INSTRUCTIONAL DESIGN AND ASSESSMENT

Using Remote Access to Scientific Instrumentation to Create Authentic Learning Activities in Pharmaceutical Analysis

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Objectives. To pilot test and evaluate a gas chromatography-mass spectrometry (GCMS) case study as a teaching and learning tool.
Design. A case study incorporating remote access to a GCMS instrument through the Integrated Laboratory Network (ILN) at Western Washington University was developed and implemented. Student surveys, faculty interviews, and examination score data were used to evaluate learning.
Assessment. While the case study did not impact final examination scores, approximately 70% of students and all faculty members felt the ILN-supported case study improved student learning about GCMS. Faculty members felt the "live" instrument access facilitated more authentic teaching. Students and faculty members felt the ILN should continue to be developed as a teaching tool.
Conclusion. Remote access to scientific instrumentation can be used to modify case studies to enhance student learning and teaching practice in pharmaceutical analysis.

Keywords: pharmaceutical analysis, case studies, Internet, laboratory, remote instrumentation, gas chromatography-mass spectrometry, Integrated Laboratory Network

INTRODUCTION

The Faculty of Pharmaceutical Sciences at the University of British Columbia offers a learning-centered lecture-laboratory course in pharmaceutical analysis in the third-professional year of the 4-year baccalaureate of science in pharmacy (BScPharm) program (4 credits; enrollment of approximately 140).[1] While this course currently introduces students to a range of pharmaceutical analysis techniques important to the hospital, community, and industrial pharmacy settings, the scope of learning activities in the course has been restricted by the limited availability of, access to, and funding for modern scientific instrumentation for undergraduate teaching purposes. One course theme in particular, gas chromatography-mass spectrometry (GCMS), includes an introductory lecture series on the topic but since a GCMS instrument is not available, does not include a corresponding laboratory exercise. Typically, students struggle with this section of the course. First-time exposure to this topic along with a lack of alternate learning activities to help students integrate GCMS theory and application exacerbates the issue. In other areas of the pharmaceutical analysis course, active-learning strategies such as case studies and "hands-on" laboratory exercises have become particularly important for student learning.[1] In order to incorporate these proven learning strategies into the GCMS component of the course, an international collaboration between Western Washington University,[2] the University of British Columbia's Office of Learning Technologies,[3] and the Faculty of Pharmaceutical Sciences was undertaken to explore the use of Western Washington University's Integrated Laboratory Network[4] as a mechanism for incorporating a GCMS-based case study into the pharmaceutical analysis course curriculum and to provide students with a remote "hands-on" experience in the operation of a GCMS instrument.

The Integrated Laboratory Network (ILN) is an innovative initiative to integrate scientific instrumentation and supporting instructional material into the classroom, laboratory, and research environments using Internet-based technologies. The ILN concept began as a campus-wide initiative to expand the use of scientific instrumentation in the undergraduate science curriculum at Western Washington University.[4] The ILN vision was to develop an electronic instructional laboratory that would: (1) renew excitement in undergraduate science education through authentic lecture and laboratory

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learning opportunities; (2) provide anytime/anyplace access to modern, state-of-the-art scientific instrumentation; (3) use a variety of affordable Internet-based tools to combine remote-control of scientific instrumentation, data collection, and analysis with video-conferencing; (4) provide supporting curricular materials including experimental protocols, searchable data repositories, self-directed learning modules and simulations, and instrument training manuals for students and faculty members; and (5) integrate fully with existing course management systems.[5] The goal of the ILN was to provide new opportunities for students to engage in "mindful" scientific activities at all levels of the curriculum.[6,7] The initial instrument purchases for the ILN were supported in part through Washington Western University's student technology fee program and major instrument manufacturers.[8] Currently, the ILN contains several high-use instruments equipped with automatic samplers which provide operation 24 hours per day and are connected to the Internet through the University's high-speed network.[4] Benchtop instruments such as gas and liquid chromatographs, mass spectrometers, atomic absorption spectrophotometers and a scanning electron microscope have been used successfully in lecture and laboratory environments across the undergraduate science curriculum at Western Washington University as well as in local high schools.

Although antecedents to the ILN for supporting pharmaceutical analysis instruction had not been reported in the pharmaceutical education literature, an emerging body of literature from a science education perspective[4-6,9-12] suggested that remote access to scientific instrumentation using Internet technologies had great potential for expanding learning opportunities in the Faculty of Pharmaceutical Sciences' pharmaceutical analysis course and for enhancing student learning about GCMS analysis. Using commonly available Internet-based tools for desktop sharing and two-way voice and video exchange, the ILN has allowed pharmacy students and instructors at the University of British Columbia to remotely access and operate the Western Washington University GCMS instrument in "real-time" during lectures. Real time access to the GCMS system provided new ways for faculty members to present the principles and theory of gas chromatography and mass spectrometry through in-class demonstrations and the development of a case study requiring the pharmaceutical analysis students to interpret data produced by the GCMS system. This type of exercise would have previously been impossible to conduct due to the lack of access to a GCMS system. This paper describes the design and assessment of a pilot project to implement an ILN-based in-class GCMS case study to teach students the principles of chromatography and mass spectrometry theory.

DESIGN

The Faculty of Pharmaceutical Sciences' pharmaceutical analysis course includes 4 hours of lecture and a 3-hour laboratory period each week, respectively, over the fall term of the academic year (September-December). The lecture component provides pharmaceutical analysis theory, while the laboratory aspect of the course provides an opportunity for students to apply theoretical concepts in a "hands-on" experimental context. Course themes include aspects of experimental design and data analysis, spectrophotometry, chromatography, and mass spectrometry. A detailed description of the course including the course design framework, the learning context, and the planning, instructional methods, and assessment strategies has been described previously.[1] Active learning, addressing different learning styles, and engaging students both individually and collaboratively in the learning process are key features of this course. Case studies and technology-based teaching methods are used throughout the course and are part of the course culture. In the context of the Faculty of Pharmaceutical Science' pharmaceutical analysis course, implementing a case study combined with Internet technologies would not be an "unexpected or foreign" type of learning activity for students enrolled in this course. However, the design of the GCMS case study and its integration into the course structure was particularly important, requiring sensitivity to the student's prior knowledge. The students enrolled in the pharmaceutical analysis course have a variety of backgrounds and abilities in the basic sciences, and the majority have not been exposed to pharmaceutical analysis, have limited understanding of science and research, and know little about chromatography and mass spectrometry. The Faculty of Pharmaceutical Sciences' pharmaceutical analysis course is taught concurrently with the third-year pharmacokinetics course.

The chromatography and mass spectrometry sections of the course were offered near the end of the term, just prior to the GCMS case study. The chromatography section provided a thorough introduction to the topic and included 8-10 hours of lectures covering the theory of chromatography. Table 1 provides the instructional learning objectives for the chromatography section of the pharmaceutical analysis course. Applications focused on thin layer, gas and liquid chromatography using a range of active-learning strategies to support student learning inside and outside the classroom.[1] The mass spectrometry section of the course focused specifically on GCMS analysis. A short lecture series (4-6 hours) was used to present

Table 1. Instructional Learning Objectives for the Chromatography Section of the Pharmaceutical Analysis Course

On completion of the chromatography section of the course pharmacy students will be able to: • define chromatography and related terms. • describe the basic principles and factors affecting separation in 4 common modes of chromatography. • develop an appropriate chromatographic system (stationary/mobile phase and detection method) for a particular separation problem involving drug mixtures. • evaluate and recommend changes to a chromatographic system to optimize the separation process.

the basic principles of GCMS and was supplemented by lecture notes available on the course web site. The lectures were predominantly didactic and no complementary laboratory activity was provided due to the unavailability of a GCMS instrument for teaching purposes. Table 2 provides the instructional learning objectives used to frame the knowledge and skills development for the mass spectrometry section of the course.

The in-class GCMS case study using the ILN was developed as an active-learning strategy and was implemented immediately following the chromatography and mass spectrometry lecture series. The global objectives of the GCMS case study were: (1) to examine the potential of the ILN as a teaching tool in the pharmaceutical analysis course, including the technology needed to support remote instrument access; (2) to use the ILN to support GCMS theory, instrumentation, and applications instruction, (3) to provide students with an opportunity to actively engage with chromatographic and mass spectral theory and data for qualitative and quantitative analyses, (4) to engage students in a learning opportunity exploring the value and relevance of GCMS analysis for the solution of pharmaceutical problems, and (5) to inject excitement into the chromatography and mass spectrometry sections of the course through a unique and innovative learning activity.

Table 2. Instructional Learning Objectives for the Mass Spectrometry Section of the Pharmaceutical Analysis Course

On completion of the mass spectrometry section of the course pharmacy students will be able to: • describe the general steps involved and the major sample ionization methods used in GCMS analysis. • recognize and apply the different types of data used in qualitative and quantitative GCMS analysis to solve pharmaceutical problems. • evaluate and assign mass-to-charge (m/z) ratios for drug molecules given fragmentation patterns. • design a GCMS assay for the identification and quantitation of a given drug for which basic physicochemical information are known

GCMS = gas chromatography-mass spectrometry

The ILN experience is facilitated through *NetMeeting*,[13] a free desktop sharing program within the Microsoft *Windows* operating system that supports audio and video exchange as well as synchronous chat. In a shared *NetMeeting* session, the computer controlling the scientific instrument acts as the host computer, with the remote computer acting as the guest. Direct connection between the guest and host computers is initiated through *NetMeeting* at the request of the guest by "calling" the internet protocol (IP) address of the host computer. Once connected, the guest computer "sees" the instrument software interface on the desktop of the host computer and can request full instrument control just as if it were connected directly to the instrument. In addition, the *NetMeeting* window, which remains open on both the guest and host computers during a shared session, facilitates the two-way audio and video exchange. Inexpensive web cameras and microphones allow the guest to see and hear the instrument and laboratory surroundings during an experiment and to communicate directly with the operator at the host end while the host can see, hear and interact simultaneously with session guests. The ILN has provided a unique opportunity for students to be exposed to and operate modern analytical instrumentation and engage in experiments that would not have been possible previously.

The GCMS case study, called "The Case of the Missing Drugs," is provided in Appendix 1. Table 3 provides the instructional learning objectives for the case study that were communicated to the students. Implemented in November 2003, the case study was completed during the last 2 lectures of the term (4 hours) immediately following the completion of the chromatography and mass spectrometry lecture sections of the pharmaceutical analysis course. Day 1 of the case study focused on the qualitative analysis aspects of the case while day 2 involved quantitative analyses including pharmacokinetics. A seating plan, based on existing laboratory group assignments, was created to maximize the available lecture hall space for group work and included 12 groups of 8-12 students each. A brief orientation to the case study along with the seating plan and an information package containing supporting data for day 1 (see Appendix 1) was provided to students 1 week prior to the activity to emphasize the session objectives and help students prepare. In addition, on day 1 each group was provided with flipchart paper, pens, and tape to record and post their in-class work in the lecture hall for peer review and discussion. A second information package, containing the quantitative and

Table 3. Instructional Learning Objectives for Days 1 and 2 of the GCMS Case Study

On completion of the GCMS case study pharmacy students will be able to: • predict and verify the elution order of the 6 drug standards based on physicochemical properties and mass spectral data. • apply qualitative chromatographic and MS analysis to establish if there is any evidence to suggest that neurosurgery team members have used or abused the surgery drugs. • assess quantitative concentration versus time GCMS data to determine drug concentration, how long a drug will persist in the body and estimate the original dose.

GCMS = gas chromatography-mass spectrometry

kinetic data for day 2, was distributed to students at the end of day 1. Three faculty members from University of British Columbia, and 1 faculty member and 1 technician from Western Washington University participated in the 2-day case study. A detailed description of this 2-day learning experience can be found at: www.pharmacy.ubc.ca/iln/index.html.

Action research methodology was used to examine the impact of the GCMS pilot project on student learning about chromatography and mass spectrometry and on student and faculty members' perceptions of the ILN as a teaching and learning tool. Action research enables instructors to reflect on and initiate positive changes to curriculum design and their teaching practice.[14] Providing a range of evidence is an authentic validation strategy for action research. For the purposes of this pilot study, qualitative and quantitative data were collected before, during, and after the completion of the case study from 4 sources. A 5-question survey instrument, distributed at the end of day 2 (Table 4) to assess student perceptions of: (1) how the addition of an mass spectrometry laboratory exercise to compliment the existing mass spectrometry lecture series would help their learning about mass spectrometry, (2) how the ILN-supported GCMS case study helped their learning about chromatography and mass spectrometry, (3) how the GCMS case study rated overall as a learning activity, (4) the extent to which the application of the ILN as a teaching tool would benefit the lecture and laboratory components of the course, and, (5) the continued development of the ILN as a teaching tool in the pharmaceutical analysis course. In addition to the questionnaire, interviews with participating faculty and log entries from the course instructor's reflective teaching journal were reviewed. Finally, a comparison was made between final examination scores on the mass spectrometry section of the pharmaceutical analysis course before and after the introduction of the GCMS case study. Qualitative data were analyzed using the constant comparative method[15] for common experiences, themes, and data discrepancies. Quantitative data were analyzed using frequency and percentage counts. Student data were collected with the assurance that all responses would be kept anonymous and confidential. For examination comparative purposes, the mean score and standard deviation on the mass spectrometry section of the 2000-2002 final course examinations (the years for which examinations were still available) were compared to those obtained for 2003, the year of implementation. Across all years, the mass spectrometry examination section had similar structure, comprised 25% of the examination total and included mass spectrometry analysis and fragmentation, and short answer, multiple-choice, and essay-style questions.

ASSESSMENT

Analysis of numeric and written student responses to survey question 1 (Table 4) indicated that 53% of students felt a mass spectrometry laboratory would "significantly" or "very significantly" help their learning about this technique. First time exposure to this topic was cited most often as the reason for their anxiety and lack of confidence in understanding mass spectrometry. For these students the mass spectrometry lectures alone did not provide enough support for their learning needs. The 47% of students responding in the "not at all," "somewhat," and "undecided" survey question 1 categories, felt that the mass spectrometry lectures along with the GCMS case study were sufficient to meet their learning needs. Many of these students indicated that the ILN activity would suffice as a substitute for a formal mass spectrometry laboratory exercise.

Student numeric responses to survey question 2 (Table 4) indicated that the GCMS case study helped their learning about chromatography and mass spectrometry at least "somewhat." Specifically, 73.5 % of respondents, derived from the "somewhat," "significantly," and "very significantly" response categories, felt that the exercise helped their learning about chromatography, and 67.6% of the students felt similarly regarding their learning about mass spectrometry. Approximately 30% of respondents found the GCMS case study "not at all" helpful to their learning about chromatography and mass spectrometry or were "undecided."

Analysis of the written responses from student survey question 2 (117/117:100% response rate) supported the numeric data analysis. The majority of student written comments (approximately 64%) indicated that the ILN helped their understanding of both chromatography and mass spectrometry. Typically, these students commented that the case study exercise helped them to clarify and

Table 4. Integrated Laboratory Network Pilot Project Student Survey Results (N = 117)*

Question	Not at All, %	Somewhat, %	Undecided, %	Significantly, %	Very Significantly, %
1. You have just recently completed a section on mass spectrometry in Pharmacy 325 but there is no lab exercise to compliment this series of lectures. To what extent would a mass spectrometry laboratory help your learning of this analytical technique?	7.8	19.6	19.6	41.9	11.1
2. Our last two lectures we have used the Integrated Laboratory Network (ILN) to apply GCMS to a pharmaceutical case. To what extent has this exercise helped with your learning about:					
a) chromatography?	13.7	36.8	12.8	29.9	6.8
b) mass spectrometry?	17.9	24.8	14.5	32.5	10.3
3. Overall how would you rate this learning activity (using the ILN to apply GCMS to pharmaceutical cases)?†	11.1	12.0	35.0	34.2	7.7
4. The ILN is an application of technology that allows students access to scientific instrumentation that they might not otherwise have access to (in this case a GCMS system). To what extent would the use of the ILN as a teaching tool benefit:					
a) the lecture component of this course?	22.2	27.4	15.4	29.9	5.1
b) the laboratory component of this course? Please comment on lecture and lab applications of the ILN.	18.8	18.8	23.1	33.3	6.0
5. Would you recommend that the ILN continue to be developed as a teaching tool in this course?‡	13.7	12.8	27.4	35.0	11.1

GCMS = gas chromatography-mass spectrometry; ILN = Integrated Laboratory Network
*Response rate: 85% (117/137 students)
†Response scale: 1 = very poor; 2 = poor; 3 = fair; 4 = good; 5 = very good
‡Response scale: 1 = strongly disagree; 2 = disagree; 3 = undecided 4 = agree; 5 = strongly agree

reinforce course concepts, showed the relevance of the course material, integrated well with their concurrent pharmacokinetics course, and allowed them to access and operate an instrument that they would otherwise not have access to. Clearly, working with the chromatographic and mass spectral data helped students develop a greater understanding of how and why experimental data and theoretical calculations are used to solve pharmaceutical problems. Seeing the ''live'' operation of the GCMS instrument through the ILN was particularly helpful. These students also found the activity fun, interesting, and interactive, and appreciated the participation of the faculty teaching team.

Approximately 36% of students commented that the GCMS case study exercise did not help their learning. Many of these students were uncomfortable with the active-learning aspect of the case, preferring to use the lecture time for review purposes. Overall, as shown by the responses to survey question 3 (Table 4), more than 76% of student respondents rated the GCMS case study activity as ''fair'' with approximately 42% of students rating the activity as ''good'' or ''very good.'' Approximately 23% of students rated the activity as ''poor'' or ''very poor.''

Approximately 60% of students responding ''somewhat, ''significantly,'' and ''very significantly'' to survey question 4 felt the use of the ILN as a teaching tool would benefit both the lecture and laboratory components of the course. In addition to providing access to scientific instruments not currently available in the pharmaceutical analysis course, student comments provided specific additional suggestions for using the ILN to support their learning needs. During lectures, students felt the ILN could be used to reinforce and review course theory and applications, demonstrate the operation of the instrument, and provide additional opportunities to generate and work with real data. In the laboratory, students suggested the ILN could be used to create new and relevant laboratory exercises using GCMS, and if possible, nuclear magnetic resonance analysis. In contrast, approximately 40% of students responding "not at all" or "undecided" to survey question 4 (Table 4) felt a strong sense of disconnection from the Network. Typically these students commented that the audio/video quality provided through *NetMeeting*, and the complicated instrument software detracted from their experience, while others felt the case study alone, without the ILN component, would have been sufficient.

As shown by the responses to survey question 5 (Table 4), 46.1% of students "agreed" or "strongly agreed" that the ILN should continue to be developed as a teaching tool in the course. In contrast, 26.5% of students "disagreed" or "strongly disagreed" with continued development and 27.4% of students were "undecided." Analysis of written comments for survey question 5 provided themes similar to those identified by students in survey question 4.

Interviews with faculty members indicated that the GCMS case study and the use of the ILN as a teaching tool positively impacted the chromatography and mass spectrometry section of the course. Interestingly, University of British Columbia faculty members previously had very limited experience with this type of active-learning strategy and very much enjoyed the experience. The team teaching approach to the case study, their multiple teaching roles, and the level of classroom interactivity helped them feel more involved in the teaching and learning process. In addition, they stated that the use of the ILN to access the GCMS instrument in "real time" allowed them to "teach the entire process" and provide students with more comprehensive and realistic instruction. Although participating faculty members stated that the case study could be implemented without the ILN component, supporting the student comments from survey questions 4 and 5, the live access to instrumentation feature made the case more authentic and an integral aspect of the learning activity. The course instructor felt the ILN-supported GCMS case study rejuvenated the chromatography and mass spectrometry sections of the pharmaceutical analysis course. All faculty participants felt the ILN should continue to be developed as a teaching tool.

Anecdotal evidence from interviews with participating faculty members also indicated the GCMS case study positively impacted student learning about chromatography and mass spectrometry. In particular, during the in-class activity, University of British Columbia faculty members noted a marked increase in the number and quality of questions posed by students as well as an enhanced ability of students to engage with and discuss key course concepts compared to previous years. Of specific importance was the ability of students to articulate the importance of GCMS in the solution of pharmaceutical problems, the connection between pharmaceutical analysis and concurrent pharmacokinetics course material, and the relevance of these topics to their training as pharmacists. During office hours and the final examination review sessions that followed the completion of the case study, faculty members noticed similar improvements in student abilities as well as decreased anxiety. In general, University of British Columbia faculty members felt students appeared more confident about their understanding of chromatography and mass spectrometry.

While instrument software access and two-way voice and video exchange were readily supported through *NetMeeting*, suggestions for improvement included the use of better quality microphones and web cameras to improve the video-conferencing experience and introducing the case study earlier in the course to improve familiarity and comfort with the technology, the instrument software, and the remote classroom experience.

In the 3 years prior to the introduction of the GCMS case study (2000-2002; $n = 369$), the mean score on the GCMS section of the final pharmaceutical analysis course examination was 78.8% ($SD = 15.5$). No change was seen in the mean final examination score in 2003 ($n = 136$) following the implementation of the case study (78.5%; $SD = 13.4$).

DISCUSSION

The scope of learning activities in the Faculty of Pharmacy's pharmaceutical analysis course has been restricted by limited availability of, access to, and funding for modern scientific instrumentation for undergraduate teaching purposes. Western Washington University's Integrated Laboratory Network is an innovative application of Internet technologies to provide anytime/anyplace access to scientific instrumentation, instructional materials, and expertise. This paper describes a GCMS case-study pilot project that incorporated "live" access to a GCMS instrument through the ILN to enhance student learning about chromatography and mass spectrometry. The global objectives of this pilot project were successfully completed, positively impacting student learning and teaching practice. While the case study did not impact final examination scores, a majority of students and all participating faculty members felt the activity improved student learning about chromatography and mass spectrometry. Faculty members enjoyed participating in the case study and felt their involvement helped them as educators. The ILN-supported case study rejuvenated the chromatography and mass spectrometry sections of the pharmaceutical analysis course. Particularly exciting was the potential of the Network for overcoming the inherent challenges facing the pharmaceutical analysis course and creating robust learning opportunities that combined both practical and theoretical aspects of pharmaceutical analysis instruction. In addition, the high level of interaction and energy evident in the classroom during the case study activity reinforced the importance of the case study as a valuable teaching tool for engaging faculty members and students in the learning process and creating a positive environment for learning to take place. These observations were corroborated by the course instructor and participating Western Washington University faculty members, and supported previous experiences at that University.[4] These observations validated previously published findings in the pharmaceutical analysis course[1] as well as in other pharmacy[16-17] and higher-education settings.[18] While the Internet connection through *NetMeeting* was robust, improvements to the videoconferencing and remote classroom experience are suggested. Further research beyond this pilot project is required to establish the impact of the case study on grades and the retention of student learning about chromatography and mass spectrometry.

CONCLUSIONS

This paper describes a pilot project that combined "live" access to scientific instrumentation, through the Western Washington Integrated Laboratory Network, with a GCMS case study to enhance student learning and teaching practice about chromatography and mass spectrometry. While the case study did not impact final examination scores, approximately 70% of students and all faculty members felt the ILN-supported GCMS case study improved student learning. Faculty felt the ILN facilitated more authentic teaching and both students and faculty felt the ILN should continue to be developed as a teaching tool. The pilot project has provided a clear example of how case studies in pharmaceutical analysis can incorporate remote access to advanced scientific instrumentation to overcome obstacles to learning and revamp the way in which the basic pharmaceutical sciences can be taught.

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Appendix 1. The case study provided to students 1 week prior to the activity.

"The Case of the Missing Drugs"

The administration at one of the larger Vancouver area hospitals has recently been faced with a very sensitive situation. Someone on the neurosurgery team is suspected of "borrowing" surgery drugs. The administration has no proof at this point other than audits of the drugs used by the team during surgery always seem to be short. The neurosurgery team is an elite group of doctors and nurses that handle only the toughest cases. They are called in at all hours of the day or night and are always under tremendous pressure in dealing with life and death surgeries. The administration decides to take action. Failure to account for the missing drugs could jeopardize the hospital's accreditation and reputation but more importantly, if one of the neurosurgery team members has a drug problem, then efforts must be made to identify the individual or individuals and provide the necessary treatment. The administration meets with the neurosurgery team and following intense discussions, the team agrees unanimously to random drug testing. Urine and blood samples are worked-up in the hospital clinical chemistry lab using a standard sample preparation protocol followed by gas chromatography/mass spectrometry (GCMS) analysis. You have been asked to consult on the case.

The hospital has provided you with the following data for your analysis:

- Chromatogram of drug standards
- Chromatograms for each of the surgical team members
- Chromatographic conditions (column length, stationary phase, mobile phase, temperature programming) and the sample preparation protocol for urine and blood samples
- Structures of the standard drug
- Mass spectra for the standard drugs
- Baseline-expanded chromatographic data and formulas sheet for the calculation of chromatographic parameters

Day 1: Qualitative Analysis

Is there evidence to suggest that any of the neurosurgery team has used or abused any of the surgery drugs?

Day 2: Quantitative Analysis

If so, how much drug is in their system? How long does it persist? What was the original dose?