Enhancing Basic Science Education in Pharmacy Through the Use of Forensic Case Studies

Dr. Helen Kim[1], Dr. Min-Jae Park[2]
[1]College of Pharmacy, Seoul National University, Seoul, South Korea
[2]Department of Clinical Pharmacy, Yonsei University, Seoul, South Korea

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Abstract

Between two-thirds and three-fourths of all pharmacy schools fail to teach forensic pharmacy, a profession where pharmacists support investigators. Therefore, a new educational activity was introduced to enhance the teaching of basic science to first-year pharmacy students. This summer program relied on episodes of Forensic Files to allow students to learn about the work of forensic pharmacists and gain more knowledge about pharmacology, toxicology, pharmacokinetics, and medicinal chemistry. I organized students into different groups to analyze the episodes they were assigned. I also had them provide reports about the incident and deliver presentations on the safety problems and how medications were part of the story. Most of the participants reported that their knowledge of basic sciences, team spirit, self-learning, and critical thinking were all better as a result of this activity. Employing real criminal cases matched Bloom's taxonomy to promote overall learning. The use of this approach can open doors to including forensic science in the curriculum of future pharmacists.

Keywords: ***Forensic pharmacy, pharmacy education, basic sciences, critical thinking, student engagement, pharmacology, toxicology, curricular innovation.***

1. Introduction

The growth in complexity of medical care has driven pharmacy education to change rapidly, along with the development of additional roles for pharmacists. Pharmacy courses worldwide are changing their teaching methods, moving away from just lectures and including new ways to learn. Both case-based learning and elective courses in specialized fields have shown great success in getting students more involved, challenging their thinking abilities, and applying what they learn. Offering students a chance to study forensic pharmacy helps them see how science can help real people, improving their cognitive skills and their career path(1).

The main science areas that are taught in most pharmacy programs include pharmacology, medicinal chemistry, biochemistry, and pharmacokinetics. This is why it is crucial to understand these subjects to know how drugs work, are safe, and can be used for treatment. For many students, these subjects are too distant from real medical practice, so they have a hard time staying interested and remembering the information. It is often challenging for drug education to connect details of chemistry and physics to their application in future careers and by healthcare providers. It has become clear to educators that teaching students using real-life experiences and cases can help them find science more relevant and easier to understand.

Forensic pharmacy serves as a link between pharmaceutical science and both legal and investigation fields. It combines the knowledge of pharmacists related to medicines, poisoning, and pharmacology with investigation tasks carried out in crime and forensics. With the help of forensic pharmacists, law enforcement agencies analyze and interpret evidence related to drugs, toxicology, drug abuse, overdose cases, poisoning, and medication errors connected to the law. Even though it is very useful and could help students learn science more in-depth, many pharmacy programs ignore or rarely focus on forensic pharmacy. Since this discipline is mostly taught as a postgraduate option, many people miss out on learning it until they are further along in their careers.

The use of forensic pharmacy in early pharmacy classes is helpful for two reasons: it shows students a creative and useful career choice and helps them re-learn the main ideas from science classes. Using forensic scenarios, students can investigate how different chemicals work in the human body, engage with study of poisons, and learn how drug introduction and excretion can be meaningful in forensics. In these cases, dealing with drug overdoses, negative side effects, and drug crimes, it is necessary to understand the science behind how drugs act in the body for accurate analysis and investigation(2).

In addition, forensic pharmacy requires people to master skills other than just content, including reasoning, critical thinking, working in a team, and communicating well. Pharmacists need these abilities since they are important for

any healthcare professional, and they are also in line with present-day education models that put a focus on the skills and knowledge needed by each learner. When they look at forensic cases, students are pushed to combine knowledge from different areas, review evidence thoroughly, and present their work logically, all of which prepares them for the wide-ranging duties they will have as professionals.

An additional important aspect of adding forensic pharmacy to pharmacy education is its impact on public health. Opioid use and other substance-related disorders have contributed to a growing number of deaths around the world due to drug overdose and toxicity. With their expertise in forensics, pharmacists can contribute greatly to preventing overdoses, tracking medication use, and aiding efforts in criminal investigations. Talking about these things in the early years of pharmacy education builds awareness of how medication is involved in social issues, which can guide them to help people and the community in a useful way.

Although there are many good reasons for teaching forensic pharmacy, there are still some barriers to do so. It is not always easy to come across real forensic cases in pharmacy that match student requirements. Moreover, it is important to fit these topics into existing schedules and make sure they work together with other important sciences. Multimedia tools and collaborative case studies are examples of innovative ways to solve problems in education. Using well-known TV series about forensic cases in combination with direct analysis and organized lessons can engage students and make them interested in forensic pharmacy(3).

As a result, this educational innovation gives first-year pharmacy students a hands-on experience in forensic pharmacy by using case scenarios. This way of teaching is in line with what the Accreditation Council for Pharmacy Education's 2025 standards call for regarding electives and courses that match a student's professional interests. In this activity, student groups look at drug and toxic compound cases from a forensic standpoint, write detailed scientific reports, and present using ideas from pharmacology, toxicology, and forensics.

By starting forensic pharmacy teaching in the first years of pharmacy school, this approach encourages students to learn more independently, develop their skills in science, get used to working with different fields, and gather professional experience. It encourages students to put what they have learned into use in real forensic settings, keeping their basic science knowledge fresh. It helps students learn how to communicate and handle teamwork, both important skills in healthcare and forensic careers.

Moreover, introducing students to forensic pharmacy helps to solve the current lack of insight into such careers and may spark interest in choosing them as areas to study or practice further. Because of this, there is now more involvement by science experts like pharmacists, which should improve the seriousness and outcome of forensic investigations.

Overall, using forensic pharmacy examples and cases in early pharmacy education can help students improve their foundational knowledge, use their minds critically, work well in a team, and better understand their future careers. Employing this new approach helps Improve learning in the course and also prepares students for roles in public health and justice in their future career. The coming sections detail how the forensic pharmacy activity was formatted and conducted, following its impact and how it could be adopted by other programs.

2. Innovative Curriculum Design: Immersing Pharmacy Students in Forensic Science Through Real-World Case Analysis

The quick progress in forensic science, mainly in molecular biology and analytical chemistry in recent years, has greatly changed how criminal investigations are carried out. Due to these new developments, the justice system is using strict and tested scientific methods more often than subjective expert opinions. It focuses on using proven science in courts, which helps make the outcomes more correct and just. Because these trends exist, pharmacy education can add forensic science to its teaching, helping students make connections with the law.

With this in mind, it was decided to develop a new learning activity for first-year pharmacy students that would introduce them to forensic pharmacy using a fun, team-learning approach. Using real forensic cases connected pharmaceutical sciences to real-world police work, helping students learn more than a simple lecture can provide. Using actual case studies leads learners to actively understand science by connecting it to practical problems in the real world.

The activity used the TV series Forensic Files, which depicts real cases of forensics, a lot of which discuss drug and medicine-related toxins(4). Every student team was instructed to study an episode related to forensic pharmacy,

where the solution of the crime depended on drug or substance science. By picking this resource, students were able to discover the science behind forensic pharmacy in a way that was interesting and not too difficult.

Students were allowed to take part only if they wanted to, since forensic cases can sometimes be hard for people to deal with. There were alternative assignments given to make sure all students could participate. Since the COVID-19 pandemic made it impossible to hold lectures in person, everything was switched to online learning quickly and the education was not affected.

Students were sorted into groups of five or six, so they could work together as teams, gaining valuable teamwork experience. Being organized in this type of group allowed individuals to talk with each other, improve their communication skills, and solve problems as a group, which are important in both pharmacy and forensics.

Lessons were set up so students would experience and understand many important aspects at different stages. Initially, teams were given access to view the Forensic Files episode they were tasked with, through curated YouTube links shared on the institution's learning management system. To further support students, additional resources explained forensic laboratory techniques and methods such as polymerase chain reaction (PCR) and enzyme-linked immunosorbent assays (ELISA).

Once the video had been reviewed, all teams were asked to prepare a report on key factors of the case. A MIX format was developed by borrowing best practices from other educational programs to make sure similarity is upheld among various groups(5). Students were asked to consider how the event affected the participants, pinpoint reasons for it, and come up with safety steps to avoid such cases from happening again. In addition, students analyzed the job of the forensic pharmacist, pointing out how their knowledge helps the investigation and leads to the resolution of a crime.

Looking into how the medicine or toxic substance leads to effects within the body and the major health problems it can cause played a vital role in our investigation. Because of this, students could see how medicinal chemistry and pharmacology knowledge are used in practical forensic situations.

The teams made PowerPoint presentations to improve their communication skills and make their findings more clear, and then delivered them. Through the use of video conferencing, professors and students could work together and discuss the topic, just as in traditional classes. Giving the presentations allowed students to practice speaking, handling information, and reasoning in a way that will be useful for their future careers as pharmacists.

Both the reports and the presentations were evaluated against a standard rubric that focused on accuracy, ways of thinking, clear understanding, cooperation, and manner of presentation. Thanks to this framework, students got objective inputs and useful feedback to help them get better.

The way this forensic pharmacy activity is set up suits the current principles in education that focus on activity, self-directed work, and observation. Doing this activity helps students practice using analysis, synthesis, and evaluation to gain a thorough understanding of information from various science fields.

Not only does the activity help students remember science facts, but it also brings them together to cooperate and present in front of others. The variety in this learning environment leads students to act independently, encouraging them to take charge of their studying and gain skills needed to improve in their careers.

It brings abstract ideas in science to life, helping students better understand those topics. By designing lessons around real forensic cases, students engage more actively and find the content to be more suitable for their needs and interests.

The curricular rundown makes students aware of forensic pharmacy as an option they may not discover in usual pharmacy training. By covering the different tasks pharmacists may perform in court, this activity helps students increase their knowledge and maybe consider specializing in related areas.

All in all, this module shows how teaching with real cases from different fields benefits both a student's learning and their essential skills. Because it can adjust to both different courses and students, it is especially helpful for pharmacy programs that want to upgrade their programs.

3. Evaluation and Reflection

Carrying out the forensic pharmacy curricular activity with students in their first year allowed us to find out more about their involvement, progress in learning, and skill-building. In April 2021, the initiative was carried out as

schools worked remotely because of the COVID-19 pandemic. However, the activity managed to fulfill its learning objectives and gained mostly positive reactions from the students involved.

The main way to measure the activity's success was through an anonymous survey for students that gathered opinions in several areas. This survey combined surveys with Likert scales and open-ended questions to get a thorough idea of both learners' experience and what they achieved.

Although half of the students took part in the survey, the report also noted that it was difficult to get everyone involved in remote and voluntary activities when everyone was facing extra stress. Still, the results from the data pointed to educational gains and set directions for future development of the program.

People's general response to the videos was very favorable. The episodes chosen to illustrate important aspects of forensic pharmacy and drug-related cases got positive feedback from most respondents. Around 68% of the students thought the videos provided great educational value and were engaging. In other words, using multimedia about real forensic investigations can attract students and help them learn the science behind it.

Out of those surveyed, most reported that the activity made key topics such as pharmacology and pharmacokinetics clearer to them. The way drugs work became more interesting to over 74% of respondents after publishing the articles, showing that the activity made these concepts clearer. Even so, not quite half of the students noticed improvements in medicinal chemistry, so more integration or added help in this area could help improve the situation(6).

As well as gaining knowledge, the activity helped build important work skills. The vast majority of students noted how important team communication was to finishing their project, demonstrating the benefits of learning together. Likewise, over three-quarters of the respondents agree that taking part in the activity made them better at presenting and critical thinking, highlighting how the activity helps learners in many ways.

Remarkably, the survey checked if the activity met Bloom's educational standards, which showed the mental skills exercised in the activity. Around 70-87% of students indicated that the exercise effectively supported comprehension, application, analysis, synthesis, and evaluation. In other words, with forensic pharmacy, students had to use critical thinking instead of just memorizing facts, which is what professional education hopes to achieve.

The open-ended responses provided detailed views into what it is like to be a student. Several participants liked learning about forensic pharmacy, as they found it an interesting job option that is not often mentioned in the field. It was mentioned by some that this activity let people relate what they were taught to real situations, helping to boost interest in the subject.

The students supplied valuable feedback on things to improve. Many suggested there should be more cases so that learners could choose from a wider range of topics and continue to stay interested. Others believed that adding more toxicology and pharmacokinetics content would help with understanding the details of the forensic cases. A couple of respondents recommended that delivering the activity in lower-stress times during the school year could be more effective for everyone.

The researchers point out that certain limitations exist when interpreting what was found. Since voluntary participation could attract more involved or content students, the responses could be biased in a positive or similar way. Due to the restrictions of the pandemic, remote learning might have reduced the amount of interkeyatiklistic and motivational interaction students have with one another. The wide range of problems and important medications involved in the cases might have altered each group's view and learning experience.

In spite of the issues, our findings prove that using forensic case-based learning is useful in teaching pharmacy. Through this activity, students gained a deeper understanding of how foundational science can help with forensic science. Teaming up required all team members to confer and interact, which are key skills for working in a pharmacy.

Furthermore, the project helped students become interested in forensic pharmacy and introduced them to a field that is constantly growing. Getting involved with these activities early prompts students to explore different pharmaceutical fields and to think about how their work affects the community(7).

To continue, using student feedback will be vital to improve the activity. Expanding what students practice, updating help materials, and making more sensible use of class time help everyone to learn and participate better. You can also add in formative assessments and peer review to help students grow and keep improving over time.

Ultimately, the activity teaches students to use interdisciplinary case-based learning, which is known to be innovative and effective in pharmacy learning. It helps students understand the basics of science, improves their

professional abilities, and widens their sense of the role of pharmacy in helping society. They make it clear why forensic pharmacy should be added and improved in educational programs around the globe.

4. Expanding Forensic Pharmacy Education to Enhance Pharmacy Practice and Student Development

Given the success of the forensic case-based learning activity, forensic pharmacy has a strong case to be incorporated more deeply into pharmacy schooling and the pharmacy field. With changes in pharmacy practices, taking on more clinical, research, public health, and specialized tasks is being seen as crucial for addressing the challenging needs of society. Because forensic pharmacy combines pharmaceutical sciences and law, it is seen as a strategic area that can boost courses in the field and widen the outlook for students' careers.

It is urgent to set up electives or designed tracks in Forensic Pharmacy as part of existing PharmD education programs. These could help you learn about forensic science, toxicology, the study of drug behavior in the body, and molecular biology as they relate to law enforcement. Here, for example, topics such as using DNA, methods that use chromatography, examining enzymes, and toxicokinetics could increase students' understanding of science and improve how they solve and investigate problems.

Accrediting groups, such as ACPE, have encouraged schools to ensure there are electives for students to follow unique interests within the field of pharmacy. Forensic pharmacy electives designed to meet these standards also answer the demand of students who want to gain valuable learning experiences. The courses can also benefit from experts in fields like forensics, toxicology, police, and law to work with students and open their minds to multiple areas of expertise.

UK pharmacy courses should try to include forensic pharmacy content in other lessons to improve both basic and applied skills. Having forensic cases in medicine, chemistry, and pharmacology lessons shows the real application of these subjects and improves how well they are understood and kept in mind(8). Additionally, having students participate in active learning, through activities like problem-based learning and case analysis, helps them pay attention and think more deeply.

In addition to education, promoting the development of faculty plays a key role in developing forensic pharmacy education further. Support should be given to professors who have an expertise or interest in forensic sciences to invent new curriculum materials, pick useful teaching methods, and lead student work in this area. Partnerships with forensic laboratories, legal organizations, and research centers can help faculty work together, learn new things, and improve their skills, all of which can help students learn better.

Forensic pharmacy education and awareness can help pharmacists play a bigger part in both public health and the justice system. Pharmacists who have learned about forensics can help with things like stopping overdoses happen, making sure medicines are safe, giving advice about poisonings, and explaining their findings in court hearings. Since the number of global drug overdoses goes up every year, these skills are extremely useful for both stopping harm and helping with investigations of drug-related offenses.

The field also provides opportunities for research and inventive work. People in this area can carry out research on testing methods, look for new ways to test drugs, or find out how drugs impact the bodies and actions of those involved in criminal cases. By promoting research, it helps future pharmacists think critically about issues and gather further information in forensic sciences.

To help institutions have an even bigger impact, they might think about offering special certificates or badges of certification that show students finished specific training in this area. Having such qualifications can help pharmacists find employment, learn new things, and play an important role in both forensic and interdisciplinary teams.

Use of technology in this field makes it accessible to a wider group and makes the learning process more engaging. Through virtual simulations, forensic databases, and interactive systems, students are able to work on analyzing and deciding cases in a secure, lifelike environment. With these new ways, students can learn in different ways and handle challenges in today's work world.

Working with groups that accredit forensic science, along with professional organizations, can raise the standard and recognition of forensic pharmacy education. By following the same standards across the world, physicians achieve

better consistency, and hospitals are able to offer high-quality care. At the same time, networks among the professional community help spread ideas and promote the specialty.

Overall, more attention to forensic pharmacy education helps further pharmacy's mission to assist society with science, patient care, and ethical service. With forensics integrated, pharmacy programs help students better understand issues related to medicines and law. Because of this integration, the pharmacist takes on both a medical role and one of assisting with group projects on medication misuse, poisoning, and responsibilities set by law.

Overall, the success of the forensic case-based learning activity emphasizes why forensic pharmacy should play a bigger part in pharmacy education. Through building new teaching materials, working with teachers more, teamwork between different healthcare groups, encouraging research, and using new tools, pharmacy programs can help prepare pharmacists who can handle the changing needs of healthcare and justice. As a result, students will learn more, have more job prospects, and the outcomes in both public health and the justice system will be better.

5. Critical Analysis

Adding forensic case-based learning to the first-year curriculum is an important advance in teaching that helps overcome several ongoing issues in pharmacy education. An in-depth analysis makes it clear that this approach brings positive results in some places, but could be improved in others. Designing, carrying out, and ending with an assessment of the activity highlighted the advantages and disadvantages of the activity, reflected by student learning, development of practical science skills, and interest.

One important advantage of forensic pharmacy is that it uses concrete scenarios to help explain hard scientific concepts. Students often find it hard to engage with subjects such as pharmacology, medicinal chemistry, and pharmacokinetics as they feel these are not directly linked to what happens in clinical care(9). Through working with cases about actual drug-related crimes, students could immediately apply the knowledge they had gained. As a result, learners understood the topic better and were also encouraged to study the actions of drugs, their toxic side effects, and the connection between drug movement in the body and adverse effects. Students reporting greater involvement in understanding drugs and pharmaceutical knowledge highlights the success of this method for joining theory and practice.

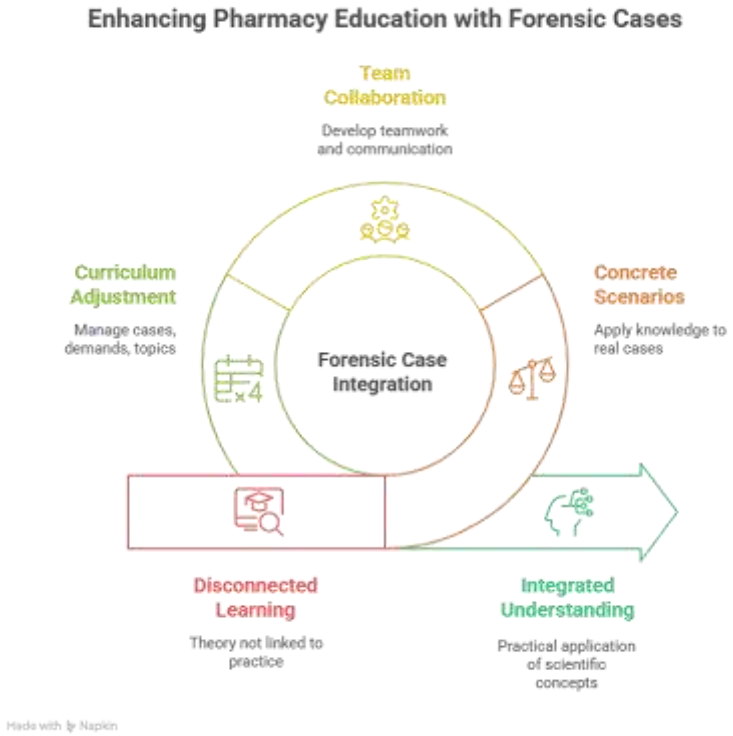

FIGURE 1 Enhancing Pharmacy Education with Forensic Cases

Besides, working together in teams developed skills needed for today's practice in pharmacy. Most students said they improved in teamwork and gained a sense of independence, thanks to collaboration and communication through e-learning. It matters since interprofessional teams in healthcare now put more emphasis on collaboration, so pharmacists are expected to deal with both clinical and legal details. Working on the assignment increased students' skills in both presenting information and critically analyzing topics, according to three-quarters of the group. It is very helpful for pharmacy students because it shows them how to think critically and make evidence-based decisions, important skills needed in every side of their field.

Applying Bloom's taxonomy helps improve the educational benefit of the activity. The students showed they were engaged with all forms of thinking, proving that the activity helped them to use higher-level mental skills. Since pharmacists in their line of work need to understand material and handle new challenges with their knowledge, comprehensive brain stimulation is necessary for professional education. The use of forensic cases made things easier by giving students the opportunity to analyze difficult cases, grab information from multiple disciplines, and assess how and what evidence is valid in a legal sense.

However, there were some obstacles and constraints that arose while the activity was being carried out. That just less than sixty percent of those eligible participated may suggest the possibility of selection and response biases. There is a chance that teachers had contact with extra motivated students more often, making it look like more students are engaged with the approach. Moreover, the need to do the activity remotely because of the pandemic restricted students from interacting and learning from each other. Though the online platform helped keep everything going, it could not provide the same depth of group collaboration and easy help from professors as in person.

Variety in the different cases made the task even more difficult. Each team was given thirteen episodes, and they differed from each other in terms of importance to pharmacy, difficulty, and how much they covered. The wide range of topics included in these studies probably made a difference for those studying them, as some were more beneficial for scientific learning or connecting to pharmacy work than others. Inconsistency might lessen students' motivation and impact their achievements, making it harder to understand the outcomes of whole survey findings. Moving forward, limiting student teams to a curated set of cases may help provide all students with fair learning opportunities.

The content on medicinal chemistry could be improved as well. Pharmacology and pharmacokinetics were highly supported by students, but medicinal chemistry was supported only by the majority. It appears that the way the activity is set up now not giving enough importance to the structure of molecules and how it affects both pharmacology and toxicology. Because medicinal chemistry is at the heart of studying drug effects and safety, giving more attention or tools to this topic could improve understanding.

Students also point out that when the lesson takes place matters a lot for engagement. Running the session while students are going through extra pressure from their schooling may have caused fewer to participate and pay attention. Scheduling tasks so that students are not overloaded during peak times could address the problem and help everyone work better. Expanding the types and topics of forensic cases as some students have stated would mean that the material would better match the interests of students and increase their motivation to learn more.

In spite of these difficulties, forensic pharmacy activity is a strong model for practical and team-based learning in pharmacy schools. It helps to bridge the gap between basic science learning and its use in practical work. Using cases in forensics helps students combine science with practical solutions, leading to both mentally and emotionally engaging lessons. Moreover, providing students with information about a pharmacy area that is lacking representation motivates them to consider various careers and meet national standards that encourage all kinds of learning.

It also supports the trend toward pharmacists playing a larger and more influential role in various public affairs. Because drug overdose and toxicity are important problems in society, pharmacists who understand forensic science can play a key role in stopping, seeking out, and shaping policies. These activities early in training give pharmacy students the ability to handle these problems effectively and responsibly once they are in practice.

All in all, the forensic case-based learning supports scientific concepts, teaches soft skills, and introduces students to real-world aspects of their field. It excels in activities designed for students to work together, learn on their own, and practice what they have learned. Nevertheless, the program should keep improving to manage different kinds of

cases, keep up with various demands in the curriculum, and strengthen certain scientific topics. As a result, forensic pharmacy education helps shape innovative, science-based, and conscious pharmacists who can respond to the developing needs in health care and law.

6.Conclusion and Future work

Learning from and applying actual forensic cases in pharmacy classes leads students to understand scientific concepts that are otherwise abstract and challenging. The model of forensic pharmacy work outlined here is a good example of current education practices that urge learners to participate, learn with others, and make their own educational choices.

The key to this technique is how it relates principles of pharmacology, toxicology, and medicinal chemistry to real-life crimes and cases, like drug overdoses and errors in taking drugs. With this connection in place, students are helped to focus both on theories and their applications in science. Moreover, working in a team through different cases allows participants to develop important professional skills, like working with others, speaking well, and learning by themselves, all of which are vital for pharmacists working under more complex healthcare rules. Using various forms of media and organized reports in class reminds students to talk about factual evidence and reflect on it, skills they can use in different fields even outside forensic pharmacy.

Furthermore, the forensic pharmacy coursework broadens students' professional options by guiding them to a specialty that most pharmacy students rarely study but is very important for society. As the numbers of opioid-related deaths keep going up worldwide, pharmacists trained in forensic toxicology and pharmacology are important for overdose prevention, checking medication safety, and legal investigations. Gaining an early knowledge of this field inspires students to choose different careers, and supports those who wish to further explore and learn about forensic pharmacy. It adds value to the pharma industry, and it also benefits public health and legal matters because it relies on scientific research.

Although the forensic pharmacy educational activity is strong, there is room for some improvement. The many variations in how different cases are built indicate that it is important to choose or modify cases to maintain a good level of learning across all teams of students. Adding more material on medicinal chemistry to the cases would help link chemistry, pharmacology, and toxicology more effectively. Logistics, such as working within the schedule and deciding on remote learning, are crucial in encouraging students to attend and participate during training.

With the growth of forensic pharmacy education, people can look forward to several interesting opportunities. Providing elective, track, or certificate courses in this area can provide students with clear plan to follow. The use of molecular biology, analytical chemistry, and biochemistry principles in forensic investigations will help make them more detailed and focused. It will be important for the faculty to work together with experts in forensic science, toxicology, and the law to improve the curriculum and teaching methods. Using technologies like virtual worlds and databases can make experiential learning more helpful for students and ready them to respond to current challenges in the forensic field.

All in all, forensic pharmacy plays an important role in society by giving pharmacy education new opportunities to develop and grow. By studying forensic cases, teachers can strengthen the basic subjects, teach important skills for professionals, and change students' ideas about the role of a pharmacist in the community. With this change, pharmacy students can expect to be prepared to meet current and future professional expectations while working ethically and collaboratively in health care and justice. If forensic pharmacy education continues to improve, it will help prepare graduates to face the wide range and challenges of modern pharmacy work..

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Conflicts of interest

The authors have no conflicts of interest to declare

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