje en el nivel medio superior del IPN. Análisis desde la docencia

Stoichiometry as a learning unit in the Upper Middle Level of the IPN. A teaching analysis

Estequiometria como uma unidade de aprendizagem no nível médio superior do IPN. Análise do ensino

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Resumen

Las estrategias en el proceso de enseñanza-aprendizaje-evaluación (PEAE) tienen un desempeño preponderante. El objetivo central fue analizar a tres docentes que desempeñaron rol de alumnas en el proceso de enseñanza del tema de estequiometría del nivel medio superior en el Instituto Politécnico Nacional (2016). Tradicionalmente, el PEAE se ha centrado en el cálculo y balance de sustancias químicas como estrategia de aprendizaje. Esto genera dificultades en la ejecución de operaciones aritméticas y algebraicas, las cuales son usadas como única forma de aprendizaje, lo que contribuye a los altos índices de desánimo, reprobación y deserción. En este trabajo se utilizó la plataforma Edmodo en cuatro fases: indagación documental, identificación de conocimientos previos, experiencia de una situación no rutinaria, y sentido y significado pedagógico. Los hallazgos muestran autorreflexión de las participantes en su papel como alumnas y en su quehacer docente.

Palabras clave: aprehender, estequiometría, estrategia didáctica, resolución de problemas.

Abstract

The strategies in the Teaching-Learning-Evaluation Process (PEAE) have a preponderant performance. The main objective was to analyze three teachers in their role as students in this process, in the subject of upper middle level stoichiometry at the National Polytechnic Institute in 2016. Traditionally, the PEAE has focused on the calculation and balance of chemical substances such as learning strategy. This leads to the difficulty in the execution of arithmetic and algebraic operations as the only form of learning and its consequent evaluation, contributes to the high rates of discouragement, disapproval and attrition. The EDMODO platform was used in four phases: documentary inquiry, identification of previous knowledge, experience of a non-routine situation, and pedagogical meaning and meaning. The findings show the teacher's self-reflection in his role as a student and in his teaching work.

Keywords: Apprehend, stoichiometry, didactic strategy, problem solving.

Resumo

As estratégias no processo de ensino-aprendizagem-avaliação (PEAE) têm desempenho preponderante. O objetivo principal foi analisar três professores que desempenharam o papel de alunos no processo de ensino da disciplina de estequiometria no ensino médio no Instituto Politécnico Nacional (2016). Tradicionalmente, o PEAE tem se concentrado no cálculo e no equilíbrio de substâncias químicas como uma estratégia de aprendizado. Isso gera dificuldades na execução de operações aritméticas e algébricas, que são usadas como a única forma de aprendizado, o que contribui para os altos índices de desânimo, fracasso e deserção. Neste trabalho, a plataforma Edmodo foi utilizada em quatro fases: pesquisa documental, identificação de conhecimentos prévios, experiência de uma situação não rotineira e significado e significado pedagógico. Os resultados mostram a autorreflexão dos participantes em seu papel como estudantes e em seu ensino.

Palavras-chave: apreender, estequiometria, estratégia didática, resolução de problemas.

Fecha Recepción: Octubre 2019 **Fecha Aceptación:** Marzo 2020

Introduction

Every problem of environmental sustainability that we are facing has its bases in chemistry and its different branches of knowledge, among them stoichiometry, a word whose origin is found in the Greek words stoicheion (element or part) and métron (measure for calculation of the quantitative relationships between reagents and products in the course of a chemical reaction). The vast field of study in this area of knowledge is made up of the reactions, composition and characteristics of the subject, aspects that tend to be challenging for students and, consequently, high failure rates.

On this situation, Obando (2013) explains that the traditional teaching of stoichiometry is one of the reasons why obstacles are created in student learning, while authors such as Arasasingham, Taagepera, Potter and Lonjers (2004) point out that In certain teaching practices there is an incomplete understanding of the chemical equation and its relation to the empirical situation. In this regard, Gabel (1993) highlights that these obstacles are due to the emphasis placed on the symbolic level and on the resolution of algorithmic problems, instead of those phenomena of the student's daily life.

From the perspective of chemical languages in stoichiometry, Galagovsky and Giudice (2015) demonstrate in their work errors made by students, which derive from transfers between expert chemical languages that have different specific syntactic codes and formats; that is, the student makes stoichiometric errors due to the basic misinterpretation of the various codes at the microscopic, macroscopic, and symbolic levels.

In addition to the problem of student learning on the subject of stoichiometry, it is important to highlight the performance of the teacher in his teaching practice. Various researches, for example, consider that didactic practices constitute a determining factor to promote student learning, which is sustained on the basis of the ideas, prejudices, values and conceptions of teaching that the teacher has (Campanario, 2003). In other words, in teaching, these features are conclusive aspects for the elaboration of the teaching strategies applied in the classroom, hence it is affirmed that the teachers' points of view in relation to teaching and learning turn out to be the biggest obstacle to making a change in your methods (Campanario, 2003).

It is true that many teachers in the area of science in general - and chemistry in particular - are aware that the constructivist teaching process usually produces great benefits to boost the learning of their students; However, when inquiries are made about teaching, it is evident that in practice traditional teaching strategies predominate, which is contradictory to their initial conceptions (Maldaner, 2000; Mellado, 1996). This reality shows that the pedagogical and didactic instruction acquired by teachers in their professional training is not fully applied, since in daily life they reproduce traditional methods that their teachers used to teach them (Martínez, 2009).

In this context, it is vital to reflect on what, how, when and why to teach, especially in the case of chemistry teachers, for which it is necessary to take into account two elements: knowledge of the discipline and development of didactic strategies based on pedagogical, epistemological and didactic aspects (Mellado and González, 2000). In addition to this, Shulman (1987) states that in order to improve chemistry teaching, teachers need to master three categories of skills: knowing the subject of their discipline, general knowledge of pedagogy and pedagogical mastery of content.

Noting the above, it can be indicated that the objective of this work was to analyze the experience of three teachers of the upper middle level (NMS) of the Higher Polytechnic Institute (IPS) to promote the self-reflection of their teaching practice on the subject of stoichiometry in non-routine situations related to environmental impact and sustainability.

To achieve this objective, the following research question was asked: How to promote the reflection of the teacher in stoichiometry at the upper secondary level in the IPN? In this goal it has been considered relevant to transcend the teaching-learning-evaluation process (PEAE) for the stoichiometry learning unit, by proposing as part of this process issues related to sustainability due to the relevance it has in today's world. Likewise, it has been taken into account that it is at this educational level that science teaching —in this case of stoichiometry— demands a pedagogical, didactic and comprehensive conception oriented to knowledge, understanding and solution of major sustainability problems.

Framework

Some fundamental principles underlie the teaching-learning-evaluation process that every teacher tries to promote, one of which is related to the Greek concept episteme, which tries to promote student learning. This function is relevant in all those activities related, firstly, with learning (knowing, knowing, discovering) and, secondly, with apprehending. From the field of epistemology, as a branch of philosophy focused on the possibilities and limitations of scientific knowledge, this difference is remarkable.

Learning includes activities such as studying, memorizing, instructing, acquiring skills to carry out an activity, etc. In this framework, the student is a passive subject who transits from one level to another and whose actions are not part of the environment, since he does not make it his own, since he only incorporates it automatically. In contrast, the verb apprehend is linked to generating and understanding knowledge from a personal and / or collective position vis-à-vis the natural and social environment. This is a posture of acquisition and generation of knowledge where the student is an active being, who apprehends with the senses and applies skills to understand the usefulness of learning stoichiometry to face challenges of great relevance such as water scarcity, food production and its environmental impact, climate change, obtaining energy, etc. The science and technology approach from sustainability provides one of the useful tools within the pedagogical and didactic paradigms to link these four main axes with each of the chemical sciences.

Apprehending is inherent in every person when its meaning is clear and acquires a personal meaning that allows answering the following questions: why in today's world are the studies of stoichiometry as well as its multiple applications necessary? Why do each one of the activities that involves learning this topic?

In addition to knowing the multiple applications in the scientific, technological, social, academic, etc., context, it is necessary, first, to learn the equation balance procedure and, later, to apprehend the subject in the aforementioned sense and meaning. This is accomplished when the learner declares the differences between learning and apprehending. The latter is a polysemic concept used in different areas of knowledge, both for science and humanities teaching. Here are some cases.

For example, in the area of acoustics of physics, Boussetta, Beyaoui, Laksimi, Walha and Haddar (2017) state: "Furthermore, microscopic observations were realized to better apprehend these damage mechanisms, and to validate the acoustic emission study carried" (p. 175). The polysemy of the apprehend concept leads to the translation of grasping the understanding or capturing its understanding (while understanding it), while the Webster Dictionary reads: "To grasp with the understanding: recognize the meaning of" (p. 55); that is, achieve their understanding (understand the meaning of its elements).

In the case of the humanities, Karim, Mohamed, Ismail and Rahman (2018) use this concept, which could be translated as an understanding of the phenomenon studied. Similarly, in Younesi and Pirnajmuddin (2018) the concept apprehends the world is translated as an understanding of the world or as a quality of a person's experience.

Regarding the practice in humanities, Dallegrave and Burg Ceccim (2018) present the following in a national congress about residency programs in health:

> It is understood that practical learning results from emotional exposure and apprehensions, and that a syllabus is made up of the possibility to apprehend questions and contextualize them, rather than creating a school syllabus based on what will be learned, especially when it comes to in-service education (p. 877).

In this case, apprehend is translated as perception of practical learning, the result of the combination of perceptual, emotional, meaning and meaning elements that the student prints on it. For their part, Hrich, Lazaar and Khaldi (2019) use the concept in a two-step evaluation proposal:

> In this context, the assessment process proposed is presented on two steps: the first step, we evaluate resources related to the competence to very their acquisition degree and to remediate if necessary, the second step will evaluate the capacity of leaner to mobilize those resources in order to apprehend a situation and respond to it in a more or less relevant way (p. 226).

In the first step, resources related to the proposed competence are evaluated for their degree of acquisition and to solve deficiencies if deemed necessary, while in the second step it is planned to evaluate the ability of the student to give meaning and meaning to the acquired learning that allows you to apprehend a given situation and act in a more or less relevant way. Apprehending, as a polysemic concept, subsumes an active learning with meaning and sense that the student incorporates when establishing conceptual relationships with reality, between the known and the apprehended. It re-signifies the acquired knowledge and, at the same time, goes beyond your previous knowledge; Now he discovers his heuristic potential and gives it meaning by motivating him to continue in this direction.

This requires the need for updating and theoretical and methodological training for teachers to carry out their work optimally. For this reason, it is stated that the training of science and / or technology teachers in Mexico today has multiple dimensions that need to be addressed in each and every one of them. This approach poses a series of challenges for institutions of higher secondary education to propose solutions in important aspects of an educational nature. It is precisely from sustainability that it is intended to promote the learning of concepts related to stoichiometric topics, aimed at service teachers in order to raise awareness of their practice in the classroom through the experience in the different scenarios that the student experiences. The aim is for the teacher to reflect on their daily activities to train critical, responsible and capable students to make decisions in the face of social and environmental situations facing the country.

For this purpose, a relevant problematic situation for society and the environment was selected: the topic of polymers, which was raised through the analysis of stoichiometric concepts in a polymerization reaction, reaction performance, limiting reagent and excess reagent to consider the benefits and impacts on the environment, mainly, as well as theoretical aspects through a laboratory practice and the development of pedagogical reflection in the classroom.

The proposal considers the use of the Edmodo educational platform to provide participants with a space for reflection supported by various materials: web pages, articles and reference books on significant information and the topic of study. In addition, the messages section was established to establish communication between the participating teachers and spaces were opened for consensual discussions and decision-making in order to promote dialogue and reflection.

For this reason, the present investigation analyzes the experiences of the teacher in his performance as a student with respect to the subject of stoichiometry to rethink his teaching practice and foster in the student an interest in chemistry, especially stoichiometry and thus benefit the development of the process of learning .

Teachers from the IPN CECyT 8 Chemistry Academy were invited to participate in the investigation. These fulfilled the requirements stipulated in the study plans and had teaching experience in teaching stoichiometric subjects at said institution. Initially 10 teachers were enrolled with the previous requirements satisfactorily fulfilled. They answered an exploratory questionnaire to identify previous ideas related to the general subject of stoichiometry: determination of the minimum formula of a compound, weight laws, stoichiometric calculations of chemical reactions, efficiency of a reaction, purity of reagents, limit reagent and excess reagent.

It should be clarified that all these topics are addressed in the programmatic content of this learning unit. The application of this first exploratory test was carried out through the Edmodo platform. Upon completion and evaluation, the passing result was obtained in only five teachers. The other five decided not to continue because their schedules collided with our work and because they lacked skills to manage the Edmodo platform. Finally, for the experience of a non-routine situation, only three teachers decided to explore the new proposed challenges.

In summary, it can be said that in these lines a didactic strategy oriented to the action of apprehending as a backbone is proposed to generate meaning, discover the heuristic potential of what is apprehended and encourage motivation in this direction. In this regard, it has been considered that the teacher's experience to face the current challenges of stoichiometry contributes to the apprehension of both perennial and current topics, through critical reflection of this field of specific knowledge. Hence the need to rethink the generation of knowledge through its mediation, not to learn (that is, to reiterate, repeat, memorize), but to apprehend (induce, decipher, contrast and innovate), and with it the possibility of rethink to build, and not to passively consume knowledge.

Materials and method

Stage 1

The method examined the following stages:

Documentary inquiry. Documentary research was carried out regarding the learning of stoichiometry and the teaching-learning process of science. The difficulty in understanding scientific texts was verified, particularly those related to stoichiometric issues due to the requirement of cognitive resources necessary to carry out treatments that would allow the content in the text to be identified (Martínez, 2011). Similarly, the disinterest of students in learning science was identified, a situation motivated by the traditional teaching received in previous educational levels (Obando, 2013). To this is added the scarce prior knowledge necessary to start learning stoichiometry, with weak or null mathematical competences such as percentage relationships, ratios and proportions, conversion and chemistry factors, nomenclature of elements and compounds, balancing of chemical reactions (Valderrama and Gonzales, 2010). Finally, the literature reports the difficulties that high school students face in their chemistry course with respect to a highly symbolic and formalized chemical language, which entails non-significant learning (Obando, 2013).

Regarding science education, Marcelo (2009) considers teacher professional development as a collaborative process, relating it to school reforms as ideal scenarios for reflecting on classroom work. In this sense, Ponte (1998) mentions various aspects to carry out professional development: permanent discussion with his counterparts, decision making, exchange of experiences in the classroom and disciplinary updating. For Perrenoud (2000), teacher training should promote the development of competencies that involve disciplinary and methodological knowledge, in addition to systematizing learning situations, facilitating and organizing their progress, actively involving students, implementing the use of technologies and promoting collaborative work.

In this direction, Day (2001) points out various goals in teacher training and calls for the continuity of knowledge of the profession from a vision planned to achieve certain ends. In the classroom context, Day mentions goals aimed at scientific and pedagogical development, permanent reflection on his educational work and constant updating on learning units.

In this way, the professional development of the teacher is recognized as a process of knowledge production to promote dialogue with their counterparts on issues related to teaching activity. In this context, updating scientific knowledge is necessary, as well as the articulation with other areas of knowledge in current science topics with social impact (for example, problematization and contextualization, problem solving, teaching from research, use of information and communication technologies, etc.).

The teacher must recontextualize pedagogy to specific content in favor of student learning (Acevedo-Díaz, 2009), articulating it with other areas of knowledge. This implies the elaboration of innovative strategies, didactic material and practices to motivate the student and involve him in the current problems of social impact.

Stage 2

Previous knowledge. A diagnostic instrument was designed in order to identify the prior knowledge necessary to learn stoichiometry, which was applied to the participating teachers. For this, it was considered to carry out the steps recommended by Luchetti and Berlanda (1998), who show the cognitive abilities of the participants. The instrument was designed based on the curricular content of Chemistry II. The necessary and sufficient knowledge was identified to equate previous knowledge. Table 1 establishes the programmatic contents in stoichiometry and the previous knowledge before starting the topic.

Tabla 1. Contenido programático de estequiometría y conocimientos previos necesarios

N.°	Contenido programático	Conocimientos previos necesarios
1	Determinación de la fórmula mínima de un compuesto	Cálculo aritmético de porcentajes de cantidades Conocimiento de tabla periódica de los elementos Concepto de peso atómico Concepto de peso molecular
2	Leyes ponderales: Ley de conservación de la materia. Cálculos estequiométricos de reacciones químicas	Conocimiento de tabla periódica de los elementos Concepto de peso atómico Concepto de peso molecular Reacción química Balanceo de reacciones químicas Regla de tres simple o factores de proporción
3	Eficiencia de una reacción	Cálculo aritmético de porcentajes de cantidades Concepto de peso molecular Conocimiento de tabla periódica de los elementos Concepto de peso atómico Concepto de peso molecular Reacción química Balanceo de reacciones químicas Regla de tres simple o factores de proporción
4	Pureza de los reactivos	Cálculo aritmético de porcentajes de cantidades Concepto de peso molecular
5	Reactivo límite y reactivo en exceso	Conocimiento de tabla periódica de los elementos Concepto de peso atómico Concepto de peso molecular Reacción química Balanceo de reacciones químicas Regla de tres simple o factores de proporción

Fuente: Elaboración propia con base en Karim *et al*. (2018)

The instrument had 25 multiple-choice problems: 10 ratio and proportion items and a simple rule of three, 5 for calculating percentage, 5 for nomenclature of chemical compounds and 5 for balancing chemical reactions. Here are two examples of reagents for direct and inverse proportions, simple rule of three, and chemical reaction balance.

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- *The decomposition of 36 g of water produces 4 g of hydrogen gas. How much gaseous hydrogen is produced when 180 g of water decomposes?*
    a. 200 g
    b. 20 g
    c. 0.80 g
    d. 0.20 g

Balance the following reaction by selecting the corresponding coefficients on each compound:

e. 2, 13, 8, 10
f. 2, 8, 13, 10
g. 1, 6, 4, 5
h. 10, 8, 13, 2

$$C_4H_{10} + O_2 \rightarrow CO_2 + H_2$$

The application of the instrument was made on the Edmodo educational platform.

Stage 3

Experience of a non-routine situation. Problem solving was promoted so that the three teachers lived the experience as students and reflected on their performance as teachers in teaching stoichiometry in the face of non-routine situations.

Contextualized learning and / or contextualized learning from science problem solving favors concept learning (Cala, Mariño and Casas, 2009), as well as the development of abilities and skills to face non-routine situations, which requires reflection, search of information, constant questioning and decision-making to issue an analyzed and defined response, a solution strategy.

For the present study, the classification of problems developed by Wakefield (1992), particularly semi-open and semi-closed problems, was determined. The first are those partially defined where some parameters are identified and the solution presents various positions, that is, more than one answer. The latter are partially defined and present a single response (Wakefield, 1992).

The problem of the offered experience belongs to semi-closed problems due to the number of participants, which allowed information search and continuous discussion. During the experience, the development of scientific procedures (observing, inferring, explaining, arguing, etc.) in consensual environments of reflection and analysis was promoted in order to promote decision-making during the solution process.

The selected problem was adapted from an exercise in the article Practical work integrated with problem solving and conceptual learning in polymer chemistry (Garritz and Irazoque, 2004). The situation contemplates the analysis of the concepts limit reagent and excess reagent in a chemical reaction, within the domain of stoichiometry. In addition, it addresses a socio-environmental problem: polymers. Its application was considered for the manufacture of consumer articles and the process for obtaining nylon 6-10, as well as for the analysis of the concepts of immiscibility, density, types of reaction, functional groups of organic chemistry. With this, the participant sought to intervene from a critical position to issue analyzed and argued solutions in consensual contexts. The text of the situation is as follows:

- *In the industrial field, the manufacture of nylon 6-10 is carried out from the reaction of a diamine and a carboxylic acid, although the process is very slow. In the laboratory the reaction could be accelerated using hexamethylene diamine and sebacoyl chloride* (Garritz y Irazoque, 2004, p. 47).

The contextualized situation had nine guiding questions to carry out the activity (Table 2); The questionnaire sets out the intention of these questions to identify possible connections with previous knowledge and new concepts, the use of analogies and the use of strategies for their solution, as well as the impact of polymers on the environment.

Revista Iberoamericana para la Investigación y el Desarrollo Educativo
ISSN 2007 - 7467

Tabla 2. Preguntas guía del problema propuesto

<table>
<tr><th>Preguntas</th><th>Intención</th></tr>
<tr><td>1. Explica brevemente si técnicamente es posible realizar el experimento para la obtención del hilo nailon 6-10 en el laboratorio, de modo que los alumnos observen la polimerización claramente. Describe el procedimiento para realizarla, considerando la hexametilendiamina y el cloruro de sebacoilo</td><td>Explicación para realizar el experimento de obtención del nailon 6-10.
Se identifican habilidades para investigar, así como curiosidad, creatividad, habilidad para indagar, seleccionar y clasificar información.</td></tr>
<tr><td>2. Si se requiere obtener 150 g de nailon 6-10, ¿cuáles serán las cantidades de los reactivos si la reacción tiene una eficiencia de 90 %?</td><td rowspan="2">Se solicita al docente las cantidades de reactivos necesarias para obtener 150 g de nailon 6-10, considerando una eficiencia de reacción de 90 %. Aplicación de los conceptos estequiométricos: ley de conservación de la materia, balanceo de ecuaciones químicas y concepto de rendimiento de la reacción.
Se requiere investigación previa de la reacción química por realizar.
Conocimientos previos: proporciones con regla de tres, factores de relación molar, rendimiento teórico, rendimiento real y rendimiento porcentual. Empleo de analogías.</td></tr>
<tr><td>3. ¿Cuál sería el reactivo límite y cuál de exceso?</td></tr>
<tr><td>4. ¿Qué sucede cuando una de las aminas de la hexametilendiamina reacciona con un cloro del cloruro de sebacoilo para formar cloruro de hidrógeno y el segundo cloro de la misma molécula reacciona con otra molécula de amina y así sucesivamente?</td><td>Explicar claramente el experimento práctico en el laboratorio y describir lo observado (la polimerización forma una cadena que es el hilo de nailon).</td></tr>
</table>

5. ¿Se producirá una cadena? Explique.	
6. Es posible observar en el laboratorio la creación de una gran molécula. ¿A través de qué medios? Explique brevemente.	Descripción de la obtención del nailon 6-10, la formación de una gran molécula y qué medios utilizaría para lograr describirla. Descripción del experimento en el laboratorio, enfatizando la formación del hilo de nailon.
7. Pedagogía. ¿Considera usted que las características del experimento pueden explicar a los alumnos los conceptos de densidad, inmiscibilidad, tipos de reacción, polimerización lineal por condensación, grupos funcionales y velocidad de reacción? ¿Puede describir brevemente cómo lo haría?	Descripción pedagógica de los conceptos implicados en la experiencia, los cuales son observables en el experimento y en la representación de la reacción de polimerización que ocurre.
8. ¿Por qué la producción mundial de polímeros sigue siendo tan grande a pesar de los graves problemas ecológicos? 9. ¿Qué propiedades tienen los polímeros sintéticos que no pueden ser igualadas por las sustancias naturales?	Indagación de razones por las que continúa la producción de polímeros aun cuando ocasiona daños al ecosistema. Enfoque CTSA. Además de explicar las diferencias de propiedades físicas entre polímeros sintéticos y naturales.

Fuente: Elaboración propia con base en Garritz y Irazoque (2004)

Stage 4

Reflection activity for the teacher (pedagogical meaning and meaning). This stage was oriented to the self-reflection of the lived experience as a student to recognize strengths, weaknesses and areas of opportunity in the restructuring of teaching practice, focused on strengthening the meaningful learning of its students. Eight questions were constructed to guide reflection on their performance in activities of stages 2 and 3.

Results

The results showed a good level of mastery by teachers in solving stoichiometry problems; however, in the ratios and proportions section they presented errors in their approach, mainly percentages of nomenclature and balance of reactions.

It was decided to name category I the use of processes for the meaning of content by teachers (Table 3), which is oriented towards the identification of relevant (or significant) elements in the problem situation to analyze information treatments and recognize their articulation . This gives the possibility of establishing new opportunities in solving the problem, in the application of chemical processes for the meaning of content by teachers.

Table 3. Indicadores *categoría I*

ER	Se **E**xplicitan los elementos **R**elevantes o significativos en la situación.
TIE	**T**ratamiento de la **I**nformación; cálculos **E**stequiométricos orientados a la acción sobre la base de las relaciones establecidas.
AI	**A**rticulación de la **I**nformación en el contexto situacional.

Fuente: Elaboración propia con base en Garritz e Irazoque (2004)

The design of a teaching strategy must start with the experience of diverse experiences and allow the teacher to notice challenges, obstacles and strengths that the student will face day after day in the classroom. Because of this, category II focuses on the teacher's self-reflection on their experience in order to rethink teaching strategies in daily classroom activities (Table 4).

Tabla 4. Indicadores *categoría II*

QQ	¿**Q**ué y para Qué?
HT	**H**erramientas **T**IC. Edmodo.
EE	**E**strategias para aprehender temas **E**stequiométricos.

Fuente: Elaboración propia con base en Karim *et al*. (2018)

An analysis method from the field of social sciences is used. The teacher's performance during the experience is evident, establishing the mechanisms used to solve the problem situation. Next, the analysis corresponding to category I (table 5) and later the analysis of category II (table 6) are presented..

Tabla 5. Categoría I. Aplicación de procesos químicos para la significación de contenidos por los docentes.

ER	**Docente A**: Indica paso a paso la técnica de laboratorio para la obtención de nailon 6-10, aunque presenta errores en el balanceo.
	Docente B: Explica el procedimiento para obtener el nailon 6-10.
	Docente C: Presenta de manera general necesidades de materiales, reactivos; control de las condiciones de reacción, sin especificaciones.
TIE	**Docente A**: El cálculo es correcto para la cantidad de reactivo de hexametilendiamina, aplicando las relaciones estequiométricas.
	Docente B: Establece las relaciones ponderales que se deben realizar para el cálculo estequiométrico de cada reactivo y el ajuste debido al rendimiento de 90 % de la reacción.
	Docente C: Escribe la reacción sin balancear, con errores en los nombres de los reactivos debajo de su fórmula en la reacción.
AI	**Docente A**: No establece con precisión que el reactivo limitante es el cloruro de sebacoilo, además trata de establecer una cadena polimérica.
	Docente B: Explica la combinación de los dos reactivos: los extremos del hexametilendiamina reaccionan con el cloruro de sebacoilo para formar nuevos enlaces de amida, creándose una cadena alternada de los dos grupos funcionales diferentes para producir un polímero denominado nailon 6-10.
	Docente C: No expone el procedimiento, solo menciona que ocurre la polimerización por condensación.

Fuente: Elaboración propia con base en Garritz e Irazoque (2004)

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Tabla 6. Categoría II. Repensar estrategias didácticas

QQ	**Docente A**: **Experiencia:** Faltó reflexionar más sobre reactivos para comprender la intención de la pregunta. **Fortaleza**: Conocimiento de propiedades de los elementos, del cálculo de peso molecular, número atómico, balanceo de reacciones, conceptos de reactivo límite y reactivo en exceso, concentración. **Debilidad**: Carencia de conocimientos en nomenclatura de compuestos orgánicos y desconocimiento de polímeros.
	Docente B: **Experiencia**: Dominio de la situación. **Fortaleza**: Dominio de conocimientos matemáticos y químicos. **Debilidad**: Desconocimiento para resolver reglas de tres, simples inversa.
	Docente C: **Experiencia**: Considera el dominio de los temas. **Fortaleza**: Considera que posee el dominio de temas estequiométricos. **Debilidad**: Falta de disponibilidad de tiempo para la actividad.
HT	**Docente A**: Dominio parcial de la herramienta tecnológica Edmodo.
	Docente B: Dominio parcial de la herramienta tecnológica Edmodo.
	Docente C: Dominio mínimo de la herramienta tecnológica Edmodo.
EE	**Docente A**: **Apertura**: Trabajo en equipo acerca de un producto comercial de interés para el alumno que se relacione con la química inorgánica. **Desarrollo:** Exposición en Power Point sobre conceptos de estequiometría, ejemplificando con el uso cotidiano de un producto. **Cierre:** Dar continuidad a la investigación realizada en la apertura y aplicación de conceptos de estequiometría vistos en el desarrollo.
	Docente B: **Apertura**: Retroalimentación de relaciones estequiométricas. Analogías sencillas sobre el tema a tratar. Resolución de problemas de procesos sencillos que involucren reactivo límite y reactivo en exceso con el fin de que el alumno conozca el proceso a seguir. **Desarrollo**: Resolución de problemas. **Cierre**: Retroalimenta el proceso de resolución del reactivo límite y reactivo en exceso a través de la discusión del procedimiento correcto, al plantear y efectuar

	cálculos estequiométricos en la solución de problemas y explicar los procesos químicos.
	Docente C: **Apertura**. Incluir en clase una actividad didáctica de una situación que viva el alumno en su vida cotidiana para relacionarla con los conceptos de masa y volumen. **Desarrollo**. Utilizar analogías, modelos y reacciones a partir de las preguntas iniciadas antes y dar ejemplos de la vida cotidiana para la comprensión de reactivo límite; utilizar la analogía de la preparación de sándwiches. **Cierre**. Plantea a los alumnos un problema integrador del tema de estequiometría para trabajarlo en equipo.

Fuente: Elaboración propia con base en Martínez 2011

Finally, as a result of research, there was a change in us: now we have the firm conviction of the need to "dare to know" as a vital tool of our teaching work so that the illustration is given, that is, "the freedom to do "Or —in Emanuel Kant's words—" the public use of reason".

Discussion

The intention of this research was to demonstrate the importance of science education (in this case, stoichiometry) in the NMS, a process that according to the dissertation exposed requires a pedagogical, didactic and comprehensive conception oriented to knowledge, understanding and solution of real problems (Valderrama and Gonzales, 2010). The discussion of the indicators is presented below based on the organized and systematic analysis developed.

Category I. Application of chemical processes for the meaning of the content by teachers ER indicator

Teachers A and B identified relevant information in the context of the situation and used existing information sources on the Web to describe the practical way of obtaining nylon 6-10 in the laboratory and the chemical reaction that occurs. Regarding stoichiometry, reaction balancing, reaction yield and limit reagent, they were satisfactorily resolved through the articulation of the information obtained.

Teacher C failed to identify relevant information for obtaining nylon and presented errors in the chemical reaction, as well as errors in the conceptualization and stoichiometric calculations for the limit reagent and yield.

TIE indicator

The teachers were unable to establish the appropriate relationship during the experiment and, with it, explain the concepts of density when observing that one liquid lodges in the upper part of the container and another in the lower one due to its different densities; the immiscibility that is observed even when they are shaken to mix them and that they separate after a time.

Likewise, the formulas allow to identify functional groups of organic compounds, which was not visualized by the teachers as they did not represent any meaning in their work, as can be seen in the responses of teachers A and C, respectively.

> Teacher A: I had no knowledge of organic compound nomenclature and polymers have many molecules. As a student I did not know the name of the compounds mentioned, but I researched them on the Internet and found the formula for each of them.
>
> Teacher C: At first with some uncertainty. A little disoriented for not knowing the formulas of the reagents or their quantities, necessary to solve the question of the limit reagent. Also, because it is a polymerization reaction that is not common for stoichiometry.

AI indicator

Teacher A articulated the information for condensation polymerization, but did not argue his answer. On the other hand, teacher B articulated the information and issued arguments for the polymer chain, also considered that it is possible to observe how a large molecule is formed when the nylon thread is separated from the interface of the two liquids in the experiment. Teacher C did not establish any articulation during his dissertation, since it did not represent any meaning to him.

Category II. Rethink teaching strategies

QQ indicator

The teachers considered that the resolution of problems is adequate to be applied with the students, since they felt good when solving the activity. However, teacher A commented that in some questions it was necessary to reflect more on the content.

Teacher A expressed the absence of obstacles when solving the problem, while teacher C did face two obstacles: the lack of availability of time and knowledge of the educational platform, while teacher B expressed the need to remember the way of solving inverse proportion rules of three.

Regarding strengths, the three teachers indicated that they focus on mastering content in their subject and mathematical concepts; however, teacher C commented on the presence of errors with his students in solving ratios and proportions in mathematics and chemistry.

To solve the activity of the stoichiometry problem, teacher A exposed some uncertainty regarding the equation that represents the polymerization reaction and calculation of the number of molecules in the polymer. For her part, teacher B indicated that her obstacle was ignorance of the formulas of the compounds.

HT indicator

Regarding the management of the Edmodo educational platform, teachers A and B commented that they had no problems, while teacher C did have problems managing it, so they experienced discomfort and uncertainty, although they recognized the great usefulness of the resource for support academic activities.

Regarding the problem of obtaining nylon, the three teachers confessed their ignorance of the reagent formulas: sebacoyl chloride and hexamethylenediamine. Teachers A and B immediately resorted to web resources to find out their formulas, as well as the reaction that is carried out to obtain nylon 6-10. The information provided in the Edmodo platform library facilitated the investigation into the situation. Teacher C faced more difficulties in obtaining the information because he did not know how to use the platform.

EE indicator

From a pedagogical perspective, teacher B expressed the importance of promoting meaningful student learning on the subject of stoichiometry using the same sequence of activities as this research, that is, adapting a project chosen by the students to investigate at the beginning of the course. and select the information, prepare conceptual maps and exposition of the work. The teacher considered a didactic sequence of opening, development and closing, although he ignores the resource of previous knowledge. Teacher A presented the problem statement in real life contexts and promoted the inquiry by students about stoichiometry concepts. Finally, it created spaces for reflection between the teams to discuss the proposals in a consensual environment. It is worth mentioning the absence of ICT in your proposal.

Teacher C included general opening activities and directed his intervention during development to conclude with an integrating activity. A teaching centered on the teacher was perceived with the student as receiver. Teacher C's proposal did not include the identification of the student's previous knowledge; It combined the three times: opening, development and closing, and the lack of didactic activities and absence of the use of web resources was evident.

Conclusions

Teachers with higher education in chemistry should strengthen their training as facilitators in learning units such as stoichiometry, since their teaching strategies are scarce, a fact that was evident when modifying this topic. Their work as teachers is focused on learning strategies that cause the student to be a passive learner. In fact, the participating teachers reproduce the learning methods they acquired during their professional training, especially with somewhat mechanical activities. This was demonstrated by applying to teachers the exercise of a non-routine subject, such as the production of polymers, whose impact on the environment is harmful.

The data obtained, therefore, shows the need to discuss and propose in the academies, and at the curricular level, an epistemological conception different from the verb learn to update it by the verb apprehend, a more polysemic concept, as expressed above lines.

The teacher is a fundamental factor to advance towards the improvement of chemistry teaching at the upper secondary level, which is why its didactic and pedagogical training is necessary; in addition to their commitment and updating their teaching practice with innovative strategies that include technological tools.

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In short, it can be concluded that there is a wide field of opportunity for chemistry teachers with the application of ICT and with the design of didactic activities that are attractive to students, which may promote more meaningful learning.

Acknowledgment

The authors are grateful for the support provided by the National Polytechnic Institute, through the Research and Postgraduate Secretariat, to carry out this research, registered under number: 20171093. Likewise, all the academics who participated.

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Escritura - Revisión y edición	Alma Alicia Benítez Pérez (principal) , Aída María Castañeda Rodríguez Cabo (igual)
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