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PAPER

Undergraduate Students' Motivation in Chemistry Lessons

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ABSTRACT

Chemistry is a core subject in most engineering degrees. The study of chemistry in particular, and of science in general, contributes to the integral development of individuals as it promotes the development of intellectual attitudes and habits such as argumentation, reasoning, and discussion, all of which are of great value to engineering students. Additionally, understanding the phenomena occurring in our environment helps in rational interpretation of reality and fosters critical attitudes toward everyday events. In this paper, we make an attempt to introduce different strategies that could increase students' motivation to learn chemistry. Chemistry teachers often struggle to engage students, create stimulating learning environments, and manage classrooms effectively. Recently, there have been numerous attempts to motivate students by making chemistry more engaging through its application to everyday situations. The effectiveness of these endeavors depends on the connection between the phenomena under consideration, their scientific basis, and the students' level of comprehension. To meet these expectations, it's essential to cater to students' interests according to their stage of cognitive development while still covering essential content and theories. The role of a number of motivational approaches, such as showcasing the relevance of chemistry in everyday situations, highlighting the challenges that society presents to this discipline in the immediate future, and aligning teaching methodologies with scientific strategies, are discussed as possible ways to stimulate students' curiosity and improve their performance in the classroom.

KEYWORDS

chemistry learning, student motivation, learning management, undergraduate students

1 INTRODUCTION

Motivation, often fueled by curiosity, is what propels us forward in life. Specifically, learning motivation refers to the willingness of students to perceive academic activities as relevant in order to try to obtain the intended benefits from

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them [1–2]. The role of the teacher is fundamental in students' learning, as they are the most influential person in the classroom. It is widely acknowledged that cultivating an environment that sparks students' expectations and ignites their interest in the subject matter presented significantly impacts the ultimate outcome of the learning process [3].

For undergraduate students, studying the sciences can be challenging and daunting, particularly during the early years as they transition to a new educational phase [4]. Engineering education involves chemistry in relevant degrees such as Industrial Engineering, Naval Engineering, Civil Engineering, Agricultural Engineering, Electronic Engineering, and others. Chemistry is not an easy subject to grasp, as it inherently deals with abstract concepts [5]. The traditional expository conception of models and theories in the pedagogical practice of chemistry contributes to the difficulty of teaching this science. Students cannot observe atoms directly or manipulate them to monitor their behavior. Moreover, learning chemistry is complicated due to the three levels of representation—submicroscopic, macroscopic, and symbolic—between which chemists navigate [6]. A proficient chemistry teacher must be equipped with tools and approaches that facilitate direct engagement and understanding of the intricate nature of chemistry. This complexity can be attributed in part to textbooks, which traditionally present content based on disciplinary logic, often without contextualizing the nature of science, its development, origins, and interactions within the social context. Additionally, textbooks may overlook the nuances of how students learn [7].

It is crucial to emphasize this nuance because, as science advances, its contents proliferate and diversify. Thus, teachers face the challenge of selecting the chemistry they want students to learn. They must also find ways to make it as accessible and comprehensible as possible.

The advantage of teaching chemistry lies in its pervasive influence in our daily lives and across all human activities, providing numerous examples for visualization. Showing the relevance of chemistry in everyday life will increase student interest and involvement in the learning process and improve academic performance [8]. It is intriguing to adopt a critical perspective on our environment, contemplating the phenomena occurring around us, endeavoring to comprehend them, and formulating potential explanations.

Everything within our environment comprises atoms and molecules, serving as the sole foundation for us to persist in generating solutions that address present and future challenges. Let curiosity serve as our driving force, guiding us as models and theories intertwine with experiments. Let us venture into the realm of chemistry with an ethos of exploration, discovery, sharing, living, and learning [9].

The aim of this paper is to propose several strategies regarding the importance of motivation in undergraduate chemistry students, as well as suggestions for enhancing this motivation in teaching practice. We have based this on an analysis of the literature on the subject and on our teaching experience, which spans nearly forty years for each of the authors, as professors of first-year general chemistry courses in different engineering disciplines at the university level.

2 STIMULATING INTEREST AND ENHANCING ATTITUDES TOWARDS CHEMISTRY

Chemistry is a scientific discipline that may evoke apprehension in some students. Chemistry teachers, in order to address and overcome this situation, must create a suitable environment for students to manage these learning difficulties, stimulate their interest in this science, emphasize the importance of chemistry in society, and find ways to teach it in an engaging and easy-to-follow manner.

2.1 Introducing chemistry to the students

There are multiple strategies for teaching chemistry to arouse the interest of students.

- To present chemistry by dispelling the mythical perceptions that once portrayed it as an activity reserved for solitary individuals, inaccessible to the masses, devoid of meaning, disconnected from everyday reality, and characterized as dangerous and sterile. These misconceptions used to associate chemistry with pollution, toxicity, or war [10].
- To present a perspective that portrays chemistry as a constantly evolving science [4], devoid of dogmas or absolute truths, which evolves within a specific social context. It is integrated into a broader framework that encompasses scientific and technological aspects and correlates them with societal progress.
- Visualize chemistry and its industry as sectors that have offered scientific and technological solutions to a wide range of global challenges, including protecting the environment by preventing pollution and reducing greenhouse gas emissions; promoting human health and well-being through the production of pharmaceuticals, medical devices, and components; using natural resources efficiently through the use of renewable raw materials; applying catalysis; and understanding how to reuse, recycle, and refine valuable metals. This is reflected in the Sustainable Development Goals (SDG) promoted by the UN [11].
- To showcase the work of researchers through the lens of addressing everyday problems with questions and answers rooted in the scientific method. This approach not only illuminates solutions applicable to various domains but also underscores their relevance in decision-making processes [12].

2.2 Attracting and motivating chemistry

In essence, it is crucial to render chemistry attractive and motivating. To achieve this, encouraging student participation, fostering expectations with captivating objectives, and involving them actively in the learning process are essential. Student motivation throughout learning episodes is pivotal in ensuring that learners persist sufficiently to successfully accomplish tasks and acquire the expected knowledge and skills [13–14].

The goal should be to ensure that knowledge reaches students in the most effective manner possible. To achieve this, it is essential to captivate their attention for most of the time and to instill in them a passion for the subject being taught (see Figure 1).

Fig. 1. How to cultivate an interest in chemistry?

Chemistry permeates all aspects of our lives; it encompasses the study of substances such as sugar, common salt, medicines, water, and more. What are these substances made of? How do they behave and interact with each other, particularly in the presence of various forms of energy such as heat and electricity? The influence of chemistry on our lives is undeniable; it surrounds us everywhere. From breathing, digestion, growth, and aging to even thought processes, we are essentially walking chemical reactors.

An effective strategy to increase motivation is to instill interests and values in students, as these factors have been reported to significantly influence their intrinsic motivation [15]. When students perceive the value of what they learn, especially in relation to their own goals and values, learning becomes more meaningful. This sense of purpose significantly increases motivation by making the learning process seem more relevant [16–17].

The ability to convey this enthusiasm undoubtedly facilitates student engagement, improves their attitude toward the subject, and consequently has a positive impact on the learning process.

3 LEARNING CHEMISTRY: APPROACHES AND INTERPRETATIVE FRAMEWORKS

Chemistry, given its inherently conceptual nature, necessitates the understanding of a series of key concepts. When difficulties arise, there's often a tendency to resort to short-term rote learning, which frequently results in the acquisition of misconceptions.

Conceptual change is considered a potent framework for enhancing chemistry teaching and learning, offering a multi-perspective approach that can be utilized to explore scientific literacy [18]. It aims to facilitate changes in the cognitive structure of students, viewing learning as a process of constructing experiences that culminate in a conception of the world akin to that of a scientist. Generally, activities that promote conceptual change reflect a teaching style characterized by active involvement of both students and teachers. Teachers encourage students to articulate their ideas, engage in rigorous thinking, and refine their explanations.

Motivation, serving as the initial phase in the learning strategy, aims to stimulate curiosity in learners, predisposing them to embrace the new learning situation.

In flipped learning, which has garnered significant popularity in recent years [19], motivation and active participation of the learner are essential to engage them in acquiring new knowledge. This approach involves learners studying the subject matter of the course before class hours, thus requiring their involvement and proactive engagement in the learning process.

In chemistry education, the objective is for students to comprehend and analyze the properties and transformations of matter [20]. They are required to grapple with numerous laws and abstract concepts while also establishing connections between them and the studied phenomena. Furthermore, students must navigate a vast array of concepts and utilize a highly symbolic and formalized language, along with analogical models that aid in representing the unobservable. Consequently, it is often stated that studying chemistry involves a high level of abstraction. To facilitate chemistry learning, three dimensions are established [21–22]. Firstly, comprehending chemistry necessitates a shift in the logic through which students organize their theories, signifying an epistemological change. They must grasp the interpretation of reality through models and accept them as abstract constructs that aid in interpreting nature. Secondly, an ontological change is essential, wherein students conceive the objects assumed in their theories as interconnected with processes involving alterations. Thirdly, understanding chemistry entails regarding matter as a complex system of interacting particles and encompasses the study of the structure and transformation of matter [23].

Since the focus of chemistry is on matter and its transformations, the topic of chemical change holds significance. Within this context, it is noted that one distinguishing factor between a chemical change and a physical change is the quantitative conservation of mass, which is tied to the preservation or alteration of the quality of matter.

During a physical change, the substance undergoes alterations in form or state without affecting its internal structure, thus retaining its identity. However, in chemical changes or reactions, the identity of the substances involved undergoes modification. This occurs due to interactions between the atoms or molecules of the initial substances, leading to rearrangements of electron shells and the breaking and formation of chemical bonds (see Figure 2).

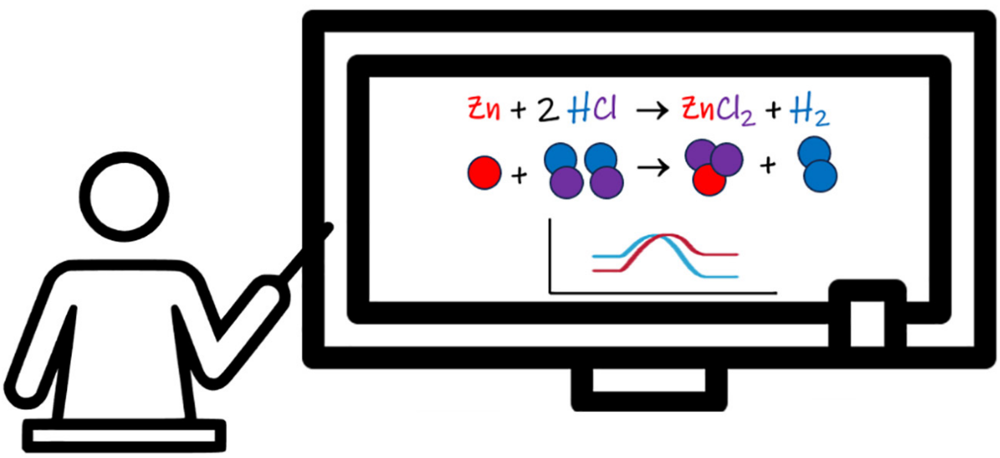

Fig. 2. Teaching chemistry: Chemical changes

Students should acknowledge that matter possesses a discontinuous nature, understanding that beyond its visible appearance or the different states in which it presents itself, it consists of atoms—tiny particles in constant motion and interaction—that can combine to form more complex structures. Many misconceptions stem from a perceived confusion between two levels of analysis: the properties of the observable physical world and the microscopic particles constituting matter in an imperceptible manner [24].

4 STUDENTS' AVERSION TO CHEMISTRY

It is widely recognized that a primary factor contributing to the decline in students' interest in chemistry is the approach to the study of this science. Chemistry courses at all levels tend to be overloaded with theoretical material and heavily focused on principles and theories [25–26]. Additionally, much emphasis is placed on solving artificial numerical problems, while relatively little attention is given to chemical reactions, which lie at the core of this science. Moreover, microscopic aspects of matter are prioritized over phenomenological aspects. This teaching approach stems from the necessity to organize knowledge, which is expanding rapidly on a daily basis. Consequently, chemistry has lost its allure and motivational appeal. Students are not exposed to the fascination of exploring something novel or the creative aspects of chemistry. Instead, it is presented to them as a collection of abstract principles with seemingly little practical relevance to their everyday lives [26].

Chemistry is an integral component of the curriculum across all educational levels. Initially, students' introduction to chemistry should be through the observation of phenomena; subsequently, at more advanced stages, they will comprehend models that elucidate the observed reality. By initially exploring the behavior of matter, questions will naturally arise, which will then be addressed through the principles taught at higher levels.

There should be a progressive and systematic initiation of learners into the realms of science and technology, providing them with a well-rounded foundational education in this domain. Additionally, it is imperative to consider students' maturity and capacity for abstraction when selecting content and methodologies. In instances where formal thinking has not yet been attained, it is more beneficial, for optimal learning outcomes, to approach the teaching of chemistry from a phenomenological perspective [27]. First, the laboratory experience, followed by abstraction. In the classroom, chemistry should be linked to relevant and significant phenomena, fostering a dynamic that encourages thinking, experimentation, and communication in accordance with the principles of the discipline. To achieve this, simply having a certain value system and posing good questions is not sufficient. The incorporation of theories that aid in conceptualization, along with the use of terminology that supports cognitive engagement and commitment from learners, is essential.

It is crucial to introduce learners to theories that are appropriate to their level of understanding and to the experimental practices they are likely to undertake. However, this task is not without its challenges and requires a thorough reassessment to identify and overcome potential obstacles [28].

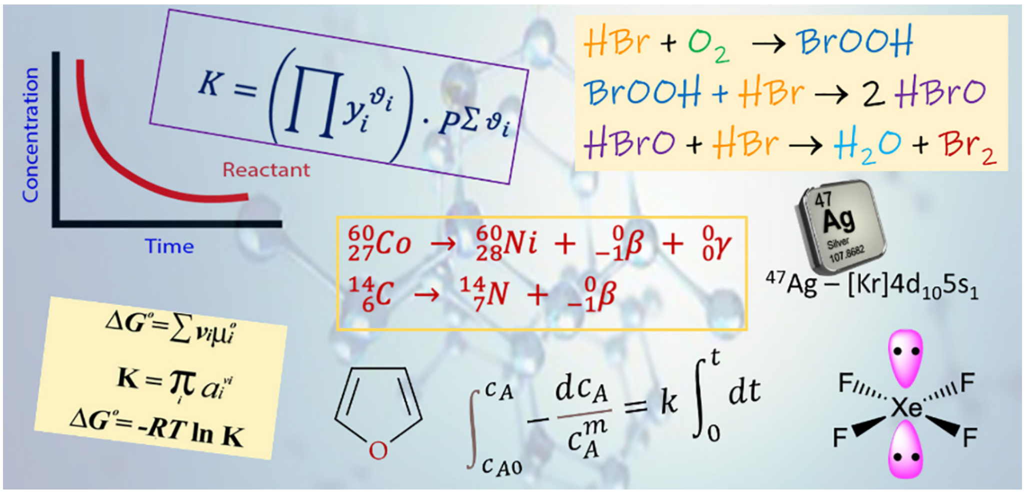

Fig. 3. Chemistry: A complex discipline

Chemistry is a discipline that heavily relies on specialized language and complex terminology (see Figure 3). Learning challenges in chemistry are often linked to its abstract nature, as it is based on concepts such as atoms, which students cannot directly observe, and utilizes symbolic language (see Figure 4) that may be unfamiliar to them [29]. Furthermore, the subject matter of chemistry—focused on the properties and behaviors of substances, their transformations, and the energy involved in these processes—is often distant from the interests of students.

They may be inclined to accept the most visible phenomena without delving into deeper understanding. Another limitation of chemistry is the asymmetric relationship between the structure of substances and their properties [30]. Relationships must be empirically investigated and cannot be generalized simplistically. While systems with identical microscopic structures are expected to exhibit the same macroscopic properties, the reverse is not necessarily true. In other words, two systems with the same macroscopic property (such as high viscosity) can possess entirely different microscopic structures. This phenomenon often leads to significant confusion and rejection among students.

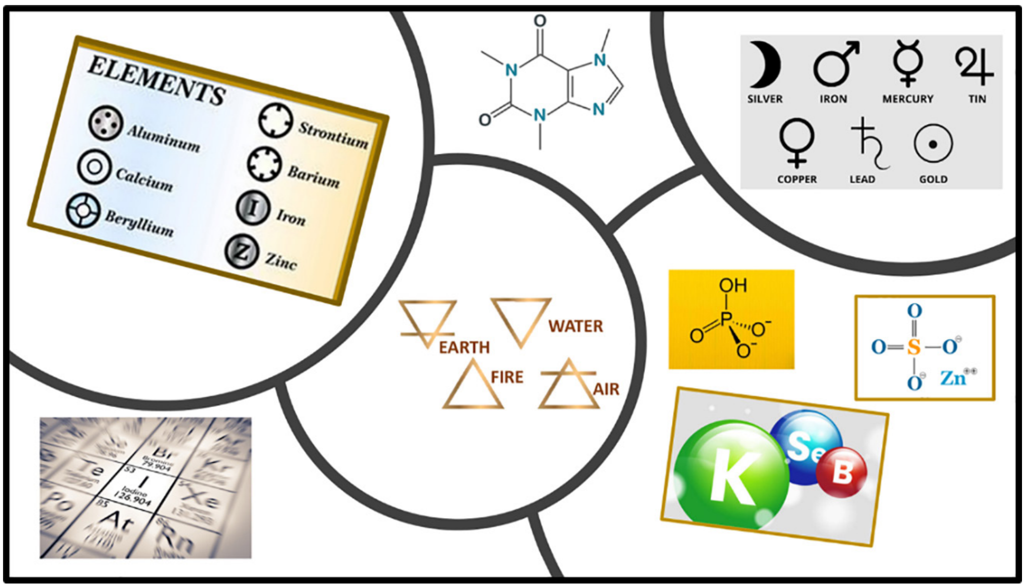

Fig. 4. Chemical symbolic language

5 MOTIVATIONAL ALTERNATIVES IN CHEMISTRY LEARNING

The teaching and learning process can often lead to a paradoxical situation: students may complain of classes being uninspiring, while teachers may assert that students have lost interest. However, fundamentally, it boils down to a single issue: a lack of motivation for learning. Intrinsic motivation [31] serves as a pivotal factor in facilitating students' academic performance [32]. This commitment must encompass both cognitive and affective dimensions. The drive to learn, discover, achieve, and understand originates from within the student, although it is the teacher who must serve as a catalyst.

Previous research reported how intrinsic motivation, the genuine interest in the subject matter, significantly influences students' performance in learning chemistry [30]. Motivational strategies that promote greater emotional and cognitive engagement with content, such as the use of practical activities, achieve greater academic success compared to more theoretical and less interactive approaches. Moreover, students who perceived chemistry as a subject more interesting and relevant to their daily lives showed better results in the evaluation process [31, 33].

When motivation is lacking, learning becomes hindered. Increased motivation to learn is not only linked to improved results but also to greater conceptual comprehension, self-esteem, social adjustment, and completion rates [31]. Here, it is crucial for the teacher to take action, not only to cultivate a positive attitude towards learning specific content but also to ignite and fortify long-term motivations in students. This involves instilling interests and values so that students themselves are inclined to take actions that facilitate new learning, fostering spontaneous activity, proactive engagement, and the formation of robust decision-making skills. Chemistry teachers can effectively address this situation (see Figure 5) by integrating motivational elements alongside the conceptual emphasis of the discipline. For instance, they can incorporate everyday situations that resonate with students, highlight the challenges that society will face in the near future concerning chemistry, align classroom teaching methodologies with problem-solving strategies utilized by scientists, and emphasize positive and relevant prospects within the field of chemistry [34].

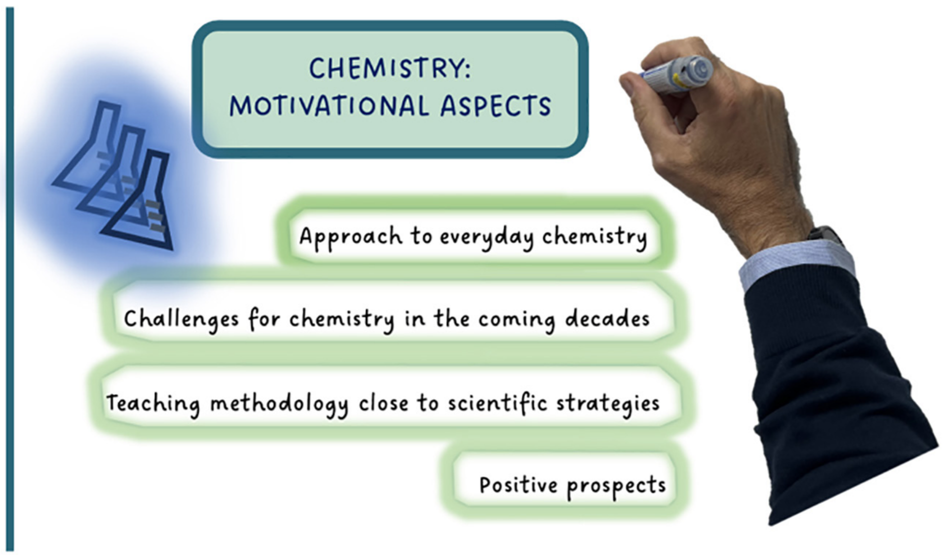

Fig. 5. Motivational strategies for chemistry learning

5.1 Chemistry in daily life

Chemistry is not only integral to our daily lives but also holds the key to our future. The goal is to enhance public recognition of chemistry as a fundamental tool for addressing societal needs. By showcasing its myriad benefits and applications that have enriched every aspect of our lives, alongside the innovations and advancements that promise a better and more sustainable world.

The chemical industry plays a key role in these aspects, since it manufactures cleaning products, cosmetics, personal hygiene and childcare articles, and producing essential materials for household appliances and facilitates optimal food preservation [35]. This contribution has significantly simplified domestic chores. In the kitchen, for example, we benefit from non-stick plastic-coated utensils, containers, and furniture; ceramic plates; transparent wrapping films; non-slip trays; internally protected tin cans; and food safeguarded against the detrimental effects of fungi and bacteria. Moreover, chemistry permeates other areas of our homes, from windows, floors, doors, and furniture to essential gadgets such as televisions, personal computers, and cell phones. It is an indispensable element woven into the fabric of our daily lives, enriching our experiences and enabling comfort and convenience.

Chemistry also plays a pivotal role in outfitting us for every occasion, whether it's a countryside excursion, a swim in the sea, a sports activity, mountain climbing, or attending a party. While natural fibers pose challenges in modification and are relatively inefficient in production, synthetic fibers offer versatility and are produced in vast quantities [36]. These fibers can be tailored to meet specific needs, providing a plethora of useful properties.

Thanks to chemistry, we enjoy waterproof materials based on microporous polyurethane, hydrophilic polyester, and Teflon. Firefighters and Formula 1 drivers benefit from fireproof suits made of aramid fibers and composites, while police officers rely on bulletproof vests crafted from polyamide and polystyrene fibers [37]. Furthermore, modern textiles, infused with nanometric particles, resist wrinkling and repel stains and liquids, all thanks to the wonders of chemistry.

Indeed, chemistry plays a vital role in food production and preservation. Fertilizers and plant protection products contribute to enhancing agricultural yields, while plastics and biopolymers utilized in greenhouse coverings, mulch, and drip irrigation systems further support crop growth. Additionally, food preservatives and environmentally friendly cryogenic gases utilized in refrigeration systems aid in transportation and preservation, safeguarding food against external elements. All of these advancements are products of modern chemical technologies, showcasing the innovative contributions of chemistry to the food industry [38–39]. It is also noteworthy to recognize the significance of chemistry in food packaging. Despite their innocuous appearance, these containers represent remarkable feats of technology. They must possess a delicate balance of being lightweight yet sturdy, with some comprising multiple layers of film, each tailored with specific functions and properties.

The selective permeability of polymer-based materials to gases such as carbon dioxide, oxygen, moisture, and light has paved the way for the development of packaging with modified inner atmospheres. When barrier properties are carefully selected, packaging materials can maintain a modified atmosphere within the container, thus prolonging the shelf life of food products. For instance, dehydrated products require protection from moisture during storage, while fatty foods must be shielded from air to mitigate oxidation. Conversely, fresh fruits necessitate breathable packaging, allowing gases to circulate within the container. Addressing these occasionally conflicting requirements, the chemical industry provides the appropriate materials [40]. Furthermore, another focal point is the production of beverage and food cans from inert metals, owing to the commercial significance of these containers due to their widespread use. Polymeric coatings, developed in research and development (R&D) chemical laboratories, are often applied to the inner surface of these metal food cans to serve as a barrier between the food and the metal surface [41]. Despite the myriad applications of chemistry across various facets of our daily lives, we have struggled to promote its true value and significance.

Unfortunately, it's common for products to be discredited by labeling them as "having a lot of chemistry." However, it would be challenging for anyone in our society to envision a world devoid of the contributions of this remarkably productive science [42]. If we delve into specifics, we can appreciate the significance of chemistry in our daily lives through concrete examples (see Figure 6).

Fig. 6. Infant formula and sunscreens, contributions of chemistry in daily life

Consider, for instance, the list of ingredients on a package of infant formula milk: whole milk, skim milk, lactose, whey protein concentrate, vegetable oils from sunflower, soy, coconut, and canola, tocopherols, galacto-oligosaccharides, arachidonic acid oil, sodium caseinate, soy lecithin, minerals (sodium, calcium, phosphorus, potassium, chloride, magnesium, iron, zinc, selenium, copper, manganese, iodine), vitamins (A, B6, B12, C, D, E, K, thiamin, riboflavin, niacin, pantothenic acid, biotin, folic acid), acidity regulators (calcium hydroxide, citric acid), choline, taurine, nucleotides (cytidine 5'-monophosphate, uridine 5'-monophosphate, adenosine 5'-monophosphate, inosine 5'-monophosphate, guanosine 5'-monophosphate), inositol, and L-carnitine. This comprehensive formula, derived from chemical substances, provides essential nourishment for infants. It's worth considering how many babies are currently being nourished by formula, a testament to the contributions of chemistry in meeting nutritional needs. Another compelling example can be found in widely used sunscreens. The invaluable contribution of chemistry to these products is evident when examining their ingredient lists, which often contain no fewer than 20 chemical substances. These may include silica, titanium dioxide, sodium hydroxide, ascorbic acid, citric acid, propylene glycol, butylene glycol, disodium EDTA, tocopherol, ethylhexyl methoxycinnamate, polymethyl methacrylate, dimethicone, ethylhexyl triazone, phenoxyethanol, acrylates, tocopheryl acetate, allantoin, ethylhexylglycerin, sodium hyaluronate, ascorbyl palmitate, or butylated hydroxytoluene. Indeed, what would our beach outings be without these indispensable products?

It is important to emphasize that the objective of chemistry courses is not limited to the assimilation of facts, theories, formulas, and equations. Emphasizing the reason and importance that this interrelated set of knowledge has for our lives and for our future will stimulate students to learn it.

5.2 Challenges in chemistry for the near future

It is important to transmit to students not only the impact of chemistry in our lives and the development of this science but also its essence, its changing, perfectionist nature. One way to do this is to expose them to new challenges, to what is yet to be discovered (refer to Table 1). The goal is to emphasize that despite being a mature science, chemistry's horizon is replete with challenges for scientists and educators [43]. Our society is evolving at an increasingly rapid pace, with changes that once took centuries or decades now occurring so swiftly that it's impossible to foresee where we will be in 25 or 50 years. Chemistry is not immune to the speed of these changes; in fact, it is one of the driving forces behind them.

Table 1. Key challenges in contemporary chemistry

Challenge	Description
1. Health and Medicine	The application of chemistry is vital in the medical industry for driving health innovation and facilitating the discovery and development of drugs and vaccines aimed at minimizing the impact of potential pandemics.
2. Food security	Ensuring the quality, safety, and nutritional value of food is essential to meet the needs of a growing and aging population.
3. Water resources management	The sustainable management of the planet's water resources necessitates effective methods of water purification and decontamination, where chemistry plays an essential role.
4. Sustainability	There is a need to develop chemical processes that minimize the consumption of natural resources and generate less waste.
5. Clean and renewable energy	Investigating and improving the development of technologies for the production and storage of clean energy using chemistry is essential.
6. Climate change	Contribution to the reduction of greenhouse gas emissions and the development of carbon sequestration technologies is paramount.
7. Nanotechnology and smart materials	There is a pressing need for the development of smart materials with the ability to adapt to their environment, change shape, or perform specific functions, particularly in fields such as biomedical engineering, robotics, nanoscience, and chemistry.
8. Green chemistry	The design of environmentally friendly chemical processes involves the reduction or elimination of hazardous substances, lower energy consumption, reduced waste production, and adherence to principles of the circular economy.

Chemistry plays a crucial role in addressing numerous challenges facing our global civilization [44]. Modern technology necessitates the development of new materials with specific properties, and chemists are tasked with designing methods to produce these materials. Similarly, the demands of modern medicine require the synthesis of specific drugs, prompting chemists to devise strategies for their production. Furthermore, society requires advancements in pollution control methods, substitutes for raw materials in short supply, safe disposal methods for toxic waste, and more efficient ways of obtaining and storing energy from eco-sustainable sources. In each of these areas, chemistry serves as a driving force for innovation and progress [45]. Chemistry is intricately linked to fields such as genomics, nanotechnology, and biotechnology, which are poised to usher in significant scientific revolutions in the years ahead. The chemical sciences will play a pivotal role in addressing these global challenges. Moreover, chemistry's impact extends to the economy, highlighting its importance in fostering innovation and development.

In addition to transmitting and emphasizing these aspects, teachers bear the responsibility of promoting scientific culture in general, and chemistry in particular, within the classroom. By fostering curiosity, critical thinking, and a passion for discovery, educators play a vital role in inspiring the next generation of scientists and innovators. This is what some researchers have called scientific literacy [46].

5.3 Workshop on fun chemistry experiments

Laboratory work is considered an essential part of chemistry education. It offers students firsthand experience in observing and manipulating scientific materials, thereby developing and refining their scientific and practical skills [47]. Laboratory activities are highly significant for arousing students' curiosity and interest, fostering critical and creative thinking, enhancing their reasoning skills, and promoting an attitude of open-mindedness and objectivity. These activities aid students in problem-solving and in explaining and understanding the phenomena they encounter in their daily lives [48].

The central focus of transitioning towards a new didactic approach to chemistry lies with the teacher. Drawing upon their experience and considering the characteristics of the student group, the teacher must adopt a specific didactic approach to the subject. By conducting simple experiments using everyday reagents, the teacher can demonstrate practical applications of chemistry that stimulate students' motivation. These experiments not only help students grasp the importance of chemistry but may also spark interest in potential future professional fields [49]. Moreover, comprehending the diverse applications of chemistry will lead to a deeper understanding of the world around them. In this regard, various captivating experiments can be proposed to unveil the almost magical and mysterious nature of chemistry, stemming from the surprising outcomes of selected chemical reactions. Some laboratory activities to be considered are summarized in Table 2.

Teachers must facilitate not only the transmission of chemical knowledge but also motivate to awaken interest in this science and ensure that students acquire chemical thinking skills [10]. Without motivation, learning comes to a grinding halt. When science is presented in a way that is disconnected from day-to-day life, many students lose interest. And if this motivation is lacking, all the effort and preparation of the teacher will be for naught. Therefore, it is crucial to underscore the importance of chemistry and its relevance to students' lives and also provide evidence to illustrate the true scope and limitations of science and scientists [34]. In addition to motivational aspects, opportunities should be offered for students to explore problems and facts, enabling them to derive useful ideas, propose explanations, consider alternative solutions, and test them.

Table 2. Selection of fun chemistry laboratory experiments

Lab Activity	Reference
1. Colour change chemical reaction experiments	[50]
2. Reveal latent fingerprints	[50]
3. Water to wine to milk to beer conversion	[50]
4. CO_2 sublimation	[51]
5. Produce hydrogen by electrolysis	[52]
6. Vinegar for peeling eggs	[53]
7. Synthesize rayon fiber	[50]
8. Self-heating food products	[53]

6 FINAL REMARKS: CRITICAL ANALYSIS

Numerous attempts have been made to uncover the nature of the relationship between student motivation and learning [33, 54]. It is not easy to quantify precisely the degree to which each of these approaches contributes to fostering motivation in learners, as there are many potentially relevant variables to be included or excluded from their conceptualizations.

It was reported that motivational strategies focused on improving students' self-perception of their abilities in the subject and enhancing interest in specific chemistry topics increased their level of engagement and academic performance.

The use of motivational approaches such as promoting interest and curiosity, as well as the pleasure of learning, shows different advantages: a) increased level of persistence in challenging tasks, which is crucial in complex subjects such as chemistry; b) promotion of deeper and more meaningful learning, which facilitates making connections between concepts and improves long-term understanding; c) development of more effective learning strategies based on self-regulation and reflection, which contributes to better academic performance; d) reduced students' performance anxiety due to motivation by interest and curiosity, as the focus is on the learning process and not on the results [55–56].

Drawbacks of these motivational strategies include that they may have some misalignment with curricular objectives, require time to develop students' interest, may not be sufficient for some students, and could present logistical difficulties in teaching large groups of students [57].

Intrinsic motivation strategies in chemistry learning involve the pursuit of self-directed motivation, do not depend on external factors, and tend to be stronger and more established, especially in the face of challenges. In addition, intrinsically motivated learners are much more likely to approach tasks with enthusiasm and creativity.

7 CONCLUSIONS

Chemistry is often perceived as a complex scientific discipline confined to textbooks and academia, seemingly disconnected from real-world applications.

Teaching chemistry involves not only imparting knowledge but also persuading students of the relevance of this science.

It is necessary to present students with familiar real-world situations, align classroom teaching methodologies with scientific research practices, and emphasize the practical and applicable aspects of chemistry. Teachers must always be receptive and open to new ideas and to new ways of approaching lessons because, in the teaching process, learning is not only with the student but also with the teacher. Explaining and addressing students' problems and concerns helps the teacher to deepen their understanding of the subject matter and expand their pedagogical resources.

There is a complex interplay between motivation, learning strategies, and performance in undergraduate chemistry learning. Strategies are needed to improve chemistry education by making it more engaging and relatable. The goal is to use a range of motivational strategies as catalysts for innovative approaches to chemistry learning, fostering engagement, curiosity, and a deeper understanding of chemistry.

Focusing on revealing how chemistry can address real-world challenges, investigating how to teach students the challenges of chemistry in modern society, and researching how to improve understanding of the conceptual principles of chemistry are some of the main areas where future research in chemistry learning should have a significant impact.

8 REFERENCES

[1] G. Pinto and M. L. Prolongo, "Stoichometry in context: Inquiry-guided problems of chemistry for encouraging critical thinking in engineering students," *International Journal of Engineering Pedagogy (iJEP)*, vol. 3, no. 1, pp. 24–28, 2013. https://doi.org/10.3991/ijep.v3i1.2313

[2] J. C. Ogunde, T. L. Overton, C. D. Thompson, R. Mewis, and S. Boniface, "Beyond graduation: Motivations and career aspirations of undergraduate chemistry students," *Chemistry Education Research and Practice*, vol. 18, pp. 457–471, 2017. https://doi.org/10.1039/C6RP00248J

[3] C. L. Bae and M. DeBusk-Lane, "Middle school engagement profiles: Implications for motivation and achievement in science," *Learning and Individual Differences*, vol. 74, p. 101753, 2019. https://doi.org/10.1016/j.lindif.2019.101753

[4] D. King, "New perspectives on context-based chemistry education: Using a dialectical sociocultural approach to view teaching and learning," *Studies in Science Education*, vol. 48, no. 1, pp. 51–87, 2012. https://doi.org/10.1080/03057267.2012.655037

[5] S. Markic and P. E. Childs, "Language and the teaching and learning of chemistry," *Chemistry Education Research and Practice*, vol. 17, pp. 434–438, 2016. https://doi.org/10.1039/C6RP90006B

[6] A. H. Johnstone, "Why is science difficult to learn? Things are seldom what they seem," *Journal of Computer Assisted Learning*, vol. 7, no. 2, pp. 75–83, 1991. https://doi.org/10.1111/j.1365-2729.1991.tb00230.x

[7] D. Bekerman, L. Pepa, E. Vaccaro, M. Alonso, and L. R. Galagovsky, "Using simulations to detect difficulties in the process of learning chemical solutions," *American Journal of Educational Research*, vol. 4, pp. 608–612, 2016. https://pubs.sciepub.com/education/4/8/5/

[8] E. L. Howell, S. Yang, C. M. Holesovsky, and D. A. Scheufele, "Communicating chemistry trough cooking and personal health: Everyday applications increase perceived relevance, interest, and self-efficacy in chemistry," *Journal of Chemical Education*, vol. 98, no. 6, pp. 1852–1862, 2021. https://doi.org/10.1021/acs.jchemed.1c00125

[9] S. Riaz, D. R. Rambli, R. Salleh, and A. Mushtaq, "Study to investigate learning motivation factors within formal and informal learning environments and their influence upon web-based learning," *International Journal of Emerging Technologies in Learning (iJET)*, vol. 5, no. 4, pp. 41–50, 2010. https://doi.org/10.3991/ijet.v5i4.1338

[10] M. Izquierdo-Aymerich, "School chemistry: An historical and philosophical approach," *Science & Education*, vol. 22, pp. 1633–1653, 2013. https://doi.org/10.1007/s11191-012-9457-5

[11] S. Axon and D. James, "The UN sustainable development goals: How can sustainable chemistry contribute? A view from the chemical industry," *Current Opinion in Green and Sustainable Chemistry*, vol. 13, pp. 140–145, 2018. https://doi.org/10.1016/j.cogsc.2018.04.010

[12] R. Khishfe, "Nature of science and decision-making," *International Journal of Science Education*, vol. 34, no. 1, pp. 67–100, 2011. https://doi.org/10.1080/09500693.2011.559490

[13] O. Díaz, E. Segredo-Morales, and E. González, "Problem-based learning. Application to a laboratory practice in the degree of Industrial Chemical Engineering," *International Journal of Engineering Pedagogy (iJEP)*, vol. 13, no. 6, pp. 139–150, 2023. https://doi.org/10.3991/ijep.v13i6.39737

[14] L. A. Jesper, J. F. D. Nielsen, and C. Zhou, "Motivating students to develop satellites in problem and project-based learning (PBL) environment," *International Journal of Engineering Pedagogy (iJEP)*, vol. 3, no. 3, pp. 11–17, 2013. https://doi.org/10.3991/ijep.v3i3.2529

[15] O. Akbari and J. Sahibzada, "Students' self-confidence and its impacts on their learning process," *American International Journal of Social Science Research*, vol. 5, no. 1, pp. 1–15, 2020. https://doi.org/10.46281/aijssr.v5i1.462
[16] A. Riswanto and S. Aryani, "Learning motivation and student achievement: Description analysis and relationships both," *The International Journal of Counseling and Education*, vol. 2, pp. 42–47, 2017. https://doi.org/10.23916/002017026010
[17] M. Baeten, F. Dochy, and K. Struyven, "The effects of different learning environments on students' motivation for learning and their achievement," *British Journal of Educational Psychology*, vol. 83, no. 3, pp. 484–501, 2013. https://doi.org/10.1111/j.2044-8279.2012.02076.x
[18] J. B. Smart and J. C. Marshall, "Interactions between classroom discourse, teacher questioning, and student cognitive engagement in middle school science," *Journal of Science Teacher Education*, vol. 24, no. 2, pp. 249–267, 2013. https://doi.org/10.1007/s10972-012-9297-9
[19] R. Bokosmaty, A. Bridgeman, and M. Muir, "Using a partially flipped learning model to teach first year undergraduate chemistry," *Journal of Chemical Education*, vol. 96, no. 4, pp. 629–639, 2019. https://doi.org/10.1021/acs.jchemed.8b00414
[20] H. Tümay, "Reconsidering learning difficulties and misconceptions in chemistry: Emergence in chemistry and its implications for chemical education," *Chemistry Education Research and Practice*, vol. 17, pp. 229–245, 2016. https://doi.org/10.1039/C6RP00008H
[21] F. C. D. Broietti, P. dos Santos Nora, and S. L. R. Costa, "Dimensions of science learning: A study on PISA test questions involving chemistry content," *Acta Scientiae*, vol. 21, pp. 95–115, 2019. https://doi.org/10.17648/acta.scientiae.v21iss1id4947
[22] J. T. Laverty *et al.*, "Characterizing college science assessments: The three-dimensional learning assessment protocol," *PLoS ONE*, vol. 11, no. 9, p. e0162333, 2016. https://doi.org/10.1371/journal.pone.0162333
[23] M. Tal, O. Herscovitz, and Y. J. Dori, "Assessing teachers' knowledge: Incorporating context-based learning in chemistry," *Chemistry Education Research and Practice*, vol. 22, pp. 1003–1019, 2021. https://doi.org/10.1039/D0RP00359J
[24] A. Berg, D. Orraryd, A. J. Pettersson, and M. Hultén, "Representational challenges in animated chemistry: Self-generated animations as a means to encourage students' reflections on sub-micro processes in laboratory exercises," *Chemistry Education Research and Practice*, vol. 20, pp. 710–737, 2019. https://doi.org/10.1039/C8RP00288F
[25] A. Hofstein and R. Mamlok-Naaman, "High-school students' attitudes toward and interest in learning chemistry," *Educación Química*, vol. 22, pp. 90–102, 2011. https://doi.org/10.1016/S0187-893X(18)30121-6
[26] M. T. Wang, A. Chow, J. L. Degol, and J. S. Eccles, "Does everyone's motivational beliefs about physical science decline in secondary school?: Heterogeneity of adolescents' achievement motivation trajectories in physics and chemistry," *Journal of Youth and Adolescence*, vol. 46, pp. 1821–1838, 2017. https://doi.org/10.1007/s10964-016-0620-1
[27] E. Østergaard, B. Dahlin, and A. Hugo, "Doing phenomenology in science education: A research review," *Studies in Science Education*, vol. 44, no. 2, pp. 93–121, 2008. https://doi.org/10.1080/03057260802264081
[28] A. Pilot and A. M. Bulte, "The use of 'contexts' as a challenge for the chemistry curriculum: Its successes and the need for further development and understanding," *International Journal of Science Education*, vol. 28, no. 9, pp. 1087–1112, 2006. https://doi.org/10.1080/09500690600730737
[29] C. A. Dewi, P. Pahriah, and A. Purmadi, "The urgency of digital literacy for generation Z students in chemistry learning," *International Journal of Emerging Technologies in Learning (iJET)*, vol. 16, no. 11, pp. 88–103, 2021. https://doi.org/10.3991/ijet.v16i11.19871

[30] A. Lahlali *et al*., "Students' alternative conceptions and teachers' views on the implementation of pedagogical strategies to improve the teaching of chemical bonding concepts," *International Journal of Engineering Pedagogy (iJEP)*, vol. 13, no. 6, pp. 90–107, 2023. https://doi.org/10.3991/ijep.v13i6.41391

[31] R. Meulenbroeks, R. van Rijn, and M. Reijerkerk, "Fostering secondary school science students' intrinsic motivation by inquiry-based learning," *Research in Science Education*, vol. 54, pp. 339–358, 2024. https://doi.org/10.1007/s11165-023-10139-0

[32] N. Oroujlou and M. Vahedi, "Motivation, attitude, and language learning," *Procedia–Social and Behavioral Sciences*, vol. 29, pp. 994–1000, 2011. https://doi.org/10.1016/j.sbspro.2011.11.333

[33] R. H. Tai, P. M. Sadler, and J. F. Loehr, "Factors influencing success in introductory college chemistry," *Journal of Research in Science Teaching,* vol. 42, no. 9, pp. 987–1012, 2005. https://doi.org/10.1002/tea.20082

[34] A. George, C. Zowada, I. Eilks, and O. Gulacar, "Exploring chemistry professors' methods of highlighting the relevancy of chemistry: Opportunities, obstacles, and suggestions to improve students' motivation in science classrooms," *Education Sciences,* vol. 11, no. 1, p. 13, 2021. https://doi.org/10.3390/educsci11010013

[35] S. Roy, "Chemistry in our daily life: Preliminary information," *International Journal of Home Science*, vol. 2, no. 3, pp. 361–366, 2016.

[36] M. S. Bodur, M. Bakkal, and H. E. Sonmez, "The effects of different chemical treatment methods on the mechanical and thermal properties of textile fiber reinforced polymer composites," *Journal of Composite Materials*, vol. 50, no. 27, pp. 3817–3830, 2016. https://doi.org/10.1177/0021998315626256

[37] P. M. Gore and B. Kandasubramanian, "Functionalized aramid fibers and composites for protective applications: A review," *Industrial & Engineering Chemistry Research*, vol. 57, no. 49, pp. 16537–16563, 2018. https://doi.org/10.1021/acs.iecr.8b04903

[38] D. J. Luning Prak and C. L. Copper, "A chemistry minute: Recognizing chemistry in our daily lives," *Journal of Chemical Education*, vol. 85, no. 10, p. 1368, 2008. https://doi.org/10.1021/ed085p1368

[39] E. Gómez-Plaza, R. Gil-Muñoz, J. Carreño-Espín, J. A. Fernández-López, and A. Martínez-Cutillas, "Investigation on the aroma of wines from seven clones of Monastrell grapes," *European Food Research and Technol*ogy, vol. 209, pp. 257–260, 1999. https://doi.org/10.1007/s002170050489

[40] S. J. Risch, "Food packaging history and innovations," *Journal of Agricultural and Food Chemistry*, vol. 57, no. 18, pp. 8089–8092, 2009. https://doi.org/10.1021/jf900040r

[41] A. Lestido-Cardama, R. Sendón, J. Bustos, M. T. Nieto, P. Paseiro-Losada, and A. Rodríguez-Bernaldo de Quirós, "Food and beverage can coatings: A review on chemical analysis, migration, and risk assessment," *Comprehensive Reviews in Food Science and Food Safety*, vol. 21, no. 4, pp. 3558–3611, 2022. https://doi.org/10.1111/1541-4337.12976

[42] B. Bensaude-Vincent and J. Simon, *Chemistry: The Impure Science*. London, UK: Imperial College Press, pp. 296, 2012. https://doi.org/10.1142/9781848168299

[43] J. Garcia Martinez, "Tackling the big challenges of the future: The role of chemistry," *Chemistry International,* vol. 38, nos. 3–4, pp. 10–15, 2016. https://doi.org/10.1515/ci-2016-3-405

[44] R. Blonder, S. Rap, and R. Mamlok-Naaman, "Frontiers of research in chemistry education for the benefit of chemistry teachers," *Chemistry Teacher International*, vol. 5, no. 2, pp. 107–111, 2023. https://doi.org/10.1515/cti-2023-0041

[45] F. Gomollón-Bel and J. García-Martínez, "Emerging chemistry technologies for a better world," *Nature Chemistry*, vol. 14, pp. 113–114, 2022. https://doi.org/10.1038/s41557-021-00887-9

[46] G. E. Deboer, "Scientific literacy: Another look at its historical and contemporary meanings and its relationship to science education reform," *Journal of Research in Science Teaching*, vol. 37, no. 6, pp. 582–601, 2000. https://doi.org/10.1002/1098-2736(200008)37:6<582::AID-TEA5>3.0.CO;2-L

[47] S. L. Bretz, "Evidence for the importance of laboratory courses," *Journal of Chemical Education,* vol. 96, no. 2, pp. 193–195, 2019. https://doi.org/10.1021/acs.jchemed.8b00874

[48] L. Vinko, S. Delaney, and I. Devetak, "Teachers' opinions about the effect of chemistry demonstrations on students' interest and chemistry knowledge," *CEPS Journal,* vol. 10, no. 2, pp. 9–25, 2020. https://doi.org/10.26529/cepsj.893

[49] P. Mahaffy, "The future shape of chemistry education," *Chemistry Education Research and Practice,* vol. 5, pp. 229–245, 2004. https://doi.org/10.1039/B4RP90026J

[50] R. B. Thompson, *Illustrated Guide to Home Chemistry Experiments*. Cambridge, UK: O'Reilly Media Inc., 2008.

[51] N. Herr and J. Cunningham, *Hands-on Chemistry Activities with Real-Life Applications*. San Francisco, CA: John Wiley/Jossey–Bass Publishers, 1999.

[52] J. C. Domínguez, R. Miranda, E. J. González, M. Oliet, and M. V. Alonso, "A virtual lab as a complement to traditional hands-on labs: Characterization of an alkaline electrolyzer for hydrogen production," *Education for Chemical Engineers,* vol. 23, pp. 7–17, 2018. https://doi.org/10.1016/j.ece.2018.03.002

[53] M. T. Oliver-Hoyo, G. Pinto, and J. A. Llorens-Molina, "The chemistry of self-heating food products. An activity for classroom engagement," *Journal of Chemical Education,* vol. 86, no. 11, p. 1277, 2009. https://doi.org/10.1021/ed086p1277

[54] T. Holocher, B. Kieslinger, and C. M. Fabian, "Applying participatory methods to address motivational aspects in informal workplace," *International Journal of Advanced Corporate Learning (iJAC)*, vol. 4, no. 1, pp. 18–24, 2011. https://doi.org/10.3991/ijac.v4i1.1412

[55] M. R. Luce and S. Hsi, "Science-relevant curiosity expression and interest in science: An exploratory study," *Science Education*, vol. 99, no. 1, pp. 70–97, 2015. https://doi.org/10.1002/sce.21144

[56] M. Ainley, "Connecting with learning: Motivation, affect and cognition in interest processes," *Educational Psychology Review*, vol. 18, pp. 391–405, 2006. https://doi.org/10.1007/s10648-006-9033-0

[57] A. Zusho, P. R. Pintrich, and B. Coppola, "Skill and will: The role of motivation and cognition in the learning of college chemistry," *International Journal of Science Education*, vol. 25, no. 9, pp. 1081–1094, 2003. https://doi.org/10.1080/0950069032000052207

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