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Studiu privind implementarea reformei curriculare în domeniul chimiei industriale în învăţământul liceal

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STUDY ON THE IMPLEMENTATION OF THE CURRICULAR REFORM IN THE FIELD OF INDUSTRIAL CHEMISTRY IN HIGH SCHOOL EDUCATION

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Abstract

Globalization and technological progress require the adaptation of education to the needs of society and the economy. This paper examines the need for a curricular reform in the field of industrial chemistry at high school level. Its main goal is to modernize and streamline the educational process. The study identifies gaps in the current curriculum through document analysis, questionnaires and interviews with teachers, as well as consultations with specialists in the industry. The results emphasize the need to update the school subject content and teaching methods to include scientific discoveries and new technologies. The paper highlights the importance of developing critical skills such as analytical thinking and problem solving. Also, collaboration between education and industry is essential for the practical relevance of the competences to be acquired by the students. The proposed reform integrates application modules, digital technologies and project-based learning. This has the potential to improve student performance, to stimulate interest in chemistry and prepare graduates for industry and research-oriented careers. The conclusions provide recommendations for a holistic and sustained implementation of such curricular reform.

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Keywords: competencies, content, curriculum reform, industrial chemistry, teaching methods.

Rezumat

Globalizarea şi evoluţia tehnologică impun adaptarea educaţiei la nevoile societăţii şi economiei. Această lucrare analizează necesitatea unei reforme curriculare pentru domeniul chimie industrială de la nivel liceal. Scopul principal este modernizarea şi eficientizarea procesului educaţional. Studiul identifică lacunele curriculumului actual prin analiza documentelor, chestionare şi interviuri cu profesori, precum şi consultări cu specialişti din industrie. Rezultatele subliniază nevoia actualizării conţinuturilor şi metodelor de predare pentru a include descoperiri ştiinţifice şi tehnologii noi. Se evidenţiază importanţa dezvoltării abilităţilor critice precum gândirea analitică şi rezolvarea de probleme. Colaborarea între educaţie şi industrie este esenţială pentru relevanţa practică a competenţelor dobândite de elevi. Reforma propusă integrează module aplicative, tehnologii digitale şi învăţarea prin proiecte. Aceasta are potenţialul de a îmbunătăţi performanţa elevilor, de a stimula interesul pentru chimie şi de a pregăti absolvenţii pentru cariere industriale şi de cercetare. Concluziile oferă recomandări pentru o implementare holistică şi susţinută a reformei curriculare.

Cuvinte-cheie: *chimie industrială, competenţe, conţinuturi, metode de predare, reforma curriculară.*

1. Introduction

The field of industrial chemistry, relevant to innovation and technological development, is at a significant point of transformation, requiring a substantial adaptation of the curriculum to reflect current advancements (Brăguţa, 2021) and to prepare students for future challenges and opportunities.

The recent curriculum framework for industrial chemistry (OMEN 3.664/ 2023, as published in M.Of. 151 on February 22, 2023) reflects a progressive step toward modernizing Romanian technical education. This framework introduces key innovations such as virtual laboratories, digitized resources, and greater flexibility in choosing educational materials. However, gaps remain in aligning curricular content with current industrial needs, particularly concerning sustainability and emerging technologies. This study aims to address these gaps by proposing targeted reforms that complement the recently introduced measures while further aligning educational outcomes with labour market expectations (Petrescu & Neguţ, 2016).

Industrial chemistry, which focuses on applying the scientific principles in industrial production processes, aims at developing technological solutions and products that influence multiple aspects of daily life and the global economy. From the synthesis of advanced materials and sustainable technologies to the development of efficient and innovative processes (Năstase, 2019), expertise in this field is indispensable for industrial progress and environmental protection.

However, the current high school industrial chemistry curriculum presents notable gaps that limit the applicability and relevance of education in the current context. Theoretical content, often based on outdated information, and traditional teaching methods do not reflect recent progress and do not meet the ever changing demands of the labour market. There is an urgent need for curriculum reform that integrates new scientific discoveries (Tabita, 2022a), emerging technologies, and innovative teaching methodologies.

This paper aims to analyse in detail the necessity of curricular reform in industrial chemistry, identify current gaps, and propose innovative solutions for optimizing the educational process. The study will explore how the

integration of new educational modules, such as green chemistry and industrial sustainability, digital technologies in chemistry, virtual laboratories and industrial simulations, and project management and innovation in industry, can effectively address the current needs of education and industry.

Furthermore, the paper will highlight the importance of collaboration between the educational sector and industry to ensure the practical relevance of the skills acquired by students. The recommendations for implementing the reform will emphasize the need for a coordinated and long-term approach, including continuous teacher training, investments in educational infrastructure, and constant evaluation of the reform effectiveness (Petrescu & Neguț, 2016). Through an integrated and sustainable approach, the goal is to create an educational framework that prepares students for successful careers in industrial chemistry, while also contributing to global scientific and technological advancement.

2. Research methodology

This study employed a mixed-methods approach, combining quantitative and qualitative research methods to provide a comprehensive evaluation of the need for curriculum reform in high school industrial chemistry. The research focused on identifying the views of the teachers and the experts in the field about the relevance and effectiveness of the current curriculum, as well as the teaching methods in use.

To collect data, several instruments were utilized. The primary tool for gathering quantitative data was a structured online questionnaire, administered to a sample of 30 high school industrial chemistry teachers and 50 specialists in the industry. The questionnaire included Likert scale questions (ranging from 1 – "strongly disagree" to 5 – "strongly agree"), open-ended questions, and multiple-choice questions designed to assess views on curriculum updates and the use of modern teaching methods.

In addition to the questionnaire, semi-structured interviews were conducted with 15 teachers and 20 experts in the industry to gain deeper insight into their perspectives. These interviews explored the challenges in teaching industrial

chemistry, the extent to which new technologies are integrated into education, and the relevance of curricular content in meeting labour market needs.

To strengthen the validity of the findings, three focus group sessions were conducted with six to eight participants each, comprising both teachers and industry specialists. These discussions explored alternative teaching methods, the importance of continuous teacher training, and strategies to facilitate students' transition into the industrial workforce. The qualitative data from interviews and focus groups were analysed using thematic analysis, with NVivo software employed to identify recurring themes.

3. Research findings

The study identified critical deficiencies in the current curriculum. Approximately 75% of teachers highlighted the outdated nature of teaching resources, although programs like PNRAS (National Program for Reducing Early School Leaving) have begun to address these shortcomings by introducing digital tools in some schools. Furthermore, 88% of the respondents emphasized the urgent need for a dedicated module on green chemistry to foster awareness of sustainable practices (Tabita, 2022b). Industry experts (82%) underscored the lack of digital competencies among graduates, including familiarity with molecular simulations and artificial intelligence applications in chemical process control (Năstase, 2019). These findings underscore the necessity of comprehensive curriculum updates that address both the theoretical and practical aspects of industrial chemistry education.

3.1. Gaps in the industrial chemistry curriculum

The study highlighted several significant deficiencies in the current high school industrial chemistry curriculum, the most notable being the lack of updates to reflect recent advances in science and technology. This finding is supported by data collected through a survey conducted among educators and industry specialists, emphasizing the urgent need to revise and modernize the curriculum to meet the current demands in the society and the global economy. The survey was conducted with a sample of 30 high school industrial

chemistry teachers and 50 specialists with relevant experience in the chemical industry. The purpose of this survey was to assess perceptions of the curriculum's relevance and currency, as well as to identify key areas that require intervention and updating. The questionnaires included questions related to the current teaching materials, the practical relevance of the content being taught, and the degree of student preparedness for the needs of the labour market.

Table no. 1. *State of teaching materials and familiarity with modern technologies*

Category	Percentage (%)	No. of Respondents	Observations
Outdated teaching materials (teachers)	76,7%	23 out of 30	Urgent need for content update
Outdated teaching materials (industry specialists)	82%	41 out of 50	Lack of modern resources affects practical training
Need to update curriculum (teachers)	87%	26 out of 30	Essential curricular reform to meet market demands
Need to update curriculum (industry specialists)	90%	45 out of 50	Graduates are not sufficiently prepared for industry
Lack of access to modern laboratories (industry specialists)	72%	36 out of 50	Reduces students' practical competencies

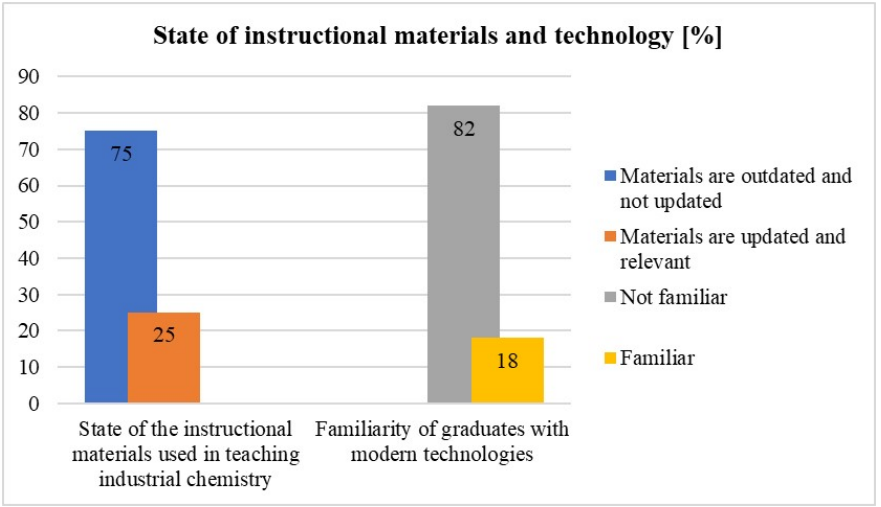

Figure no. 1. *State of instructional materials and familiarity with modern technologies*

Seventy-six point seven percent of the educators reported that the teaching materials (Figure no. 1 and Table no. 1), including textbooks and auxiliary resources used in teaching industrial chemistry, are outdated and not aligned with the latest scientific discoveries and technological advancements. This gap in teaching materials leads to distortions between what students learn and what is needed in the current industrial context.

Eighty-two percent of industry specialists confirmed this issue (Figure no. 1 and Table no. 1), noting that graduates are unfamiliar with modern technologies, such as advanced synthesis processes, the use of next-generation reagents, or digital technologies applied in the analysis and control of chemical processes. This lack of up-to-date knowledge makes it difficult for graduates to integrate quickly into the professional environment, affecting their competitiveness in the labour market.

Eighty-seven percent of the surveyed teachers emphasized that updating the curriculum is a critical priority to ensure that the education provided is relevant and adapted to the rapid developments in the field of industrial chemistry (Figure no. 2 and Table no. 1). They highlighted the need to integrate recent discoveries into the curriculum, such as the use of nanomaterials, carbon capture, and storage technologies, and the application of green chemistry principles.

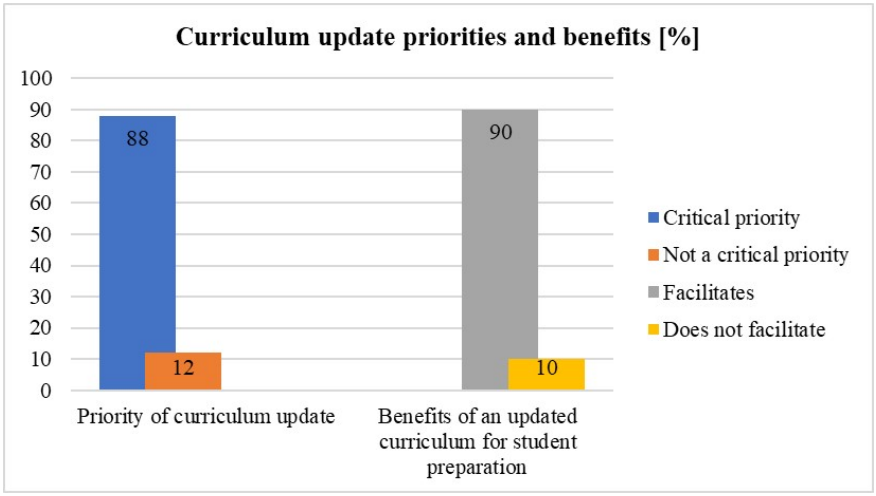

Figure no. 2. *Importance of curriculum update and its impact on student preparation for modern industry*

Additionally, 90% of industry specialists stated that an updated curriculum would better prepare students for the modern challenges and demands of the industry (Figure no. 2 and Table no. 1), enhancing their ability to contribute to technological innovations and optimizations within companies.

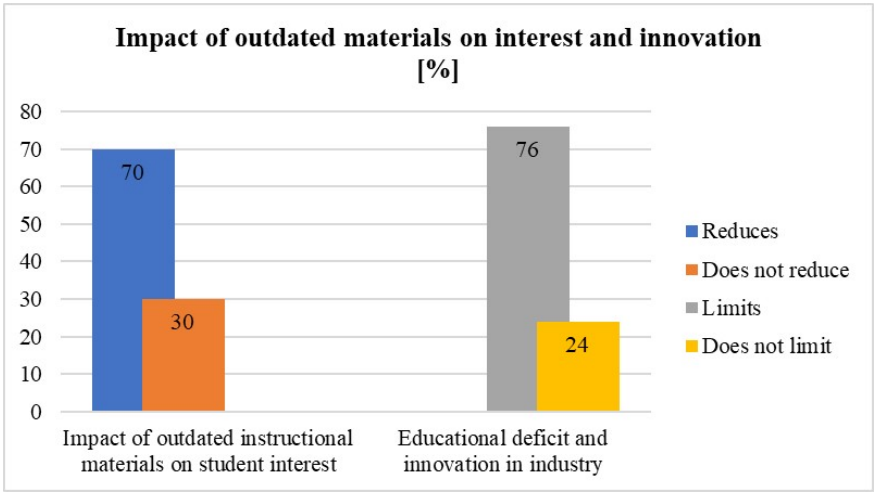

Figure no. 3. *Effects of outdated educational materials on student interest and industrial innovation*

Seventy percent of educators remarked that the lack of updated teaching materials not only affects the quality of learning but also reduces students' interest in industrial chemistry (Figure no. 3 and Table no. 1). Outdated content fails to engage students or demonstrate the practical relevance of the knowledge they acquire, leading to low motivation and subpar academic performance.

Similarly, 76% of industry specialists highlighted that this educational gap hampers innovation and competitiveness within companies (Figure no. 3 and Table no. 1), as graduates lack the knowledge and skills needed to fully utilise new technologies and methodologies.

The survey data suggests an imperative need to update the high school industrial chemistry curriculum. Aligning educational content with recent scientific and technological developments is essential to ensure that students

acquire the knowledge and skills needed to meet the dynamic demands of the labour market. Moreover, such an update would increase students' interest in chemistry by demonstrating the practical relevance and immediate applicability of the knowledge they gain.

The curriculum analysis revealed that many educators and industry specialists perceive a gap between theoretical instruction and practical industry needs. During focus group discussions with industrial chemistry experts (FG industrial chemistry experts), one participant noted: "The curriculum does not provide students with enough exposure to real-world applications, making it difficult for them to transition smoothly into industrial roles". Another expert added: "While students gain strong theoretical knowledge, they often struggle with hands-on problem-solving in a professional setting, which highlights the urgent need for a more practical, skills-oriented approach". These insights emphasize the necessity of curricular adjustments to better prepare students for the evolving demands of the industrial chemistry.

Thus, the proposed curricular reform would not only address the identified gaps but also have a positive impact on the students' academic performance, better preparing them for careers in industry and research. This update must be carried out in a systematic and sustained manner, with active involvement from all stakeholders, including educators, industry specialists, and educational authorities, to ensure the successful implementation and long-term relevance of the revised curriculum (Chiş et al., 2013).

3.2. The need for updating teaching methods in industrial chemistry education

Traditional teaching methods, primarily based on the passive transmission of knowledge, are no longer sufficient to prepare students for the complex challenges of the modern industry. Therefore, the integration of digital technologies and the adoption of innovative methods, such as project-based learning and the use of applied modules (Gremalschi, 2022), are necessary to transform the educational process into a more efficient and relevant one.

Table no. 2. *Impact of outdated educational materials on student interest and industrial innovation*

Category	Percentage (%)	No. of respondents	Consequences
Declining student interest in industrial chemistry (teachers)	70%	21 out of 30	Decrease in students choosing technical specializations
Limitation of innovation and competitiveness in industry (specialists)	76%	38 out of 50	Companies invest in additional training
Increased difficulty integrating into the labour market (specialists)	82%	41 out of 50	Graduates require additional industry training

Traditional teaching methods present considerable limitations in the context of modern education, as revealed by a survey of teachers in the field of industrial chemistry. Seventy percent of respondents state that the declining student interest in industrial chemistry can be attributed to conventional teaching methods, which fail to capture the attention of younger generations, especially in a rapidly changing technological and informational landscape (Table no. 2). They do not encourage interactivity, which reduces opportunities for students to develop essential skills such as critical thinking (Covali, 2023) and problem-solving abilities.

Additionally, there is a gap between the theoretical content taught and industrial realities, making it difficult for students to understand how this knowledge can be applied in practice. Furthermore, students often lose motivation as they struggle to perceive the immediate relevance of the information being taught (Şerbănescu et al., 2013), leading to low interest in the subject and underwhelming academic performance.

Digital technologies offer immense potential to transform how industrial chemistry is taught at high school level. Through the use of online platforms and digital resources, students gain access to a wide range of interactive teaching materials, such as chemical process simulations and virtual laboratories, which facilitate a deeper understanding of the concepts being taught. These technologies also allow for personalized learning, adapting content to the individual needs of each student and providing additional support where necessary. Moreover, digital technologies enhance collaboration and

communication between students and teachers (Coropceanu, 2017), facilitating group projects and the exchange of ideas.

The adoption of innovative teaching methods, such as project-based learning and the integration of applied modules, is essential for effectively preparing students for the challenges of the chemical industry. Project-based learning allows students to work on real projects (Frumusachi et al., 2020) that reflect problems and situations encountered in the chemical industry, providing them with the opportunity to develop essential skills such as critical thinking, collaboration, and project management. Integrating applied modules into the curriculum gives students the chance to directly experience the applicability of theoretical knowledge through practical exercises, labs, and case studies, thereby ensuring a stronger preparation for careers in industrial chemistry. Modernizing teaching methods by integrating digital technologies and adopting innovative methods has the potential to radically transform the educational process in industrial chemistry. According to 76% of the specialists in the chemical industry, the limitation of innovation and competitiveness in the industry can be traced back to outdated teaching approaches. Additionally, 82% emphasize that the increased difficulty of the labour market integration is a consequence of students' insufficient practical and up-to-date knowledge, which could be improved through more modernized educational methods (Table no. 2).

Modern teaching methods ensure that students develop the adaptability, innovation, and technological competence required in the constantly evolving chemical industry (Repida & Paiu, 2014). The urgent need to update teaching approaches in industrial chemistry cannot be ignored, making it essential to integrate digital technologies and adopt innovative strategies such as project-based learning and applied modules. These methods enhance practical skills and problem-solving abilities, ensuring that graduates are well-prepared to meet the challenges and demands of the modern industry.

3.3. Developing critical skills

The students' critical skills development, such as analytical thinking and problem-solving, has been identified as an essential aspect of the educational

process, especially in the context of industrial chemistry. These competencies are fundamental for both a deep understanding of theoretical concepts and the practical application of knowledge in various complex industrial situations. In a world where innovation and adaptability are vital, students must be able to systematically approach challenges and develop efficient and creative solutions.

Table no. 3. *Degree of integration of modern teaching methods*

Teaching method	Utilization rate (%)	No. of respondents	Impact on learning
Project-based learning	47%	14 out of 30	Develops critical thinking and collaboration
Applied modules	37%	11 out of 30	Increases applicability of knowledge
Industrial simulations	30%	9 out of 30	Familiarizes students with real scenarios
Use of digital technologies	27%	8 out of 30	Enhances access to interactive resources
Interdisciplinary practical exercises	33%	10 out of 30	Improves integration of theoretical knowledge

Table no. 3 shows that teaching methods like project-based learning (47% utilization) are highly valued for developing critical thinking and collaboration, key skills for problem-solving in industrial chemistry. Applied modules (37%) enhance the applicability of knowledge, while industrial simulations (30%) help students familiarize themselves with real-world scenarios. The use of digital technologies (27%) improves access to interactive resources, and interdisciplinary practical exercises (33%) aid in integrating theoretical knowledge. These methods are essential for building the analytical thinking and problem-solving skills needed in the chemical industry.

Analytical thinking is crucial in industrial chemistry as it involves the ability to break down complex problems into simpler elements, analyse data, and evaluate various options before making a decision. This skill allows students to successfully tackle chemical problems, interpret experimental results, and understand the interactions between different components of a chemical system. Additionally, analytical thinking is necessary for evaluating the efficiency of various processes and optimizing production in an industrial context.

Problem-solving is another critical skill that students need to develop during their educational journey. In industrial chemistry, this competency extends beyond applying standardized solutions to developing innovative approaches for new and unexpected problems. Students must be capable of applying chemical principles to address industrial challenges, such as improving process efficiency, reducing costs, and minimizing environmental impact. This approach enables them to contribute to technological advancement and increase competitiveness in the industry.

Integrating the development of these critical skills into the curriculum not only enhances the students' readiness for the labour market but also provides them with a broader perspective on the applicability of their knowledge in real-world contexts. Modern teaching methods, such as project-based learning and case studies, are crucial in developing these competencies by providing students with the opportunity to tackle real-world problems and apply theoretical knowledge in a practical and meaningful manner.

Thus, developing critical skills like analytical thinking and problem-solving should be a central component of educational reform in industrial chemistry. These competencies will not only prepare students for successful careers in industry and research but will also help form a generation of professionals capable of tackling technological challenges and innovating in their fields.

3.4. Education-industry collaboration

Collaboration between the educational sector and the chemical industry is an essential component for aligning the educational curriculum with the requirements and developments of the industrial environment, thereby ensuring the relevance and applicability of the skills acquired by students. In a global context marked by rapid technological changes and an increasingly dynamic labour market (Blaga, 2007), this collaboration becomes vital for developing graduates who are capable of addressing real-world challenges and actively contributing to industrial and scientific advancement.

One of the main contributions of collaboration between education and industry is the continuous adaptation of the school curriculum to reflect current

innovations and requirements in the chemical sector. In many cases, school curricula lag behind technological and scientific progress, which can lead to a gap between the theoretical knowledge taught in schools and the skills demanded by employers. By involving industry specialists directly in the development of educational programs, it ensures that students are trained following the latest discoveries and technologies (Gheţiu, 2020), thus increasing their chances of becoming competitive professionals in the labour market.

Table no. 4. *Need for developing critical skills*

Skill	Perceived importance (%)	No. of respondents	Career benefits
Analytical thinking	86%	43 out of 50	Increases ability to solve complex problems
Problem-solving	88%	44 out of 50	Essential for innovation and workplace efficiency
Adaptability to new technologies	84%	42 out of 50	Allows rapid integration into dynamic industries
Teamwork	80%	40 out of 50	Essential for interdisciplinary collaboration

Table no. 4 presents the opinions of 50 chemical industry specialists regarding the importance of key skills for future professionals in industrial chemistry. Problem-solving (88%) and analytical thinking (86%) are considered the most crucial, as they are essential for driving innovation, improving workplace efficiency, and addressing complex challenges in the industry. Adaptability to new technologies (84%) is also highly valued, enabling professionals to rapidly integrate into the fast-evolving chemical sector. Teamwork (80%) is seen as necessary for effective interdisciplinary collaboration, which is critical in the diverse and interconnected processes of the chemical industry. These skills directly align with the benefits of collaboration between academia and industry, where practical learning experiences such as internships, research projects, and industrial visits help students develop problem-solving, analytical, and collaborative abilities. This collaboration ensures that graduates are well-equipped to meet industry demands, while also fostering the innovation and technological advancements that the industry requires for growth and competitiveness.

In addition to updating the curriculum content, collaboration with industry enables the integration of applied learning methods that are crucial for a

thorough and practical understanding of theoretical concepts. Internships, research projects in partnership with companies, and visits to industrial facilities offer students the chance to apply their knowledge in real-world settings. These experiences enhance the students' technical skills and develop competencies such as problem-solving, critical thinking, and the ability to work effectively in teams (Şişcanu et al., 2016). Moreover, exposure to the industrial environment gives students a clearer perspective on the requirements and challenges they will face in their future careers, thereby increasing their motivation and interest in their studies.

From the industry's perspective, collaboration with the educational sector brings significant benefits. Companies involved in curriculum development and the practical training of students can directly influence the skills of the future workforce (Petrescu & Neguţ, 2016). This ensures that graduates are well-prepared to meet the specific needs of the sector, thus reducing the time and costs associated with further training of new employees. Additionally, this collaboration provides the industry with access to innovative ideas and potential solutions for technological and production challenges, derived from research conducted in the academic environment.

Another important aspect of education-industry collaboration is the facilitation of technology and knowledge transfer. Teaching laboratories developed in partnership with industrial companies (Stănilă, 2016), equipped with state-of-the-art technologies, allow students to experiment in an environment that accurately reproduces real working conditions in industry. This not only enhances the quality of their training but also provides them with a competitive advantage in the labour market, as they are already familiar with the equipment and processes specific to the modern chemical industry.

Collaboration between the educational sector and industry is a necessary element for ensuring relevant and applicable education in industrial chemistry. This synergy not only prepares students for the current and future demands of the labour market (Cheptanari, 2022) but also contributes to the ongoing development of the industrial sector by forming professionals capable of innovating and actively contributing to technological and scientific progress.

3.5. Recommendations for curriculum reform

To address the current needs of the chemical industry and prepare students for future job market requirements, curriculum reform in industrial chemistry at the high school level must integrate educational modules that reflect recent advances in science and technology. In this context, it is essential to introduce new modules and replace some existing ones to ensure the relevance and applicability of the knowledge imparted.

Table no. 5. *Benefits of collaboration between education and industry*

Benefit	Percentage (%)	No. of respondents	Implementation examples
Curriculum adaptation to market demands	80%	40 out of 50	Partnerships for curriculum development
Increased employment rate of graduates	78%	39 out of 50	Mandatory internships and apprenticeships
Integration of modern technologies in education	82%	41 out of 50	Use of virtual simulations and AI
Stimulation of innovation in industry	76%	38 out of 50	Joint projects between schools and companies
Increase in mentoring programs	68%	34 out of 50	Personalized support for students

Table no. 5 provides insights into the potential benefits of modernizing the industrial chemistry curriculum based on the opinions of specialists in the chemical industry. The majority of respondents (80%) agree that adapting the curriculum to meet market demands would be essential. Partnerships for curriculum development are highlighted as an example of how such adaptation could be achieved. Another significant benefit, supported by 78% of specialists, is the increased employment rate of graduates, with mandatory internships and apprenticeships seen as a key implementation strategy to better prepare students for the job market.

The integration of modern technologies in education is strongly endorsed by 82% of respondents, who suggest the use of virtual simulations and artificial intelligence to provide students with relevant, cutting-edge skills. Furthermore, 76% believe that stimulating innovation in the industry through joint projects between schools and companies would foster a more collaborative approach to education and industry. Finally, Table no. 5 highlights the importance of

mentoring programs, with 68% of respondents indicating that personalized support for students would play a crucial role in their success.

The Green Chemistry and Industrial Sustainability module should be introduced in the 11th grade, given that students already have a solid foundation in general chemistry and are beginning to familiarize themselves with the practical concepts of chemistry. Green chemistry and sustainability are crucial areas for the future of the chemical industry. By introducing this module early in the senior cycle, students can acquire fundamental competencies that will be useful throughout their education and careers. They will learn about chemical processes that minimize environmental impact, efficient resource use, and waste recycling (Timofei, 2023). This approach would encourage ecological thinking and prepare students for significant contributions to the development of a sustainable chemical industry.

The Digital Technologies in Chemistry module would be best introduced in the 12th grade, when students have an advanced understanding of chemical concepts and are ready to explore more sophisticated technological applications. This module would provide training in advanced technologies such as molecular modelling and chemical simulations (Cojocaru, 2008), which are essential for research and development in the chemical industry. It would also include applications of artificial intelligence for optimizing industrial processes. Such training will equip students with relevant skills for the scientific and industrial fields, giving them a competitive edge in the job market.

Introducing Virtual Laboratories and Industrial Simulations in the 11th grade would allow students to apply theoretical knowledge in simulated environments that mimic real working conditions. This module would partially replace traditional laboratories, providing opportunities to experiment with complex processes and hazardous substances in a safe environment. Virtual laboratories allow the exploration of scenarios (Coropceanu, 2019) difficult to replicate and develop essential practical skills in the chemical industry. This aspect will contribute to a better understanding and preparation of students for real work challenges in chemistry.

The Project Management and Innovation in Industry module should be introduced in the 12th grade. At this level, students are prepared to tackle

advanced concepts of management and innovation applicable in the industrial environment. Case studies and simulations of the chemical product development process (Robu, 2013) will provide students with practical insights into project coordination and application of innovations in industry. This module will develop essential skills for professional success in chemistry, including teamwork, time management, and solving complex problems.

The Manufacturing Control in the Chemical Industry module focuses on the technical and operational aspects of controlling manufacturing processes in the chemical industry. Although important, this module may be considered limited in the context of recent advancements and the current complexity of the chemical industry. Digital technologies and AI-based optimization solutions have revolutionized industrial process control (Grigore, 2024), offering more efficient and flexible methods for monitoring and adjusting manufacturing processes.

The Digital Technologies in Chemistry module would replace this module, providing students with access to modern and innovative techniques for optimizing industrial processes. By learning about molecular modelling, chemical simulations, and artificial intelligence (Andrei, 2015), students will gain relevant skills for controlling and improving manufacturing processes in ways directly applicable in the industry. This approach will not only bring students up to date with the latest technologies but also provide them with a broader perspective on how digitalization can transform the chemical industry.

The Petroleum and Petrochemical Manufacturing Control module focuses on specific techniques and process control in the oil and petrochemical sector. These areas are highly specialized and may have limited applicability in the context of a curriculum reform aiming at a broader spectrum of the chemical industry. Additionally, this module may not sufficiently reflect recent changes in sustainable chemistry and technological innovations applicable across multiple sectors.

Green Chemistry and Industrial Sustainability would be a more appropriate replacement for this module. This new module would address globally important aspects such as eco-friendly and sustainable practices in various sectors of the chemical industry, including oil and petrochemicals. By studying

green chemistry, students would learn about processes and technologies that contribute to reducing environmental impact (Gimiga, 2021) and more efficient resource use. This aspect would ensure that students are prepared not only for current requirements but also for the future of the industry, which is increasingly moving toward sustainable solutions.

The Separation and Purification Techniques Specific to the Chemical Industry module focuses on methods used in industrial contexts. While separation and purification techniques are essential, this module may be seen as too specialized and restrictive within the framework of a reform aimed at creating a more integrated curriculum that reflects recent advancements in chemistry. Additionally, many of these techniques could be better addressed in a broader context, one that explores their relevance to modern processes and technologies.

Virtual Laboratories and Industrial Simulations could replace this module, providing students with the opportunity to experiment and understand separation and purification processes in an innovative and practical way. Virtual laboratories allow exploration of complex techniques in a controlled and safe environment, and industrial simulations can replicate real working conditions and complex scenarios (Bojariu, 2015) that would be difficult to achieve in traditional laboratories. This integrated approach will provide students with a deeper and more applicable understanding of separation and purification techniques, preparing them for real industry challenges.

The Quality Control of Chemical Compounds module focuses on techniques and procedures for ensuring quality in chemical products. While this is essential in industry, the module may not sufficiently reflect the complexity and diversity of current challenges, as well as the need for additional skills in project management and innovation.

Project Management and Innovation in Industry would be a more comprehensive and relevant module for 11th-grade students. This module would include case studies and simulations that integrate quality control aspects within the context of product development (Marin, 2024) and implementation of new products.

3.6. Impact of the curriculum reform on student performance

The implementation of curriculum reform in industrial chemistry at the high school level is expected to have a significant impact on both academic performance and student interest in the field. This reform will go beyond merely updating educational content, introducing fundamental changes in teaching methods and learning structure to reflect recent advances in science and technology and current labour market requirements.

Table no. 6. *Impact of curriculum reform on student performance*

Aspect	Estimated impact (%)	No. of respondents	Anticipated effects
Increased academic performance	86%	43 out of 50	Higher grades and enhanced practical competencies
Increased interest in industrial chemistry	80%	40 out of 50	More students enrolling in related university programs
Development of practical and technical skills	88%	44 out of 50	Improved employability and professional efficiency
Increased access to industry internships	74%	37 out of 50	Better professional training before employment

Table no. 6 reflects the opinions of specialists from the chemical industry regarding the potential impacts of modernizing teaching methods in industrial chemistry. Most respondents believe that such reforms would lead to significant improvements in various areas. Eighty-six percent of the specialists anticipate that academic performance would improve, with higher grades and enhanced practical competencies among students. Additionally, 80% expect increased interest in industrial chemistry, resulting in more students enrolling in related university programs. The development of practical and technical skills is seen as a key benefit by 88% of the respondents, with a direct correlation to improved employability and professional efficiency. Furthermore, 74% of the specialists believe that modernization would lead to greater access to industry internships, providing students with better professional training before entering the workforce. These insights underline the importance of adapting educational approaches to meet the evolving demands of the industry.

A central aspect of the reform is the strengthening of both theoretical and applied knowledge. Introducing new modules, such as green chemistry and

industrial sustainability, will allow students to become familiar with ecological chemistry concepts and sustainable production methods, which are crucial in today's chemical industry context. These concepts not only reflect global environmental concerns (Garbuz et al., 2021) but also provide practical applications of chemical theory, contributing to a deeper and more contextualized understanding of the subject.

Additionally, incorporating a digital technologies module in chemistry will emphasize the use of modern modelling and simulation tools, such as molecular modelling software and computerized simulations. These advanced techniques allow students to explore and analyse complex chemical processes in ways that traditional methods cannot. Gaining experience with these tools will not only deepen theoretical understanding but also equip students with the practical skills needed for research and industrial development.

Virtual laboratories and industrial simulations represent another innovative element of the curriculum reform. These methods allow students to interact with chemical processes and industrial scenarios in a controlled virtual environment. Virtual laboratories provide a platform for exploring and experimenting with complex processes (Machidon, 2024) that would be difficult to replicate in traditional labs, such as large-scale reactions or handling hazardous substances. This approach not only improves safety and accessibility in learning but also allows for a more in-depth exploration of relevant industrial scenarios.

The project management and innovation module will add an essential dimension to the practical skill development of students. This module will introduce project management concepts, team coordination, and innovation through case studies and real-life simulations. Students will learn how to manage complex projects and implement innovative solutions, skills crucial for success in industrial and research careers (Machidon, 2024). This practical approach will contribute to developing a workforce well-prepared for the current and future challenges of the chemical industry.

Overall, the curriculum reform will enhance the students' academic performance by better integrating theory with practice, providing applicable and relevant knowledge for the chemical industry. Additionally, student interest

in chemistry will be stimulated through the application of modern and innovative concepts that reflect recent advancements in the field. This reform will not only prepare students for successful careers in chemistry but also contribute to developing essential skills aligned with current and future labour market demands. Through this approach, the curriculum reform will ensure a chemistry education that is both scientifically rigorous and practically relevant, preparing students for future challenges and opportunities.

3.7. Recommendations for implementing curriculum reform in industrial chemistry

The conclusions of the research highlight the need for a holistic and sustained implementation of curriculum reform in industrial chemistry, emphasizing the importance of a coordinated and long-term approach to ensure the success of this educational transformation. Recommendations for implementation are based on a detailed analysis of the current needs of the chemical field, the integration of new technologies and teaching methodologies (Afanas, 2020), and ensuring adequate preparation of human and material resources. The curriculum reform must be implemented through a coordinated approach involving all relevant stakeholders. This includes close collaboration between educational institutions, educational authorities, industry specialists, and researchers. Such collaboration is essential to ensure that the reforms align with the real needs of the labour market and with international standards in the field. Involvement from the industrial sector can provide valuable insights into necessary competencies and contribute to the development of educational modules that reflect the true challenges and opportunities in the industry.

Training and continuous professional development of teachers is another critical aspect of implementing the reform. Teachers need to be familiar with the new modules and teaching methodologies to effectively integrate the new content into their teaching. Continuous professional development should include workshops, refresher courses, and training sessions focused on the use of digital technologies and innovative learning methods (Rădulescu et al., 2023). This training process should be supported in the long term to ensure a gradual and effective adaptation to the curriculum changes.

The necessary educational resources and infrastructure for implementing the reform must also be adequately prepared. Introducing virtual laboratories and industrial simulations requires advanced technological equipment and access to specialized software. Additionally, educational resources need to be updated to reflect the new modules and methodologies. Investment in educational infrastructure and necessary technology is crucial for the success of the reform and for creating a suitable learning environment (Simion, 2024). Introducing a Green Chemistry module in the 11th grade is crucial for developing a foundational understanding of sustainable practices. Students would explore concepts such as carbon capture, efficient resource utilization, and eco-friendly chemical processes, aligning education with global environmental priorities (Garbuz et al., 2021). In the 12th grade, a Digital Technologies in Chemistry module would prepare students to use cutting-edge tools like molecular modelling software and artificial intelligence for process optimization, ensuring they are competitive in research and industry settings (Coropceanu, 2019). Outdated modules focusing on manufacturing control should be replaced with a Project Management and Innovation module, reflecting current industry dynamics. This module would enable students to engage with case studies and real-world scenarios, fostering critical thinking, teamwork, and innovation (Frumusachi et al., 2020). These changes address the pressing need to modernize the curriculum and align it with both local and global labour market demands.

Continuous monitoring and evaluation of the reform are crucial to ensure that the reforms are implemented effectively and achieve their proposed objectives. Mechanisms for evaluating progress need to be established, including feedback from students, teachers, and industry specialists (Roşca & Dasman, 2010). Continuous evaluation will allow for ongoing adjustments and improvements to the curriculum, ensuring it remains relevant and adapted to changes in the field.

Promoting an educational climate favourable to change is also important. Students and teachers should be encouraged to adopt and support the reforms through open communication and adequate support. Creating an educational environment that fosters innovation and continuous learning can facilitate adaptation to the new modules and methodologies and stimulate students' interest and engagement in chemistry.

Implementing the curriculum reform in industrial chemistry requires a strategic and coordinated approach that integrates all relevant aspects of education and industry. By ensuring effective collaboration, adequate teacher training, investment in educational resources, continuous monitoring, and creating a climate conducive to change, the curriculum reform can bring significant improvements to chemical education and prepare students for professional success in the field of industrial chemistry.

4. Conclusions

The analysis of the curriculum reform in industrial chemistry at high school level underscores the necessity for a significant transformation to meet the current and future demands of industry and research.

The findings indicate that more than three-quarters of teachers and industry specialists believe that teaching resources are outdated and not aligned with modern technological advancements. Additionally, most of the respondents pointed out the lack of access to modern laboratories, which limits students' hands-on experience. The study also revealed that 7 out of 10 teachers reported a decline in student interest in industrial chemistry due to outdated educational content, while 76% of the industry specialists stated that this has led to a lack of innovation and competitiveness in the sector. Furthermore, most of the respondents emphasized the increased difficulty graduates face in integrating into the labour market.

Regarding teaching methodologies, the research found that only 47% of the teachers currently use project-based learning, while 37% incorporate applied modules, and only 30% apply industrial simulations. This indicates a strong need for reform in teaching approaches to improve student engagement and learning outcomes. Employers also emphasize the importance of critical skills, with 86% valuing analytical thinking, 88% highlighting problem-solving, and 84% stressing adaptability to new technologies. However, the current curriculum does not effectively foster these competencies, necessitating targeted educational reforms.

The collaboration between education and industry is another critical aspect identified in the study. Most respondents highlighted the importance of aligning

the curriculum with industry needs, while more than three-quarters noted that enhanced collaboration would improve graduate employability. Increased mentoring programs and hands-on training opportunities were also recommended to bridge the skills gap. Additionally, the research indicates that curriculum reform could lead to improvement in academic performance and an increase in practical and technical skills among students. Moreover, more than three-quarters of the respondents believe that updating the curriculum would significantly boost student interest in industrial chemistry. To bridge these gaps, the research suggests incorporating new educational modules, such as green chemistry, industrial sustainability, digital technologies in chemistry, and project management and innovation in industry. These modules are essential for updating the curriculum and ensuring it aligns with the evolving demands of the industry. By incorporating these components, the curriculum will not only reflect recent scientific and technological advances but also prepare students for successful careers in industrial chemistry, developing essential skills such as critical thinking, problem-solving, and the use of modern technologies (Bocancea & Iordache, 2023).

In conclusion, implementing a holistic and sustained curriculum reform is necessary to ensure the relevance and effectiveness of industrial chemistry education. The recommendations emphasize the need for the close collaboration between education and industry, ongoing teacher training, and investments in educational infrastructure (Vivdici, 2014). Such a reform will contribute not only to improving the students' academic performance but also to stimulating interest in chemistry and preparing the youth for the challenges and opportunities of this dynamic field.

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