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CHEMICAL EDUCATION AS A FOUNDATION FOR DEVELOPING RESEARCH COMPETENCE IN MASTER'S STUDENTS OF PHARMACY

This article analyzes the role of core chemical disciplines (general and inorganic chemistry, analytical chemistry, physical and colloidal chemistry) as fundamental elements in developing research competence among master's students in pharmacy. Research competence is understood as a complex set of knowledge, skills, and abilities that include cognitive, procedural, and reflective components necessary for independent scientific research in the pharmaceutical field. Chemical education provides not only a deep understanding of molecular and physicochemical processes underlying pharmaceutical sciences but also fosters the development of methodological and practical skills essential for conducting precise, reliable, and reproducible experiments.

General and inorganic chemistry form the cognitive foundation by developing analytical thinking, the ability to formulate hypotheses, and interpret experimental observations. Analytical chemistry contributes to enhancing procedural accuracy, teaching students to assess measurement uncertainty, validate methods and comply with quality standards, which are critical in professional pharmaceutical practice. Physical and colloidal chemistry develops skills in modeling, systems thinking, and integrating theoretical models with experimental data, enabling students to effectively plan and analyze complex chemical processes.

Practice-oriented learning, including case studies, laboratory work and group discussions, stimulates the development of independence, critical thinking, teamwork skills, and promotes active knowledge acquisition through real-world application. Assessment encompasses both written reports and interactive sessions with active student participation, aimed at developing practical skills, understanding methodological aspects, and discussing potential problem situations.

Special attention is given to the role of the instructor as a learning process facilitator, who supports students' transition from acquiring theoretical knowledge to active research activity, provides motivation, mentorship and creates an atmosphere conducive to forming a research culture. Such an approach prepares future pharmacists capable of conducting independent scientific research and implementing results into professional practice.

Key words: research competence, chemical education, pharmaceutical education, practice-oriented approach, professional education.

Problem statement. The preparation of master's students in pharmacy requires a robust integration of theoretical knowledge, experimental skills and critical thinking capacities to meet the demands of modern pharmaceutical science. Research competence is the ability to design and conduct scientific investigations, interpret data and apply findings in professional practice. While pharmacy curricula traditionally include a wide range of biomedical, clinical, and social science disciplines, chemical education forms the epistemological and methodological foundation for research-oriented thinking [Murry, Hughes, Singh, Travlos, Engle]; [Roman].

Analysis of recent research and publications. Recent studies in science education emphasize that chemical disciplines not only provide knowledge of molecular structure, reaction mechanisms and analytical techniques but also cultivate procedural accuracy, statistical reasoning and problem-solving skills essential for experimental work [Hardy, Sdepanian, Stowell, Aljohani, Allen, Anwar, ... & Wright]; [Bain, Rodriguez, & Towns].

General and inorganic chemistry lays the groundwork for understanding chemical laws and molecular behavior [Fu, Wang, Xia, Li, & Zhang]; [Pazicni & Popova], while analytical chemistry strengthens precision, method validation, and data integrity in compliance with pharmaceutical quality standards [Pushkarova, Chkhalo, Reva, Zaitseva, & Bolotnikova]; [Pushkarova & Zaitseva]. Physical and colloidal chemistry equips students with the capacity to model complex systems, predict physicochemical properties and evaluate interactions critical for dosage form design and biopharmaceutical performance [Patel & Thareja].

The literature consistently highlights the crucial role of chemistry education in preparing pharmacy students for independent research activities. Winkelmann et al. demonstrated that integrating research-inspired laboratory modules into general chemistry courses significantly enhances students' inquiry skills, including hypothesis formulation, experimental design and data interpretation, while simultaneously boosting their research self-efficacy [Winkelmann, Baloga, Marcinkowski, Giannoulis, Anquandah, & Cohen]. Similarly, Agustian et al. emphasized the importance of authentic laboratory experiences within pharmaceutical sciences education, noting that faculty perceive hands-on engagement with analytical techniques as essential for developing students' practical competencies and readiness for professional research environments [Agustian, Pedersen, Finne, Jorgensen, Nielsen, & Gammelgaard].

Poloyac et al. identified core research competencies necessary in clinical pharmaceutical sciences, underscoring the need for training that integrates conceptual knowledge with methodological rigor and critical thinking, which aligns with fostering the cognitive, procedural and reflective components of research competence [Poloyac, Empey, Rohan, Skledar, Empey, Nolin,... & Kroboth].

Further supporting these findings, Jørgensen traced the longitudinal development of pharmaceutical students' laboratory skills, highlighting that repeated and structured laboratory experiences contribute to gradual improvement in both technical proficiency and reflective abilities, essential for autonomous research competence [Jørgensen].

Together, these studies provide compelling evidence that a well-structured, practice-oriented chemistry curriculum, incorporating both traditional and innovative teaching modalities, is fundamental to equipping future pharmacists with the comprehensive research skills necessary for scientific inquiry and professional practice.

Purpose of the article. The purpose of this study is to analyze the role of core chemical disciplines (general and inorganic chemistry, analytical chemistry, physical and colloidal chemistry) as foundational elements in developing research competence among future master's in pharmacy.

Main material

Chemistry as a foundation for developing research competence

Chemistry occupies a central role in the pharmaceutical education, providing not only essential scientific knowledge, but also serving as a dynamic foundation for cultivating research competence. Research competence is a multifaceted construct encompassing cognitive, procedural, and reflective components that enable future pharmacists to design and conduct rigorous scientific inquiries. The core chemical disciplines – general and inorganic chemistry, analytical chemistry, physical and colloidal chemistry – each contribute distinctively to these components by nurturing critical thinking, precise measurement, validation skills and the capacity to model and interpret complex phenomena. The following sections explain how targeted, practice-oriented learning activities within these disciplines collectively facilitate the development of comprehensive research competence in pharmacy students [Al-Thani, Saad, Siby, Bhadra, & Ahmad].

General and inorganic chemistry: building cognitive foundations

General and inorganic chemistry provide the essential cognitive framework that underpins students' analytical thinking and pattern recognition abilities – skills critical for formulating and testing scientific hypotheses. At the initial stages of pharmacy education, students engage with foundational concepts including periodic trends, electronic configurations, chemical bonding theories and elemental reactivity. These concepts create a robust conceptual scaffold that supports tackling progressively complex research problems. Empirical observations (colour changes, precipitate formation, reaction kinetics) helps students critically assess and refine their hypotheses. Through this iterative inquiry process, students strengthen logical reasoning and develop the ability to translate abstract theoretical principles into concrete, testable scientific questions – core cognitive elements of research competence.

Analytical chemistry: enhancing procedural and quantitative skills

Analytical chemistry sharpens students' procedural competence by emphasizing precision, measurement uncertainty evaluation, rigorous method validation and compliance with quality assurance protocols. These skills are crucial in pharmaceutical research, where adherence to strict regulatory standards ensures data reliability and patient safety. Mastery of these methodological principles equips students to perform accurate, reproducible analyses and fosters a disciplined approach to scientific investigation. Such competencies are indispensable for research competence within professional pharmaceutical settings.

Physical and colloidal chemistry: fostering modelling and systems thinking skills

Physical and colloidal chemistry engage students in developing modelling skills, abstract reasoning and systems thinking – competencies vital for addressing multifactorial and dynamic research problems. Key topics such as thermodynamic equilibrium, solubility, diffusion, adsorption, properties of high-molecular compounds and the behavior of colloidal solutions provide theoretical frameworks and practical tools to simulate, analyze and interpret complex chemical phenomena. This discipline encourages integrating multiple variables and considering chemical system interactions, cultivating a holistic understanding necessary for designing robust experiments and advancing research competence.

Integration of chemical disciplines in research competence development

Together, these disciplines illustrate how chemistry education forms a structured yet flexible environment that nurtures the cognitive, procedural and reflective dimensions of research competence. By incorporating case-based and practice-oriented learning, chemistry courses transform students from passive knowledge recipients into active scientific investigators, prepared to contribute meaningfully to pharmaceutical research.

Assessment strategies to support research competence development

Effective assessment is integral to fostering research competence by providing structured feedback and motivating active engagement with complex scientific problems. In pharmacy education, assessment strategies are tailored to reflect the specific demands of each chemical discipline while supporting integrated research skills development.

In general and inorganic chemistry, assessment focuses on students' abilities to formulate hypotheses grounded in chemical principles, design controlled experiments and critically analyze qualitative data such as colour changes or precipitate formation. Common formats include laboratory reports and class discussions that focus on evaluating reasoning, precision and clarity in describing chemical phenomena.

Analytical chemistry enhances students' procedural competence. This is paramount in pharmaceutical research, where compliance with stringent regulatory standards is essential to ensure the reliability and safety of experimental results. Practical tasks include case studies that simulate real-world analytical challenges, requiring students to apply quantitative analysis, interpret complex data sets, and develop solutions grounded in sound scientific reasoning. Mastery of these methodological principles equips students with the ability to conduct accurate and reproducible analyses, fostering a disciplined approach to scientific investigation that is critical for research competence in professional pharmaceutical contexts. Assessment includes comprehensive written reports and collaborative discussions aimed at developing students' practical skills, fostering critical reflection on methodological accuracy, emphasixing reproducibility as wells as the identification of potential sources of error.

Assessment in physical and colloidal chemistry focuses on applying systems thinking to complex chemical phenomena. Students collaborate in small groups to brainstorm and explore experimental strategies, analyze data collectively and discuss potential challenges. This collaborative process enhances critical thinking, problem-solving abilities and teamwork skills, preparing students for real-world scientific research environments.

Across all disciplines, cumulative assessments such as portfolios of research cases and mini-project defenses encourage knowledge synthesis, originality in hypothesis development, and critical self-reflection. Formative feedback supports iterative learning and metacognitive growth, facilitating internalization of research standards and fostering autonomy.

Role of the teacher as a research facilitator

The teacher's role extends beyond content delivery or laboratory supervision to that of a facilitator of inquiry and mentor guiding students through intellectual, methodological and affective aspects of research. Recognizing that research competence is constructed through active engagement, reflection and iterative experimentation, educators design open-ended, authentic tasks that encourage critical inquiry and problem-solving resilience.

Facilitation includes scaffolding research activities by providing strategic guidance at key stages – helping refine research questions, advising on controls and modeling data interpretation – while maintaining student intellectual responsibility. Teachers also emphasize ethical considerations such as data integrity and safety, supporting gradual internalization of research norms.

Creating a reflective learning environment is crucial and can be achieved through debrief sessions, maintaining research journals and conducting critical analyses of scientific literature. Finally, teachers foster a culture of inquiry by modeling curiosity, openness, and valuing both successes and failures as learning opportunities. This environment nurtures intellectual risk-taking and critical questioning, preparing future pharmacists to confidently and ethically participate in research-intensive pharmaceutical domains [Gautam & Agarwal]; [Schnellert, Sinclair, & Butler].

Conclusions. The analysis presented in this study highlights the essential role of core chemical disciplines (general and inorganic chemistry, analytical chemistry, physical and colloidal chemistry) as foundational pillars for developing research competence in future pharmacists. These disciplines provide not only the conceptual frameworks necessary to understand molecular and physicochemical principles underlying pharmaceutical sciences, but also the methodological and procedural skills required for authentic scientific inquiry. Approached through a practice-oriented perspective, chemistry education evolves beyond the mere accumulation of knowledge to become a dynamic environment for cultivating critical thinking, technical proficiency, and reflective abilities that define research-competent professionals.

Each chemical discipline contributes unique yet complementary elements to the overall development of research competence. General and inorganic chemistry strengthens students' abilities in analytical thinking and hypothesis generation; analytical chemistry emphasizes precision, methodological rigor and data integrity; while physical and colloidal chemistry fosters skills in modelling and integrating theoretical and empirical data.

Looking ahead, further research should focus on developing integrated chemistry-pharmacy courses that clearly aim to build research competence by combining laboratory work, data analysis, and literature review. Incorporating digital tools, such as virtual labs and collaborative platforms, could also expand opportunities for research-oriented learning, especially in blended or distance education settings.

In conclusion, chemistry education plays a crucial role in preparing future pharmacists with the necessary skills for scientific research. Through well-designed, practice-based learning and supportive teaching, students can gain both the knowledge and practical abilities required for pharmaceutical research and professional development.

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ХІМІЧНА ОСВІТА ЯК ОСНОВА ФОРМУВАННЯ ДОСЛІДНИЦЬКОЇ КОМПЕТЕНТНОСТІ МАЙБУТНІХ МАГІСТРІВ ФАРМАЦІЇ

У статті проаналізовано роль основних хімічних дисциплін (загальної та неорганічної хімії, аналітичної хімії, фізичної та колоїдної хімії) як фундаментальних елементів у формуванні дослідницької компетентності майбутніх магістрів фармації. Дослідницька компетентність розглядається як комплекс знань, умінь і навичок, що включають когнітивні, процедурні та рефлексивні компоненти, необхідні для самостійного проведення наукових досліджень у фармацевтичній сфері. Хімічна освіта забезпечує не лише глибоке розуміння молекулярних і фізико-хімічних процесів, що лежать в основі фармацевтичних наук, а й сприяє розвитку методологічних і практичних навичок, важливих для проведення точних, достовірних і відтворюваних дослідів.

Загальна та неорганічна хімія формує когнітивну основу, розвиваючи аналітичне мислення, здатність формувати гіпотези та інтерпретувати експериментальні спостереження. Аналітична хімія сприяє підвищенню процедурної точності, навчанню оцінювати невизначеність вимірювань, валідувати методи та дотримуватись стандартів якості, що є критично важливими в професійній фармацевтичній діяльності. Фізична та колоїдна хімія розвиває навички моделювання, системного мислення та інтеграції теоретичних моделей із експериментальними даними, що дозволяє здобувачам освіти ефективно планувати та аналізувати складні хімічні процеси.

Практико-орієнтоване навчання, зокрема кейс-методи, лабораторні роботи та групові дискусії, стимулюють формування самостійності, критичного мислення, навичок командної роботи і сприяють активному засвоєнню знань через застосування їх у реальних ситуаціях. Оцінювання охоплює як письмові звіти, так і інтерактивні сесії з активною участю здобувачів освіти, спрямовані на розвиток практичних умінь, осмислення методологічних аспектів та обговорення можливих проблемних ситуацій.

Особливу увагу приділено ролі викладача як фасилітатора навчального процесу, який підтримує здобувачів освіти у переході від засвоєння теоретичних знань до активної дослідницької діяльності, забезпечує мотивацію, наставництво і створення атмосфери, що сприяє формуванню дослідницької культури. Такий підхід сприяє підготовці майбутніх фармацевтів, здатних до самостійного проведення наукових досліджень та впровадження результатів у професійну практику.

Ключові слова: дослідницька компетентність, хімічна освіта, фармацевтична освіта, практико-орієнтований підхід, професійна освіта.

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