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Artículos científicos

Enseñanza de la ciencia: sesiones prácticas bajo el enfoque de investigación dirigida para el fortalecimiento de competencias científicas

*Science teaching, practical sessions under the directed research approach for
the strengthening of scientific competences*

*Ensino de ciências: sessões práticas sob a abordagem de pesquisa dirigida
para fortalecer habilidades científicas*

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Resumen

En un entorno de bajos resultados académicos y carencia de habilidades científicas elementales para la resolución de problemas y la toma de decisiones basadas en hechos, el presente trabajo tuvo por objetivo el desarrollo e implementación de una propuesta de enseñanza de la química a través del trabajo práctico bajo la perspectiva teórica de la investigación dirigida que coadyuvara al desarrollo de competencias científicas. De este modo, con un enfoque sustentado en la investigación-acción, el trabajo se dividió en dos momentos: el primero recuperó aspectos de la problemática actual en enseñanza de las ciencias relacionada con la falta de competencias científicas en la educación obligatoria, y los fundamentos teóricos que sustentan la propuesta de intervención del segundo momento, siendo este el proceso de diseño, implementación y evaluación de una serie de secuencias didácticas para el trabajo práctico en la química bajo la perspectiva de la investigación dirigida. La implementación de las secuencias se realizó con un grupo de 45 alumnos en un plantel del Colegio de Bachilleres del Estado de Tamaulipas, México, uno de los múltiples subsistemas de educación media superior en el país. Al contar con varias etapas, el trabajo presentó una metodología mixta que va desde la cuantificación de indicadores para evaluar la competencia científica (comunicación de hallazgos) hasta la descripción cualitativa a manera de estudio de caso de los productos entregados por los estudiantes. Los resultados obtenidos sugieren que es posible implementar sesiones prácticas bajo un enfoque de investigación que acerque a los alumnos al trabajo de los científicos, y que esto no se limita a un entorno específico, sino que puede ser llevado a cabo en cualquier espacio donde se haga ciencia e inclusive en modalidad de educación a distancia. Asimismo, las secuencias didácticas implementadas fortalecieron diferentes competencias; sin embargo, la evaluación se centró en la capacidad para comunicar hallazgos de manera oral y escrita, donde los cuatro estudiantes valorados mostraron un leve progreso entre la primera y la última sesión (considerando que fueron dos secuencias) sobre todo en aspectos como la apropiación del lenguaje científico y la relación de sus hallazgos, hipótesis previas y preguntas de investigación.

Palabras clave: competencias científicas, enseñanza de las ciencias, investigación dirigida, sesiones prácticas, trabajo práctico.

Abstract

In a context of low academic results and lack of basic scientific skills for the solving problem and based on facts decisionmaking, the present research aimed at the development and implementation of a chemistry teaching approach through practical work based on the directed research perspective, which will help the scientific competences development. In this way, with an investigation-action approach, which divides the work in two moments: the first one recovers those aspects of the current science teaching problem related to the lack of science competences in obligatory education, and the teorical fundament that supports the intervention proposal of the second moment, being this one the disign, implementation and evaluation process of a serie of didactic secuences for the chemistry practice work under the directed research´s perspective. The implementation of the didactic secuences was performed with a 45 students group belonging to the Colegio de Bachilleres del Estado de Tamaulipas´ school in Mexico, being this one of the multiple Middle Education subsystems of this country. By having different phases, the research has a mixed methodology that goes from indicators quantification for the science competence evaluation (comunication of findings) until the qualitative description by way of case study of the accademic products delivered by the students. The obtained results suggest that it is possible to implement practical sesions under a research approach that get students closer to the scientists work, and this is not limited to an specific space (like a laboratory), but it is able to make it happen in any enviornment where science can be done and also in distance education modality. In addition to, the didactic secuences that were implemented strengthened different abilities, however, the evaluation was focused in the capability of students to comunicate their findings orally and in academic writing, where four students who were assessed showed a small progress between the first and the last sesion (considering they were two secuences) specially in aspects such as scientific language appropriation and the ability to link their findings with previous hypothesis and research questions.

Keywords: Scientific competences, science education, directed research, practical sesions, practical work.

Resumo

Em um ambiente de baixos resultados acadêmicos e falta de habilidades científicas elementares para resolução de problemas e tomada de decisão baseada em fatos, o presente trabalho teve como objetivo desenvolver e implementar uma proposta de ensino de química por meio do trabalho prático, sob a perspectiva teórica da pesquisa dirigida que contribuiria para o desenvolvimento de habilidades científicas. Dessa forma, com uma abordagem baseada na pesquisa-ação, o trabalho foi dividido em dois momentos: o primeiro recuperou aspectos do problema atual do ensino de ciências relacionado à falta de competências científicas na escolaridade obrigatória, e os fundamentos teóricos que sustentam a proposta de intervenção do segundo momento, sendo este o processo de concepção, implementação e avaliação de uma série de sequências didáticas para trabalho prático em química sob a perspectiva da pesquisa dirigida. A implementação das sequências foi realizada com um grupo de 45 alunos em um campus do Colegio de Bachilleres del Estado de Tamaulipas, México, um dos múltiplos subsistemas de ensino médio do país. Com várias etapas, o trabalho apresentou uma metodologia mista que vai desde a quantificação de indicadores para avaliação da competência científica (comunicação de resultados) até a descrição qualitativa como estudo de caso dos produtos entregues pelos alunos. Os resultados obtidos sugerem que é possível implementar sessões práticas sob uma abordagem de investigação que aproxime os alunos do trabalho dos cientistas, e que esta não se limita a um ambiente específico, mas pode ser realizada em qualquer espaço onde seja feita. ciência e até mesmo na modalidade de educação a distância. Da mesma forma, as sequências didáticas implementadas fortaleceram diferentes competências; no entanto, a avaliação incidiu sobre a capacidade de comunicar os resultados oralmente e por escrito, onde os quatro alunos avaliados apresentaram um ligeiro progresso entre a primeira e a última sessão (considerando que foram duas sequências), sobretudo em aspectos como a apropriação do linguagem científica e a relação de seus achados, hipóteses prévias e questões de pesquisa.

Palavras-chave: competências científicas, ensino das ciências, investigação dirigida, sessões práticas, trabalho prático.

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Objective

Design and implement alternative teaching strategies in the practical work of chemistry, which lead to better learning results and contribute to the development and strengthening of scientific competence: communication of findings.

Introduction

In a world of constant changes, where scientific and technological advances rise by leaps and bounds and daily decisions are made that, unconsciously, put the situation of present and future generations at stake, it is pertinent to reflect on the work of education in around that state of acting instinctively and not very rationally, where the ideal of scientific literacy is still very far from the expected result.

It is in this context of scientific illiteracy where the null discernment of the language of science leads to blind decision-making, in which educational systems strive to change the current approach to teaching, specifically in those training fields that, for their didactic nature, they have the ability to transform the lives of individuals, giving them the ability to see consequences, where others would see only one more step in the daily routine.

Disciplines such as chemistry and biology provide the subject with tools that would not be possible to learn if they were excluded from academic curricula; however, even when these subjects belong to the common core of almost all countries, the situation shows that a large part of the population lacks these skills. It is enough to see the results of the National Survey on the Public Perception of Science and Technology carried out by the National Institute of Geography and Statistics (Inegi, 2017), where, broadly speaking, the preliminary result shows the little interest, knowledge and skills related to science and technology. It is worth doing an introspection from educational authorities to science teachers at all levels and question what is the purpose of science teaching and if the current approach is the correct one to achieve it.

In this sense, the present work is developed under the premise that teaching science has as its mission the development of scientific competences, which endow the individual with capacities that open his panorama around two possibilities: working to produce, apply and disseminate knowledge (work of scientists) or, failing that, have the bases for individual and joint decision-making based on facts regardless of the work carried out in society. To achieve this mission, it is necessary to change the focus on learning isolated concepts and

algorithmic routines that persist in many schools, the result of which in the first instance causes a total lack of interest on the part of the student towards science, which results in a lack of knowledge, skills and attitudes at the end of their compulsory training.

In this way, the following study starts from the current panorama of science teaching, which provides us with evidence of the existence of a problem related to citizenship education, to later inquire about those science teaching approaches that have been developed over the years. throughout history, recovering the most relevant of each of them with a view to the development of scientific skills to finally arrive at a proposal for educational intervention based on the approach of directed and applied research through what is known as work in laboratory.

Perspectives or approaches in science education

It is easy to believe that science didactics arises as a result of a specialization of general didactics, however, various analyzes suggest that it does not have a strict dependency relationship with disciplines such as pedagogy, psychology or the natural sciences themselves, but rather that is supported by them, but emerges in history as an independent discipline as a result of Anglo-Saxon curricular reforms and Latin methodological innovations (Adúriz, 2000).

In this sense, it is important to analyze the didactics of science as a consolidated and independent field of study, since many of the theoretical perspectives that address the teaching-learning processes in this area arose at the same time as the development of the various conceptual frameworks. and scientific discoveries, and a way was sought to transfer these methods of generating knowledge to the school context. Within these theoretical approaches there are four main ones: learning by discovery, conceptual change, directed research (DI) and the science, technology and society approach. In this work, the ID approach will be discussed, for which its general characteristics will be highlighted, as well as its advantages and disadvantages to contemplate a theoretical background that supports the design of the proposal for practical sessions by ID.

Directed research

One purpose of science teaching is to transform the student's everyday preconceptions into concepts closer to scientific reality, as well as to show and try to imitate the path that scientists followed to reach a certain conclusion. Based on this ideal, different trends have emerged as an alternative to traditional teaching, which was not bearing the expected results. One of these emerging trends is directed research, whose foundation is focused on the active construction of knowledge and learning to learn (Moya, Chaves and Castillo, 2003). This seeks to integrate the essential components of science: concepts, problem solving and practical work, which for many years have been approached in isolation.

As well as conceptual change, another ideal of science teaching, and which it aims to achieve through directed research, is the development of scientific competence, which — according to the PISA test— is characterized by the ability to identify and explain scientific phenomena, as well as using scientific evidence (Franco, 2015).

In this sense, this competence will be achieved by bringing students closer to the context in which scientists work, a quality that is inherent in research-based teaching, which adopts the different phases of scientific work as a reference: the need for a problem, the existence of knowledge previous theory, hypothesis development, research design, etc. (Jiménez and Oliva, 2016).

Going into detail, just as the origin of theories, laws and principles are problems, the engine of learning towards a new concept is the surrounding situations. In this way, the mediation process towards new knowledge is translated into a logical sequence, made up of the following steps: problem statement, expression of ideas around it, hypothesis statement, strategy design (experiment), analysis of results, communication of findings, contextualization of concepts in the environment, application of learned concepts and approach to new problems (Moya *et al.*, 2003).

In short, we can find different ends for directed research; one already mentioned would be to achieve conceptual change, but seeing the nature of its application we can add another one, which is closer to the development of scientific competence, which will be achieved by bringing the student closer to the context of science research, applying with their respective differences the scientific method for solving problems in the school environment. This perspective is the theoretical axis that guides the design of practical sessions for the development of scientific skills.

Practical sessions under the directed research approach

López and Tamayo (2012) — in a study carried out at the University of Caldas, Colombia— affirm that the current panorama of laboratory practices presents a methodology in which the student follows a simple series of recipe-type instructions. In this, he learns only algorithmic questions to later draw a conclusion of the facts, leaving aside the meta-analysis of his work, coupled with a greater concern for learning concepts than for procedural and attitudinal knowledge.

Following the same line, Hodson (1994, cited by Flores, Caballero and Moreira, 2009) points out that three fundamental aspects must be taken into account in the teaching of science: learning science (theoretical knowledge), learning the nature of science (methodologies and relationship with society), and learning to do science (integrative practice for problem solving), although it should be noted that these particularities by themselves are insufficient.

Hodson, like López and Tamayo (2012), agree that in order to achieve these objectives, the recipe-type methodology, which only allows learning a series of algorithmic questions and certain skills, must be set aside, in order to seek a practical approach that allows the student pose researchable questions, formulate hypotheses, design experiments, contrast results and communicate their findings, with which they can experience a real process of scientific research.

Therefore, in recent decades, a considerable number of investigations have been developed that seek to change the approach to teaching science with the aim of gradually developing scientific skills. This movement begins with the American and European curricular redesign of the last century and reaches Latin America in the first years of this century (first to Colombia, Brazil and Argentina, and in recent years to Mexico). For example, works such as that of Hernández and Salamanca (2018) are similar to the present proposal, since it aimed to evaluate the improvement of certain scientific skills through the implementation of directed research in the area of chemistry, which improves to some degree the level of achievement in scientific skills.

Based on the above, and due to the growing interest in studies based on the design, implementation and evaluation of interventionist teaching/learning sequences (Ametller, Guisasola and Zuza, 2020), this paper proposes a redesign of practical work that integrate the experimentation process within a research protocol that considers other aspects of the

knowledge generation process. All the elements related to the design of these sequences are mentioned in the methodological section.

Scientific competence

Competencies can be explained from different theoretical perspectives, which has generated multiple classifications that allow us to understand, among many aspects, their purpose in the formation of the ideal citizen, one who has the necessary skills to perform in academic, work and personal life. or that, in other words, he is competent and an active and functional member of society.

One more classification, which will be developed for the purposes of this study, contemplates those competencies that, from the curricular point of view, are acquired, strengthened and consolidated through the teaching and learning of science. Therefore, the intention is to find an adequate definition of said concept, to exemplify some of the competences that students develop in science and to develop specific didactic situations for the development of these abilities.

First of all, more than a single and immutable definition, it is intended to reach a conception of scientific competences that allows to base the objectives and goals of the didactic sequences under this approach, which is summarized in accompanying the students in the development of said scientific skills.

A first approach is offered by Hernández (2005), who, based on his analysis, makes a division between the competencies that allow doing science and those that all citizens should possess regardless of the role they play in society. It is important to recover this separation, since —as has been mentioned— the skills that are of interest for the purposes of this work are those that we should all possess in order to make decisions as a population and the ability to solve problems. Likewise, it is these competencies that are of interest to the educational system, which has made efforts throughout history to transfer the work of scientists to the classroom.

In summary, Hernández points out that all those fundamental skills to produce, generate and apply scientific knowledge in a comprehensive manner can be considered scientific competencies, and they are transversal because they are applicable to any disciplinary field, whether natural or social sciences.

For their part, Sánchez and Gómez (2013) highlight the importance of scientific training from basic levels, where investigative processes are encouraged that allow the

student to develop skills such as curiosity, question formulation and problem solving, which opens the range of attributes that allow describing in detail the aspects of the skills that are strengthened in science.

The contributions recovered at the moment allow us to visualize the connotation that the term scientific competences has adopted, which is used by many authors in a unique way, since they place it at the top of a hierarchy of concepts derived from it. In other words, from the academic point of view, scientific competence could be understood as a series of skills that make up a graduation profile, a situation that occurs with the secondary education curriculum, where a certain number of skills make up those traits that every student should have at the end of their training at the middle level.

In this sense, there are many works that see scientific competence as a set of skills. For example, Chona et al. (2006) points out that scientific competence is the subject's ability to correctly use scientific language, develop experimental skills, organize information and work as a team. For their part, Adams, Turner, McCrae and Mendelovits (2006) add another series of attributes such as the ability to identify problems, explain phenomena, draw conclusions based on facts and thus acquire new knowledge. Finally, Furman and Podestá (2009) explain that current curricula should guide their actions towards the development of certain scientific skills, such as observation and description, formulation of research questions, formulation of hypotheses and descriptions, design and performance of experiments, generation of theoretical explanations, understanding of scientific texts and argumentation.

In conclusion, scientific competence can be considered, like others, an ability that an individual possesses, which gives him a state of greater curiosity about natural phenomena and facts in order to have a great capacity for observation to detect of problems, placing it at the beginning of a logical research sequence in which other skills such as those mentioned will have to be put into practice on the way to the construction of new knowledge or the solution of a problem.

This allows us to contemplate that, in a science class, strategies must be generated that resemble the scientific research process, emphasizing not only the result, but also the process, since it is this didactic moment where the student will have to wake up and exercise contiguously all these capacities that will be useful not only for the purposes of scientific subjects, but also in completely different ones and in general for life.

Method

As this is an educational intervention project, the methodology used will be based on the didactics of science, while in the instrumental and technical question the plans and study programs of the SEP will be taken as a reference, and the planning formats will be adapted. institutional didactics to the needs of the work. In this sense, the General Law of Education (LGE) (2019) indicates that the plans and study programs will land in a tangible way in the students through the direct intervention of the teachers, who through a process —known as didactic sequences— They will seek to manage teaching-learning with the aim of developing or strengthening these skills until they reach the expected levels of achievement. In the particular context of the state of Tamaulipas, the didactic sequences have three main components: didactic situation, tasks for learning, and evaluation for learning (Secretaría de Educación Pública [SEP], 2017).

Didactic situation: The student is presented with a problematic or challenging situation and the process to solve it is established.

Tasks for learning: Extra class work that will strengthen the skills used in solving the problem.

Assessment for learning: It will seek to assess mainly the process, and not just the result, following the guidelines of the LGE (2019), which states in article 21 that "the assessment will be comprehensive, assessing the knowledge, abilities, skills, and considering the achievements established in the programs".

On the other hand, the National Institute for the Evaluation of Education (INEE) (2019), in a work that describes the teaching work, indicates that the didactic sequences are executed in three moments: beginning, development and closing.

Start: The student's previous knowledge is investigated through triggering questions, brainstorming, representations or exemplifications.

Development: Instructions are given, the form of evaluation, the organization of the group, and the evaluation is formative.

Closing: The synthesis of the subject is offered, request for extra class tasks, as well as reflections and conclusions, and the evaluation is summative through rubrics, portfolio of evidence, essays, reports, etc.

This model of didactic sequences is carried out by the majority of EMS teachers in the country, and can be used in different contexts, and not only in the traditional physical environment of the classroom.

Due to the nature of the project, the method that has been chosen to design the intervention is that of practical situations, since—as López, Serra and Vilà (2015) mention—the SPR are considered a methodological tool that favors the link between knowledge theoretical and practical experiences.

Likewise, for the control and comparison of results between the first and last sequence, the quasi-experimental method will be used, since it is considered an "intervention in which it is verified to what extent a treatment achieves its objectives, according to the mentions of a pre-established set of indicators" (White y Sabarwal, 2014, p. 1).

Proposal of didactic sequences under the directed research approach

The methodological model on which the format of didactic sequences is based has been discussed, which is applicable to any subject at the upper secondary level in Mexico; however, it is also pertinent to describe those aspects that differentiate the current proposal from conventional practical sessions.

Zárraga, Velázquez and Rodríguez (2004) mention that the idea of a laboratory—that is, a space in which man could carry out his experiments—arises from his interest and curiosity produced by the observation of multiple phenomena that he appreciated. in your daily walk.

The same work adds that the chemical laboratory as such emerged in medieval times with alchemical studies, where the knowledge produced was informal and based on qualitative observations. It was not until 1825 that Justus von Liebig established the first modern laboratory to complement the chemistry chairs at the University of Giessen, Germany. In this a large number of discoveries were made and the scientific method was applied at its best. It is this laboratory model that has been taken up by multiple schools, and has been installed in a similar way using work tables, water, electricity, landfills, ventilation ducts, etc.

This concept of experimental laboratory has limited creativity around the development of strategies where the student can carry out a school research process, and has isolated the activities for the development of procedural skills, completely separating them

from conceptual and attitudinal knowledge. , dividing the science classes in two: the theoretical class in the traditional classroom and the practical class in a school laboratory.

Based on the contributions of this work, it is intended to clarify the fact that an experiment is only part of a larger research process, which has been designed based on previous observations, questions and hypotheses. In this way —being one of the main purposes of the directed research to seek the development of a scientific competence that brings the student closer to the context of science research, applying with their respective differences the scientific method for solving problems in the school environment — The following proposal seeks for the student to reach the new knowledge through a logical sequence, consisting of the following steps: problem statement, expression of ideas around it, hypothesis statement, design of strategies (experiment), analysis of results , communication of findings, contextualization of concepts in the environment, application of learned concepts and approach to new problems (Moya et al., 2003).

Finally, prior to the description of the proposal, it is necessary to cite the classification of the practical work of Schwab and Tamir (cited by Valverde, Jiménez and Viza, 2006), which indicates that the level of openness classifies cognitive processes in experimental levels. that are developed in a practical training that can go from the lowest levels of traditional practices to those of research practices. In this sense, Bloom (cited in the same work) places six categories in a hierarchical manner, according to the effort they require.

Tabla 1. Niveles de abertura del trabajo práctico

Categoría del experimento	Niveles de abertura (P: planificado por el profesor. A: realizado por el estudiante)					
	Plantear problema	Formular hipótesis	Planificar el experimento	Realizar experimento	Apuntar datos/observaciones	Conclusiones
1	P	P	P	P	P	A
2	P	P	P	P	A	A
3	P	P	P	A	A	A
4	P	P	A	A	A	A
5	P	A	A	A	A	A
6	A	A	A	A	A	A

Nota: Se muestra el nivel de esfuerzo realizado por el estudiante según la categoría del experimento

Fuente: Elaboración propia

According to table 1, the category of experiment six is the one with the greatest openness, since in it the student develops all the steps of the investigative process, while category 1 would be the one with the least openness, since the student only issues conclusions of a sequence previously designed by the teacher. In that sense, the greater the opening, the greater the cognitive process that the student develops; however, it is necessary to consider the academic level, knowledge and previous skills of the student before starting the logical sequence of research, since the lower the research references of the student, the greater the support that will be required from the teacher in the accompaniment of the activities of the sequence.

Considering the above, a diagram is presented below that exemplifies the design of sequences by directed research, which is located between categories three and four, alternating the activities of hypothesis formulation and design of experiments, which are carried out in conjunction with the student considering his context.

Figura 1. Diagrama sobre la propuesta de secuencias didácticas bajo el enfoque de investigación dirigida



Nota. La figura muestra el diagrama de flujo de las secuencias didácticas bajo el diseño de la SEP, que está fundamentada en la investigación dirigida para el trabajo práctico.

Fuente: Elaboración propia

Results

The intervention was carried out at the Colegio de Bachilleres del Estado de Tamaulipas (COBAT), on campus 02 located in the municipality of Matamoros, Tamaulipas, with a group of 45 first-semester students in the subject Chemistry I, whose study plan studies is available at the DGB and on the COBAT website.

Of the 45 students, four were selected for the detailed analysis of their products, which were evaluated with the previously designed instruments together with the didactic sequences.

It is important to point out that the entire process was carried out virtually due to the situation of sanitary confinement that arose as a result of the events caused by the global pandemic that occurred at the beginning of 2020 and continued in 2021. For this reason, it was necessary to resort to digital platforms. The selected tool was the Google package, specifically Classroom, Drive and Meet (the first was the virtual classroom where students delivered the products of each session to be reviewed later). The second corresponds to a database in the cloud where the works were saved automatically, and both teachers and students could organize and systematize the information. Finally, the third corresponded to a tool to make group video calls essential for the experimental sessions, which were live.

Next, the analysis of the products requested in each didactic sequence is presented, their respective qualitative description and the observations made in the field diary, remembering that each sequence followed the format and methodology of the SEP: beginning, development and closing.

Didactic sequence 1: Why don't different substances mix?

Type of practice: Level 1

Competition of the DGB: CDBE5. Contrast the results obtained in an investigation or experiment with previous hypotheses and communicate their conclusions.

Scientific competence: Communication of findings.

Field diary

To carry out a sequence of observations and the qualitative evaluation of the strategy and the progress of the students by sequence and session, the field diary was used as an instrument.



Start (1 h)

The first session began with the Google Meet tool and an electronic presentation where some concepts related to density were reviewed, which would be associated with the phenomenon to be analyzed and the research question. It is important to mention that these concepts had already been worked on by the group attended and the head teacher in their regular sessions, so only brief feedback was provided.

Subsequently, and continuing with the virtual session and the use of electronic presentations, the student was presented with the phenomenon to be studied and some questions were asked to continue with the activation of previous knowledge, which were answered orally.

Figura 2. Diagrama del fenómeno estudiado en la secuencia 1

En un recipiente se observa la distribución de 3 sustancias diferentes; agua, aceite y alcohol. El orden de distribución de abajo hacia arriba comienza con el agua, seguido del aceite y finalmente el alcohol.



Nota. Fenómeno de densidad estudiado.

Fuente: Productos personales del alumno

The phenomenon consisted of a container containing three substances (water, oil and alcohol) that, due to their different densities, did not mix and were distributed in the container according to said physicochemical property. The questions asked for the activation of previous knowledge were these: why does this happen? And which substance has a higher density? These are ordered with the aim of predicting the possible responses of the students and thus starting the process of scientific investigation through observation. Most responded as expected, pointing out that the substances did not mix due to their density and that water was the densest substance of all, followed by oil and alcohol. The fact that the students began

to use concepts such as weight and volume, which are directly related to the density of substances, was striking. It is important to point out that, although many students already have the answer that explains the phenomenon, the objective of the sequence was not to answer a practice, but to provide tools for the student to communicate their findings in writing, which would be worked on independently. gradually as the sequence continues.

Taking into account the degree of the student (first year of high school) and the fact that it was the first session and previous knowledge, the complexity of the practical session was level one. In this —according to Herron's classification (sf, cited by López and Tamayo, 2012)— the student is given the question and the method to find the answer. In this sense, the triggering research question was provided, with the exception that the answer and the experimental design were carried out jointly during the session. The questions to answer methodically were these: what would happen if I poured honey into the container? And in what substance (water, oil, alcohol or honey) would each of the following objects be distributed: a coin, a plastic lid and a piece of carrot?

For this first session, the possible answers or hypotheses were made in groups considering the aforementioned aspects, as well as the experimental design, through oral participation and teacher guidance, with the challenge that, in the next sequences, it was the students who recorded individually their hypotheses and design their experiment.

This concluded the first session or beginning of the didactic sequence with a practical approach, remembering that based on the experimental design carried out, the students would prepare a space in their homes to carry out the experiment during the session, counting in advance with the required substances and materials.

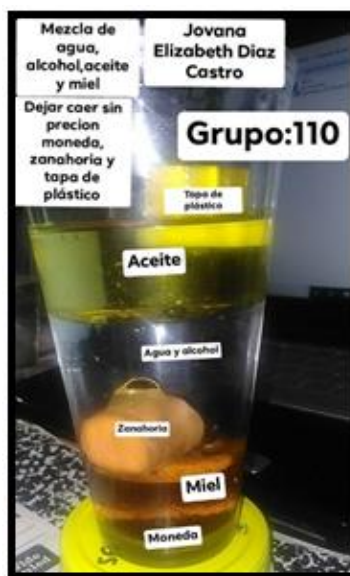
Developing (1 h)

The next session was held to continue with the sequence, whose main objective was to carry out the experiment designed together with the students and make the corresponding observations and records. First, a feedback of the research questions, the hypotheses raised and the experimental design was carried out, for which it was verified that the students had the space, substances and materials necessary for the session, which in their entirety could be found in House.

Subsequently, the experiment proceeded; The teacher provided the step-by-step instructions, trying to get everyone on the same page, taking into account the online modality and the difficulties it brings for a personalized education.



Figura 3. Experimento casero



Nota. Experimento casero realizado por un alumno del grupo atendido.

Fuente: *Productos personales del alumno*

Taking into account the above, the students carried out the experiment step by step, and in each of them the teacher asked questions related to the student's predictions: what happens? Where is the honey positioned? density? They were some of the questions asked for the students to answer using the concepts worked on at the time. However, there were situations where, for example, the alcohol was positioned in the same place as the oil, or where a certain object was not placed in the substance where it should be, so the order was given to make annotations in this regard.

At the end of the experiment, instructions were provided on the instruments requested for the evaluation of the competence, which would consist of the records of their observations of the experiment carried out and a guide questionnaire, which would be of a formative nature, that is, a guideline to carry out the product. final that would consist of a conclusion of their findings and the corroboration of the hypotheses regarding the experiment. Of these products, the observations and the guide questionnaire would be reviewed qualitatively, while the conclusion would be evaluated quantitatively using the previously designed rubrics. Said work would be carried out during extra class hours; later, it would be shared on the Google Classroom platform as homework and finally it would be evaluated and given feedback by the teacher.

Closing (1h)

Having provided the students with three days after the experiment to carry out the requested products, as well as an extra day for their evaluation and feedback, a final closing session was scheduled with the aim of exemplifying through two works (one with autonomous performance and the other with insufficient performance) the areas of opportunity to work on for future sessions. Students were also given the opportunity to present their conclusions verbally, guiding the session through key questions. By this point, the autonomous students had already perfectly mastered the concepts related to the phenomenon, and were more familiar with the work methodology in science, to the point where they related their results to the hypotheses raised. To compare the differences between an autonomous student with the other performance levels, the work of two students will be analyzed below.

Results in the evaluation of the competence: communication of findings

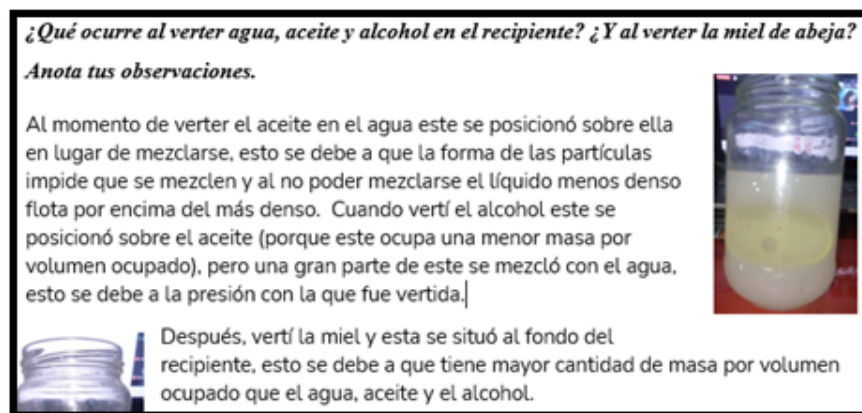
Student 1

Performance level: 3.

Observations and guide questionnaire

In the first stage, which aimed to answer the question, what would happen if I pour honey into the container? Through the experiment, student one describes the events that occurred, making correct use of the concepts of density, volume, and mass, adding an attempt to explain the phenomenon as a result of the particle model with the phrase the shape of the particles prevents them from mixing (second and third lines). This demonstrated the level of performance of the student, who, at the beginning of a basic course, already tries to understand the natural world from the symbolic level of chemistry.

Figura 4. Observaciones del alumno 1



Nota. Fragmento del reporte escrito del alumno 1 (experimento y registros).

Fuente: *Productos personales del alumno*

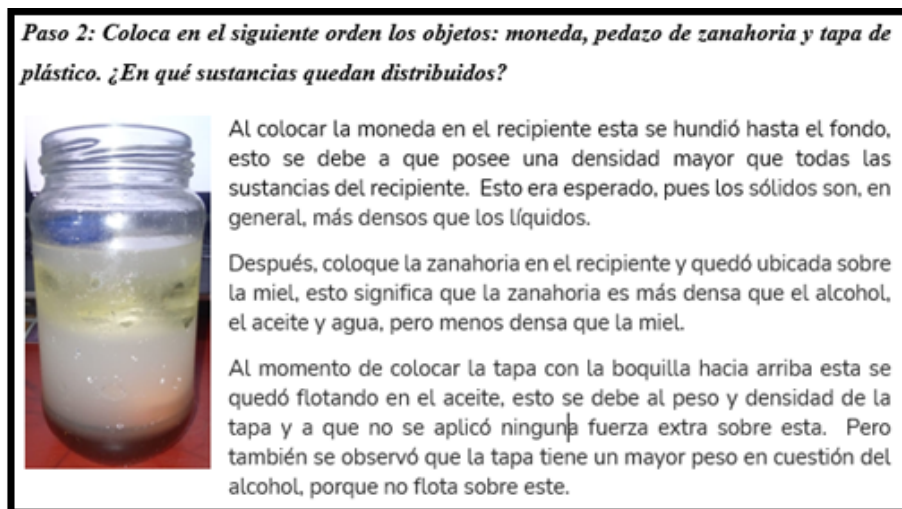
It is pertinent to add that, as indicated, the student was able to perceive an unexpected fact according to his previous knowledge, that is, it was expected that the alcohol —being the substance with the lowest density— would be placed on top of the oil; however, the student mentions in the penultimate and last line the following: "A large part of it was mixed with the water, this is due to the pressure with which it was poured." This teaches not only the ability to experiment, but also to monitor and justify events that were not part of his hypothesis. Thus, in this first stage of the experiment, it remained to explain the relationship between the hypothesis and its results.

For the second stage of the experiment, an attempt was made to answer the following question: in which substance (water, oil, alcohol or honey) would each of the following objects be distributed: a coin, a plastic lid and a piece of carrot? to compare the results with the possible answers proposed. In this case, the autonomous level student once again shows the conceptual mastery of the phenomenon, in addition to adding complementary explanations; for example, in the first paragraph he mentions that "solids are generally denser than liquids", which demonstrates his ability to clarify alternate events from different levels of chemical language, making use of the models and laws that he knows. .

In the second and third paragraphs, the student again demonstrates his mastery of the concepts associated with the phenomena he observes, and makes comparisons between the densities of the substances and materials that he adds. In addition to this, it manifests the control it has over the experiment itself, by pointing out in the second and third lines of the last paragraph that the lid floats in the oil, but not in the alcohol due to its density since no

external force was applied. on it, implying that the fact of applying a greater force would have brought with it different results.

Figura 5. Observaciones del alumno 1



Nota. Fragmento del reporte escrito del alumno 1 (experimento y registros).

Fuente: Productos personales del alumno

Up to this point, the student demonstrated outstanding command of concepts, experimental control, and explanations provided; however, he still did not contrast his findings with previous hypotheses, which was necessary to be able to demonstrate autonomous performance in the assessed scientific competence. For this reason, as part of the strategy, instructions were given to complete a questionnaire as a guide prior to the final communication of their conclusions.

The questionnaire of this sequence consisted of two questions as a summary and reflection: in the first question the student confirms his mastery in relation to the concepts of the phenomenon studied: density, volume and mass to understand that, although substances have the same volume, their weight is not necessarily the same. In the second questioning, the aim was to highlight the progress in the development of the student's formal thinking by observing their ability to explain phenomena without the need to observe them experientially. In this sense, the student answers the question using their knowledge, pointing out that adding salt to the water would increase its mass and volume, thus increasing its density, also adding that it would also increase the amount of particles present (oxygen, hydrogen, chlorine and sodium), making use of the symbolic and conceptual level of chemistry.

Figura 6. Cuestionario guía

1. ¿Qué sustancia tiene mayor cantidad de masa por volumen ocupado? ¿Por qué?

En base a las observaciones podemos notar que las sustancias están ordenadas de mayor a menor densidad: Primero está la miel, después el agua, luego el aceite y por último el alcohol. La miel es la sustancia con mayor densidad porque acumula más masa en un volumen determinado, mientras que el agua, el aceite y el alcohol acumulan menos masa, con respecto a la miel, en el mismo volumen.

2. ¿Si mezclo sal en el agua, esta se hará más o menos densa? ¿Por qué?

Más densa, al mezclar el agua con la sal aumenta la masa y el volumen y dado que $D=m/v$, por ende, también aumenta la densidad. Esto se debe a que cuando se vierte la sal en el agua y se mezcla, los compuestos se unen fuertemente aumentando la cantidad de masa por un volumen ocupado, porque ahora no solo tienes hidrógeno y oxígeno, ahora tienes más partículas: hidrógeno, oxígeno, sodio y cloro.

Nota. Fragmento del cuestionario guía respondido por el alumno 1.

Fuente: Productos personales del alumno

Final communication of findings

The final communication of the findings was made in the form of a written conclusion, which was evaluated using a rubric; Next, the student's results are presented, as well as the description of their values.

Figura 7. Comunicación final de hallazgos

Conclusiones

En base a las observaciones realizadas en el experimento, podemos notar que las sustancias quedaron ordenadas de mayor a menor densidad: Primero está la miel, después el agua, luego el aceite y por último el alcohol. Con esto podemos notar que la primera hipótesis, la cual decía que la miel quedaría ubicada entre el agua y el aceite, no se cumplió, porque la miel quedó situada al fondo del recipiente, debajo del agua. Esto se debe a que tiene una mayor cantidad de masa por volumen ocupado (densidad) que el aceite y el agua.

Como segunda hipótesis se decía que al La moneda y el pedazo de zanahoria se iría al fondo y la tapa de plástico flotaría en el alcohol. Esta no se cumplió completamente, ya que la zanahoria quedó situada sobre la miel, esto sucedió porque la zanahoria es más densa que el alcohol, aceite y agua, pero tiene una menor densidad que la miel. Por otro lado, cuando se colocó la tapa de plástico en el recipiente, quedó flotando sobre el aceite y no sobre el alcohol, como se especulaba, esto se debe al peso y densidad de la tapa. En cambio, la moneda si se fue al fondo, esto sucedió porque tiene una densidad mayor que todas las sustancias del recipiente y aleja a las partículas de las sustancias y se hace un espacio así mismo.

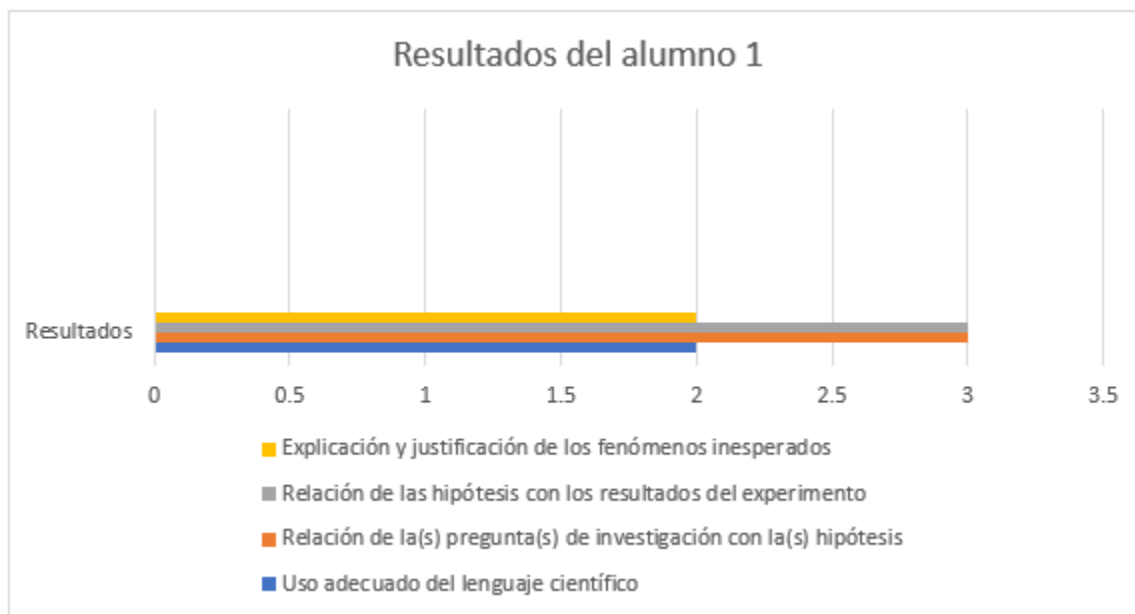
Como conclusión tenemos que un líquido menos denso flotará por encima de uno más denso, porque tiene una menor cantidad de masa por volumen ocupado.

Nota. Comunicación final de hallazgos (alumno 1).

Fuente: Productos personales del alumno

The following graph shows the results in each of the indicators designed in the rubric that aims to assess scientific competence (communication of findings). Student 1 obtained a performance of level four in each aspect (the first of them evaluated the use of scientific language). Observing his work, it is possible to appreciate how he correctly uses concepts related to the phenomenon studied (density, mass and volume). The following indicator shows the way in which the student relates the entire process as a single job, and not as isolated elements or tasks, since he is able to mention the relationship between the research questions raised and the hypotheses that arose as a result of them. The third indicator is similar to the previous one, since it compares the two previous hypotheses with the results obtained in the experiment, mentioning that the first assumption that it indicated (that the honey would be located between the water and the oil) was wrong, and that the The second prediction fulfilled the fact that the coin went to the bottom, but the piece of carrot floated in the honey. Finally, a last indicator evaluated the student's ability to observe phenomena that did not occur as planned, a fact that is fulfilled in the fourth, fifth and sixth lines of the second paragraph, where the student indicates that the plastic lid floated in the oil, and not in alcohol, as speculated.

Figura 8. Resultados en la rúbrica



Nota. Resultados del alumno 1.

Fuente: Elaboración propia

Student 4

Performance level: 2

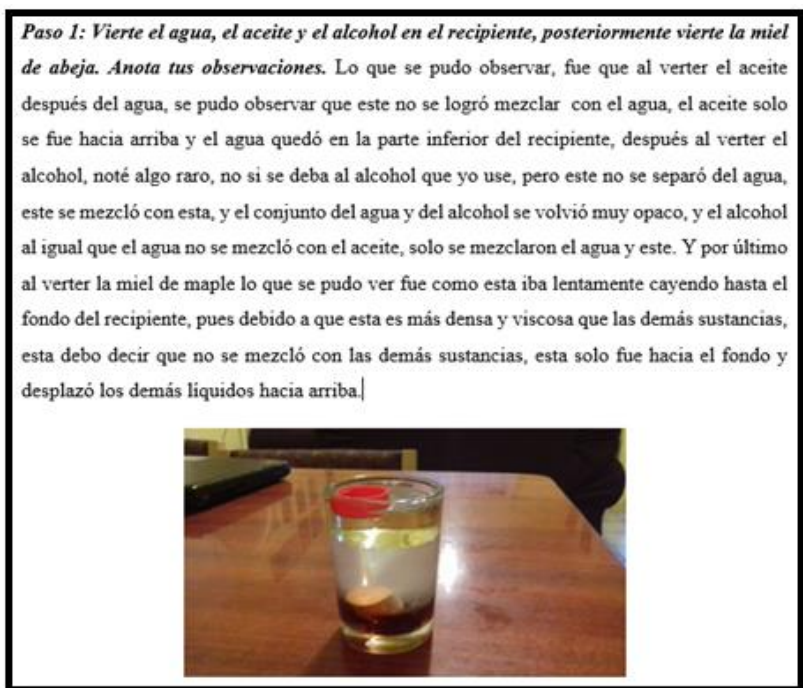
Observations and guide questionnaire

Student four obtained a performance similar to the previous one, at least from the quantitative point of view; however, the fact that reporting their findings is similarly weighted does not necessarily mean that they have the same areas for improvement. This question is intended to be analyzed through the qualitative description of its products.

In the case of the observations of the experiment, in the first section —corresponding to the first test carried out to answer the research question, what would happen if I poured honey into the container?— the student shows great effort to communicate all the facts that they caused him curiosity, taking care in turn not to lose sight of the main purpose: to corroborate the hypothesis. With the sentence of the fourth, fifth and sixth lines ("after pouring the alcohol, I noticed something strange, I don't know if it is due to the alcohol that I used, but it did not separate from the water, it mixed with it") demonstrates that Although the sequence is focused on evaluating the ability to communicate findings, it also develops and strengthens other scientific skills in the student. In this case, the ability to make observation patterns begins (the first step of the scientific method), which is useful for both the student and the teacher, since this simple observation can serve as a starting point for future sequences. , on the understanding that the possible answer is that alcohol is soluble in water, but due to an error in the force with which it was introduced: it crossed the oil barrier and decomposed into ions upon contact with water, forming a solution of alcohol in water. This answer —which the teacher knows— is the path to follow to generate with the students a process of investigation and learning by discovery.

Returning to the central focus of the sequence, the student makes good use of the concept of density and adds that of viscosity, which, although not used very well, demonstrates that effort to try to share their observations in writing.

Figura 9. Observaciones del alumno 2



Nota. Fragmento del reporte escrito del alumno 4 (experimento y registros).


Fuente: Productos personales del alumno

For the next stage of the experiment—which sought to answer the question in which substance would the following objects be distributed: a coin, a plastic cap and a piece of carrot—, like the previous student, describe the sequence of events, but up to this point he does not point out the relationship between the research questions and the results of the experiment. Something that is striking is that the student in line three recognizes the phenomenon that occurred in the previous stage, pointing out that there is a mixture between alcohol and water, inferring that he has a preconception of what a mixture is and of the law conservation of matter, pointing out that alcohol did not disappear, but is part of a new substance.

Figura 10. Observaciones del alumno 2

Paso 2: Coloca en el siguiente orden los objetos: moneda, pedazo de zanahoria y tapa de plástico. ¿En qué sustancias quedan distribuidos?

El orden en que quedaron distribuidos los materiales fueron los siguientes: Primeramente coloqué la moneda, y esta quedó hasta el fondo del recipiente junto con la miel, Después se colocó el trozo de zanahoria y esta quedó en la mezcla de agua y alcohol , y totalmente al ras de la miel, este atravesó es aceite y quedó en la mezcla de agua y alcohol, flotando sobre la miel, Y por último se colocó la tapa de plástico, esta quedó flotando sobre el aceite y se podía ver como esta flotaba con la oportunidad de recogerla sin tener que sumergir la mano en las mezclas



Nota. Fragmento del reporte escrito del alumno 4 (experimento y registros)

Fuente: Productos personales del alumno

In the case of the guide questionnaire, with the aim of guiding the student towards his final communication and to consolidate the use of the revised concepts, the student makes good use of the concept of density and the relationship it has with weight and volume, adding that the container containing the honey (possibly glass) was denser. In the second question, he correctly explains that adding salt to water will make the resulting substance denser; however, he makes a mistake by mentioning that the volume will not increase. This situation, in a traditional science teaching environment, would be seen as a disadvantage and the situation would be resolved by correcting the student's response, which would limit their ability to reason and start a new research process. In the case of the proposed approach, this generates a new phenomenon to observe, new unknowns to solve and new hypotheses to test, so that the error could be used to ask the following: if I pour such an amount of salt into a glass of water will it increase its volume? This would generate a hypothesis and the need to design an experiment, which would repeat the cycle.

Final communication of findings

Figura 11. Cuestionario guía

Cuestionario guía

1. ¿Qué sustancia tiene mayor cantidad de masa por volumen ocupado? ¿Por qué?
La miel, pues se observó cómo esta quedó hasta el fondo del recipiente y pues el envase donde contenía la miel antes, era el más pesado de todos, claro, tenemos que tomar en cuenta el material de los envases de las demás sustancias, sin embargo, el envase de la miel, era mucho más pesado de lo que se podría esperar

2. ¿Si mezclo sal en el agua, esta se hará más o menos densa? ¿Por qué?
Si, esto debido a que, si nosotros agregamos sal, aunque su volumen no aumentará, si lo hará su densidad, esto es debido a que el agua tiene la capacidad de disolver la sal, y esto en consecuencia crea más masa en un espacio donde no afecta el volumen

Nota. Fragmento del reporte escrito del alumno 4 (cuestionario guía)

Fuente: *Productos personales del alumno*

It was mentioned at the beginning of the analysis of this student that, despite obtaining a score equal to the previous one, his works were far from being the same, because while one provides both observations and limited conclusions, the other shows interest, curiosity and eagerness for communicating everything that seems interesting to you.

Regarding the indicators that evaluate their final communication of findings, indicator 1 demonstrates a good use of the associated concepts, this being perhaps one of the greatest effects produced in the student. What affects his final grade are the last three indicators, since the student at no time relates the questions and hypotheses raised with the results obtained, and although he talks about other phenomena where the concepts of density, mass and volume are applied (that can also be used in favor of learning), are not directly related to the central axis of the work.

Figura 12. Comunicación final de hallazgos

Conclusiones

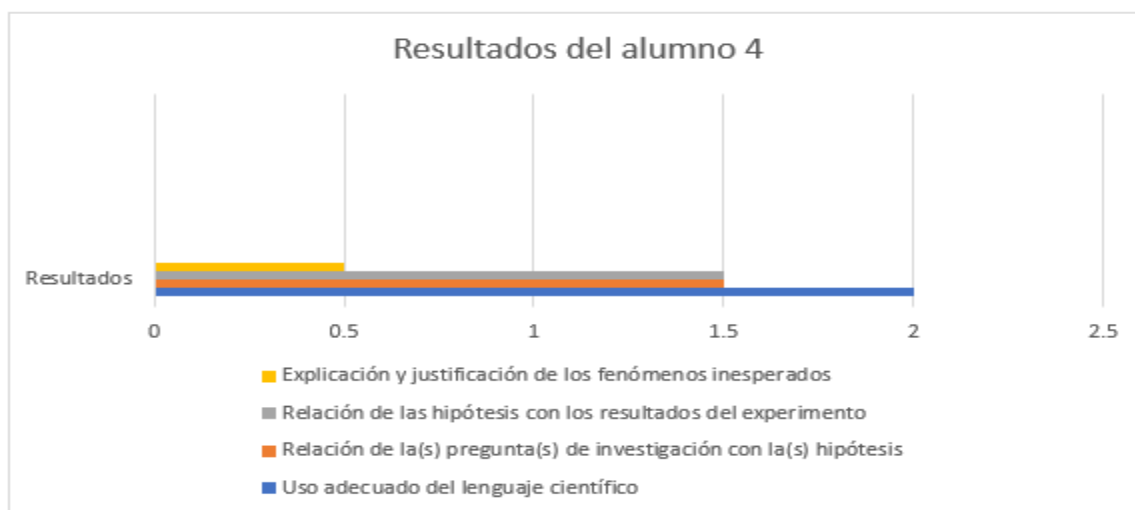
En conclusión, con este experimento se puede deducir que tan densos son algunos materiales y sustancias, Por ejemplo gracias a esto podemos saber que la miel es más densa que el agua, o que el agua es más densa que el aceite, y esto explica también por qué hay algunos líquidos que no se pueden mezclar entre sí por más que se revuelvan, esto explica igual, porque algunas partes del océano no se mezclan, y parecen divididas por una tensión superficial, debido a que una mar puede tener más sal y por ende más denso que el otro.

Nota. Comunicación final de hallazgos (alumno 3)

Fuente: Productos personales del alumno

The area of opportunity in this case is not aimed so much at the student, but perhaps at the teacher's performance, since the student generated very good observations and records, but when integrating all his findings he was not able to do so. This could be improved in the future if more attention is paid to the instructions given to the student, who may not have fully understood the purpose of the shared evaluation instrument, or was not aware of the product to be evaluated. Finally, a study like this also questions the evaluation itself, that in an environment of academic processes, where a grade really affects the student, qualitative aspects (observations, in this case) should also be considered when issuing an evaluation. value judgment and weigh it.

Figura 13. Resultados obtenidos en la rúbrica



Nota. Resultados del alumno 2

Fuente: Productos personales del alumno

Discussion

Regarding the mode of operation of the proposal, the conditions of distance education and on digital platforms in which the implementation of didactic sequences was carried out, limited in a certain way the impact on the population served in accordance with the objectives initially set. . Some of the weaknesses of the work were, for example, the fact of working only with a part of the group due to connectivity problems, and also aspects related to group control, since it was sometimes difficult to be aware of each student to provide a personalized teaching or an individual review especially in the experimentation stage. On the other hand, a clear strength when using this approach was perceived when evaluating the products, since it was possible to analyze in detail, based on the established criteria, each one of the products and provide feedback to the respective students.

When talking about the implementation of the intervention, taking into account the student's grade (first year of high school) and their previous knowledge, the complexity of the first practical session was level one, which —according to the Herron classification (nd, cited by López and Tamayo, 2012)— serves to give the student the question and the method to find the answer. In this sense, the triggering research question was provided. As the sessions passed, the level of openness of the practices increased according to the students' learning pace.

Certainly, in many sections of the theoretical reference of this work, a criticism of the practices carried out as "cooking recipes" is mentioned (López and Tamayo, 2012). To change this reality, a series of steps were carried out during the experiment, but designed by the student himself so that he had the opportunity to get involved in it.

In relation to the students' progress, one of the main differences —and what drew attention to student 1, whose performance was outstanding in almost all aspects— was the fact that external sources were used in the second sequence to enrich their findings. , which you didn't implement in the first one.

On the other hand, and thinking of a third sequence, the student could be supported with tools different from the discipline, as in the case of academic writing skills or collegiate work with another subject to strengthen transversality (SEP, 2017).

On the other hand, student 4 —being the one with the lowest performance between one sequence and another— was the only one that reflected a negative difference in the results of both sequences, which shows a setback. Therefore, the following sequences should

be adapted or reinforced with elements that provide academic support to students with low performance or stagnation, which would imply taking advantage of their previous knowledge (Jiménez y Oliva, 2016).

Limitations

It is important to mention that the work underwent constant modifications from its objectives, through its methodological design, as well as its implementation due to the pandemic and the remote work modality. Initially planned as a face-to-face work, it was necessary to adapt its form of operation to a virtual environment, although the general objective was preserved, which was the strengthening of scientific competencies through the implementation of an alternative proposal to traditional science teaching. .

In addition to the above, there were problems such as the number of students present at the virtual meetings, since it was less than the sample initially considered. Similarly, communication and feedback on the products requested from students represented a greater challenge due to problems of connectivity and access to the digital platform by them.

Finally, the fact of working in an educational institution with its own calendar of activities and models of management and internal intervention conditioned the time of application of the proposal, for which it was tried to interfere as little as possible with the functions of the institution and the head teacher of the group.

Conclusions

The main objective of this work was to design and implement alternative teaching strategies in the practical work of chemistry, which would lead to better learning results and contribute to the development and strengthening of scientific competence: communication of findings. In this sense, an action-research model was developed that, in the first instance, recovered fundamental theoretical aspects for the development of an educational intervention proposal that would later have to be applied to a sample of students. After the theoretical-practical study carried out, the following conclusions have been reached:

The current science teaching approach focused on the learning of concepts and algorithmic issues has generated negative results in the development of scientific skills such as the formulation of hypotheses, experimental control, reporting of results and communication of findings.

Laboratory work under a research approach that aims to imitate the work of scientists and transfer it to the classroom is the ideal for the development of these scientific skills; Likewise, it is possible to design didactic sequences for practical work that form an integral part of the chemistry study programs, and are not seen as an isolated or secondary work that bears little relation to the work in the classroom.

On the other hand, to integrate practical work as part of a sequence governed by one or more expected learning, it is recommended to reduce the number of experimental practices carried out in the school period, but that these in turn have a greater complexity and number of dedicated sessions. to the development of a research process.

Based on the results and the review of theoretical background, it is considered that practical work in chemistry is not limited to a physical space, since any place where the student is able to arouse his curiosity about some phenomenon and start a process in search of responses. In this sense, it is possible to carry out laboratory practices under the directed research approach even in a distance education situation.

When talking about the proposal, it slightly improved the results in the student's ability to communicate the findings of an investigation in writing because due to time issues it was only possible to carry out two sequences; however, the description of the implementation of the intervention left information on other variables and results that were not contemplated at the beginning, and although only one competence was evaluated and weighted, the products made by the students allowed us to observe that each one of the scientific competencies were put into practice, which makes it possible to visualize that future sequences can focus on the evaluation of one or more competencies.

Certainly, to choose the level of openness or the freedom that will be given to the student in each of the stages of the work, aspects such as previous knowledge and skills must be taken into account, since the student's ability to develop a process of Autonomous research is directly proportional to the baggage of skills that it possesses.

Another point to note is that at the end of an experimental process, once the phenomenon studied is understood, it is possible to continue with new discoveries without having to go through the experimentation stage, since it is enough to present a series of data and generate researchable questions. from them so that the student can infer the possible answers and reach conclusions based on facts. To achieve the above, the student must have considerable advances in the development of formal thinking, an ideal that is achieved

through the teaching of science under this approach, considering that the experiment is only one stage of a process of discovery and development of knowledge. broader competencies.

Finally, the goal of the practical work is to achieve total autonomy in the learning process, where the student himself develops and manages his steps in view of solving a problem, explaining a phenomenon or answering a research question.

Future lines of research

From these conclusions arise certain recommendations for future studies; Firstly, the position of changing the traditional focus of practical work and opting for research-type strategies is maintained, where one starts from the observation of a phenomenon to later actively use the concepts associated with it, also contemplating the gradual introduction of the chemistry levels. Similarly, the study gives rise to new research questions, for example: how to design and implement this type of activities in large groups? One hypothesis in this regard is to use data that has already been systematized from an experiment previously carried out by people outside the classroom, from which new questions, assumptions and conclusions emerge.

Finally, a question that remains in the air to be investigated later is how to improve the evaluation of tasks as complex as practical work in terms of effectiveness and efficiency.

Considering that the evaluation carried out in this work complied in relation to quality, but that it was worked with a single competence and with four students, this would undoubtedly be different in a group of 45 students and in a curricular context that demands the punctual revision of topics or lessons.

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Análisis Formal	Antonio de Jesús Maldonado Estrada (Principal) Evelia Reséndiz Balderas (Igual)
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Recursos	Antonio de Jesús Maldonado Estrada (Principal) Evelia Reséndiz Balderas (Igual) Rosa Delia Cervantes Castro (Apoya)
Curación de datos	Antonio de Jesús Maldonado Estrada (Principal) Evelia Reséndiz Balderas (Igual) Rosa Delia Cervantes Castro (Apoya)
Escritura - Preparación del borrador original	Antonio de Jesús Maldonado Estrada (Principal) Evelia Reséndiz Balderas (Igual) Rosa Delia Cervantes Castro (Igual)
Escritura - Revisión y edición	Antonio de Jesús Maldonado Estrada (Principal) Rosa Delia Cervantes Castro (Igual)
Visualización	Antonio de Jesús Maldonado Estrada (Principal) Rosa Delia Cervantes Castro (Igual)
Supervisión	Evelia Reséndiz Balderas (Principal) Rosa Delia Cervantes Castro (Principal)
Administración de Proyectos	Evelia Reséndiz Balderas (Principal) Rosa Delia Cervantes Castro (Principal)
Adquisición de fondos	Evelia Reséndiz Balderas (Principal) Rosa Delia Cervantes Castro (Principal)