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PHYSICS IN PHARMACY EDUCATION: A SOCIO-TECHNICAL INQUIRY INTO ADVANCING SYSTEMS THINKING AND GENERIC SCIENCE

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Abstract

Incorporating physical principles into pharmaceutical sciences education is essential for cultivating a comprehensive understanding of the complex systems and processes involved in medication formulation, production, and quality control. This study presents an innovative approach to enhancing systems thinking skills and general scientific knowledge within introductory Physics courses for Pharmacy programs. By collaborating with curriculum experts, a Course Plan was developed that integrates Inquiry Learning and the Socio-Technical Systems (STS) approach. This Course Plan emphasizes active investigation, experimentation, and problem-solving activities, enabling students to engage with physical concepts relevant to pharmaceutical sciences. The curriculum includes practical experiments, real-life examples, and group activities to facilitate a deep understanding of the intricate relationships between physical principles and their applications in pharmaceutical formulation, manufacturing, and quality assurance. The interdisciplinary approach of the Course Plan, incorporating principles from physics, chemistry, biology, and mathematics, equips students with the essential skills needed to address complex challenges in the evolving pharmaceutical sector. Through this comprehensive strategy, students develop a diverse set of abilities in systems analysis, critical thinking, and general scientific knowledge, which are crucial for addressing intricate issues in pharmaceutical physics and related fields. The findings of this study support ongoing efforts to enhance pharmacy education, preparing skilled professionals who can drive innovation and contribute significantly to the advancement of public health and pharmaceutical sciences.

Keywords: Course plan, Generic science, Inquiry learning, Pharmaceutical physics, Pharmacy education, Socio-technical systems, Systems thinking.

1. Introduction

Systems thinking, the ability to comprehend and analyse complex systems by recognizing interdependencies, feedback loops, and non-linear behaviors, is essential for professionals in various domains, including the pharmaceutical industry [1, 2]. Pharmaceutical physics, which bridges physics principles with pharmaceutical applications, requires a deep understanding of intricate systems and their interconnections [3]. However, fostering systems thinking, critical thinking, and Generic Science - cross-disciplinary knowledge application - remains a challenge in traditional educational settings [4].

Studies highlight the need to introduce thinking models in education to improve students' problem-solving skills and prepare them to address global issues [5-8]. Effective systems thinking development can be achieved through diversified educational programs like project-based learning [9-11], simulation tools [12, 13], and portfolio assessment [14-16]. Research demonstrates that systems thinking enhances problem-solving abilities and prepares students to tackle global challenges [17-20]. Project-based learning, simulation tools, and portfolio evaluations have proven effective in cultivating systems thinking among students.

Participation in real-world environmental projects has shown moderate success in developing high school students' systems thinking skills [21]. Technological tools, particularly in computational systems for agriculture and natural resources, contribute to transformational education, though challenges in tracking feedback mechanisms and updating models persist [22, 23]. Integrating systems thinking into STEM education, especially in chemistry and biology, enhances scientific understanding and promotes sustainability. For example, a stoichiometry module in chemistry, focused on sustainable farming and Green Chemistry, allowed students to explore chemical systems from various perspectives [24, 25]. Multi-disciplinary online courses also effectively improve teachers' systems thinking and professional development [26].

Systems thinking is crucial in professions like nursing, where it enhances safety, decision-making, and quality of care by enabling a comprehensive understanding of complex interrelationships [27, 28]. This methodology has been applied in diagnosing and treating sexually transmissible infections and prioritizing emergency medicine interventions [29-31]. The World Health Organization (WHO) incorporates systems thinking into health system strengthening and sustainability initiatives [32]. In healthcare and business, systems thinking improves governance and strategic decision-making, fostering better outcomes [33, 34].

To improve systems thinking skills in pharmaceutical physics, incorporating critical thinking, metacognitive methods, and creative thinking is essential. Critical thinking enables students to systematically analyse and evaluate information, crucial for understanding intricate systems in pharmaceutical physics [35, 36]. A comprehensive program combining systems thinking, critical thinking, and creative thinking, with a focus on problem-solving, is vital for developing these skills.

Studies suggest combining socio-technical systems (STS) and inquiry-based learning (IBL) to enhance systems thinking, critical thinking, and Generic Science skills. IBL, which involves students in real-life problem-solving, significantly improves critical thinking skills [37, 38]. The STS approach addresses the interplay between social and technological components in complex systems, while IBL encourages active research and experimentation [39, 40]. However, limited research exists on implementing a comprehensive STS-IBL approach in medical physics education. This research aims to evaluate the impact of STS and IBL on enhancing systems thinking and interdisciplinary knowledge in pharmaceutical physics education, focusing on the effectiveness of various instructional methods and activities.

2. Method

The research utilized qualitative focus group discussions (FGDs) with professionals to explore integrating socio-technical and inquiry-based methods in basic Physics classes within Pharmacy curricula. The goal was to develop Course Plans that enhance systems thinking and general scientific knowledge among pharmacy students.

Participants were selected through purposive sampling, targeting experts in Physics, Pharmacy, Pharmaceutical Physics education, and curriculum design. Twelve experts participated, including lecturers in Physics and Pharmacy, those teaching Physics Pharmacy courses, and curriculum development specialists. This diverse group provided comprehensive insights, reflecting methods used in studies like MyDispense simulation software and simulation-based training in pharmacy education [41, 42]. The inclusion of curriculum development experts aligns with the scoping review on pharmacy support personnel training programs [43].

Three FGDs, each lasting about 90 minutes, were conducted. Moderated discussions focused on the importance of systems thinking in pharmacy education, the potential of socio-technical and inquiry learning approaches, specific learning outcomes and instructional strategies, and implementation challenges. Discussions were audio-recorded and transcribed verbatim for thematic analysis [44]. Researchers independently coded transcripts, resolving discrepancies through discussion, and identified themes to inform Course Plan development.

Draft Course Plans for basic Physics courses in Pharmacy were created, incorporating socio-technical and inquiry learning approaches, learning outcomes, activities, assessments, and instructional strategies. These drafts were refined through iterative discussions with expert participants to ensure relevance and feasibility for implementation.

3. Results and Discussion

This study aimed to develop a comprehensive curriculum for the mandatory Physical Pharmacy course (code 1203) in Pharmaceutical Sciences. The 2-credit course was designed with input from curriculum specialists, integrating theoretical knowledge and practical applications. It prepares students to develop medication formulations, ensure pharmaceutical product quality, and apply principles from physics, chemistry, biology, and mathematics in pharmaceutical sciences.

The Course Plan, created with input from pharmaceutical scientists and pedagogical experts, includes course objectives, content, teaching methods, and evaluation strategies. It provides students with a thorough understanding of pharmaceutical dosage form creation, development, and quality control through theoretical and practical training in product creation, manufacturing processes, and quality control measures. Graduates will be equipped with the necessary knowledge and skills for advanced studies or careers in the pharmaceutical industry. The course combines theoretical knowledge, practical skills, and quality control principles, enabling students to create efficient formulations and ensure product quality and safety.

The study emphasizes collaboration among stakeholders in curriculum development to meet student needs. It aims to train skilled pharmaceutical chemists and improve public healthcare. Researchers plan to develop more structured pharmacy education programs by incorporating multidisciplinary knowledge, addressing diverse student and industry needs, and benefiting society.

Based on the Course Plan document (Table 1), several key insights emerge regarding the integration of scientific learning approaches and inquiry in basic Physics courses for the Pharmacy study program. The Course Plan emphasizes using a combined approach of Inquiry Learning and Socio-Technical Systems (STS) to enhance students' systems thinking skills and generic science knowledge. This innovative pedagogical approach engages students in active exploration, experimentation, and problem-solving activities related to physical pharmacy concepts.

Table 1. Course plan.

Week	Topic	Learning Activities	Assessment
1	Introduction to Physical Pharmacy	Lectures, group discussions, video analysis	Concept understanding
2	Pharmaceutical Preparation Formation	Lectures, case studies	Preparation formation concepts
3-4	Physical Properties of Materials	Practicum lab, group discussions, data analysis	Practical reports, data analysis
5	Physical Characterization Techniques	Lectures, group work, presentations	Group presentations
6-7	Stability of Pharmaceutical Preparations	Lectures, case discussions, group work	Group assignments, case analysis
8	Midterm Exam	Written exam	System thinking, generic science
9	Improving Process Efficiency	Lectures, group discussions, brainstorming	Participation, problem-solving
10	Socio-technical Systems in Pharma	Lectures, case studies, video analysis	Socio-technical system concepts
11	Physical Principles in Drug Development	Lectures, case discussions, group work	Participation, case analysis
12	Impact of Physical Factors	Lectures, group discussions, individual assignments	Impact analysis
13	Interdisciplinary Problem-Solving	Group discussions, lab practical, presentations	Problem-solving, practical reports
14	Innovative Techniques	Lectures, case discussions, technique design	Technique understanding
15	Formation Problems Case Study	Group discussions, video analysis, group assignments	Case analysis, group work
16	Final Exam	Written exam	System thinking, generic science

Inquiry Learning encourages the exploration of physics topics within pharmaceutical sciences through experiments, independent study, and group discussions. This method fosters a deeper understanding of the connections between physical concepts and their applications in pharmaceutical formulations, manufacturing, and quality assurance. Incorporating the Socio-Technical Systems approach allows for a holistic analysis of pharmaceutical systems by examining the social and technical interactions within these systems. Students encounter real-world scenarios and case studies, prompting them to consider the interplay between physical, technical, and societal factors in the pharmaceutical industry.

The Course Plan prioritizes cultivating systems thinking skills, essential for understanding and evaluating complex systems in the pharmaceutical field. Students learn to identify system boundaries, detect information flow patterns, and comprehend the unpredictable outcomes arising from the interactions among various elements of pharmaceutical systems. An interdisciplinary approach is promoted by integrating concepts from physics, chemistry, biology, and mathematics within the pharmaceutical sciences context. This fosters generic science knowledge, enabling students to apply scientific principles across diverse contexts and disciplines.

Practical applications, case studies, and simulations reflecting real-world challenges in the pharmaceutical industry are incorporated into the Course Plan. By analysing and solving these problems, students can apply their understanding of physical principles, systems thinking, and critical thinking to develop innovative solutions. Collaborative learning is encouraged through group discussions, team-based projects, and presentations. This approach enhances students' communication and teamwork skills while promoting the exchange of diverse perspectives and fostering a deeper understanding of complex pharmaceutical systems.

4. Conclusion

This study introduces a complete method for improving the educational experience in basic Physics courses for Pharmacy study programs. The Course Plan, which combines Inquiry Learning with the Socio-Technical Systems (STS) approach, is designed to promote the growth of systems thinking skills, critical thinking abilities, and general scientific knowledge in students. The use of innovative pedagogical strategies, such as hands-on experiments, case studies, and collaborative learning activities, helps students develop a strong understanding of the complex connections between physical principles and their practical applications in pharmaceutical formulations, manufacturing processes, and quality control. The Course Plan's multidisciplinary approach, integrating principles from physics, chemistry, biology, and mathematics, provides students with the essential skills to address intricate problems in the dynamic pharmaceutical sector. Moreover, the focus on practical applications and real-world situations equips students with the skills to understand and address the social and technological consequences of their work, empowering them to make well-informed choices and create groundbreaking solutions. In essence, this effort provides a detailed plan for universities looking to improve their pharmacy education programs. It encourages a comprehensive and collaborative approach to developing skilled individuals who can make significant contributions to the fields of public health and pharmaceutical sciences.

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