Themis: Research Journal of Justice Studies and Forensic Science

Volume 5 Article 8

5-11-2017

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Higher education online science courses generally lack the hands-on components essential in understanding theories, methods, and techniques in chemistry and biology. Companies like eScience Labs construct kits to facilitate online learning, which provide students with hands-on activities relevant to their science courses. In order to evaluate ease, efficacy, and comprehension of the forensic science kits by eScience Labs was completed while writing observations of the activities during and after completion; the lab manual learning objectives were compared to results of activities and two stopwatches took elapsed time of each activity to compare with the stated times in the kit manual. This method determined that the eScience manual does not provide enough information for a college freshman to fully understand the topic; however, combining these labs with professor provided online lectures would allow full comprehension of the forensic science applications or techniques. Recommendations to obtain maximum learning outcomes include requiring the completion of prerequisites like algebra and general chemistry. With these aspects combined, the eScience lab kit is a great addition to an introductory forensic science course as it provides safe and interactive hands-on activities.

Keywords
online education, hands-on learning, online course, forensic science kits

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Introduction

Higher education facilities are offering students more online courses for many reasons (Allen & Seaman, 2014). One of these reasons includes cost benefits, such as electronic documents that save ink and paper (Chandler, Park, Levin, & Morse, 2013). Another is the traveling convenience of online courses that save students a commute to campus or allow professors and/or students to log into the class during a convenient time (EScience Labs, LLC, 2014). The increase in technology access allows for more course offerings and better applications to maximize the idea of "distance learning" (Sahin, 2006). Studies have shown that hands-on activities allow optimal learning for students and the increase in technology has influenced the development of computer-simulated activities for lab-based online courses.

Companies like eScience Labs build kits designed to facilitate many science-based experiments for online courses (Carolina, 2016; eScience Labs LLC, 2014; Flinn Scientific Inc, 2016; Home Science Tools, 2016). The kits are bought and either delivered to the professor or school to distribute among students or delivered directly to the students. Students may complete these lab exercises at home when their schedule permits, although course requirements vary among institutions, such as specific check-in times for an online class at one university versus only assignment deadlines for another university. eScience Labs specifically states that the goal of creating the kits is to provide academically rigorous lab experiences to online learning students, helping them pursue their degree if they cannot make it to campus (2014). A review of eScience Labs kits meant for middle school to college students states that the kits "[strive] to make science relevant to [the] student" (HomeSchool Reviews.com, 2008).

The efficacy of the 13 home lab exercises from eScience Labs forensic kit was evaluated for use in an online forensic science course. The forensic science kit included topics in material, biological, and chemical evidence. The kit provided a safety guide with safety equipment, an exercise manual, online tutorials, and necessary tools to conduct the experiments. The hypothesis is that the eScience Labs kit will efficiently, effectively, and safely teach students many basic forensic science techniques without the presence of an instructor or supervisor. After completion of the experiments, students will understand forensic science applications, such as interpreting pattern evidence, fingerprint patterns, and firearm analysis. Overall, the kit should greatly complement an online introductory forensic science course.

Literature Review

Online natural science courses need a laboratory component to fully provide the learning experience of the subject (Oliver & Haim, 2009). Vogt, Cook, and Muise (2013) conducted a study to determine if a newly designed sequence of astronomy laboratory projects effectively taught students scientific exploration and how to scientifically find solutions. Four of the projects were hands-on activities designed for students to complete with common household items and the remaining four were computer-based projects. The projects also included manuals, instructor guides, video tutorials, template laboratory reports, and additional resources specific to each project. Each project also described the course learning objectives students should achieve after completing the labs. For comparison purposes Vogt, Cook, and Muise used the projects for an on-campus course one semester and an online course the second semester. Overall, despite higher withdrawal rates in the online course compared to the on-campus course, students in the online course learned just as much, sometimes more, than on-campus students using the laboratory projects. The study also showed that knowing math beyond algebra helped students succeed in the class (Vogt, Cook, & Muise, 2013). This may suggest that students completing the eScience Labs forensic kit may have an increased likelihood of successful course completion with prior forensic knowledge.

Oliver and Haim (2009) conducted a seven-year study on teaching methodologies of an introductory digital design course. For the first three years, students were taught using traditional, on-campus methods; the remaining four years were taught using home laboratories. At the beginning of the semester, professors provided the home laboratories to each group of three students. After completion of the semester, students evaluated the laboratories. Overall, the average grades for each class were better for the home laboratory courses than for traditional courses. There were also positive opinions from students of the home lab method, with approval ranging from about 77% to 100% each year. Oliver and Haim stated that using the home labs prevents scheduling constraints while still providing similar real-world challenges through the labs (Oliver & Haim, 2009).

Heise (2006), a former computer architecture professor from Columbia College, compared utilization of computer simulations with hands-on activities for a computer architecture course. Heise agreed that in order to teach about computer hardware, a course must include a strong laboratory component. Heise taught the course multiple times with either computer simulations or physical laboratories. His findings showed the physical laboratories enhanced the learning of students more than the computer simulations. In the courses involving physical laboratories, students' test scores improved and their interest in the subject increased. The students in the computer simulation courses often submitted incomplete projects while the majority of students in the physical laboratory courses strived to complete each lab. Higher interest in building a simpler processor helped students retain information better rather than clicking on a simulated processor until the correct areas were chosen (Heise, 2006).

Other scholars suggest combining both hands-on laboratories and computer simulations to optimize a student's learning experience. Chandler, Park, Levin, and Morse (2013) suggest that a single form of learning is not enough and combining hands-on activities with online learning would be the most effective learning method. The hands-on portion of this method varied between physical projects and face-to-face interactions with teachers, classmates, or colleagues. Chandler and colleagues assessed follow-up evaluations of the course and pre-test and post-test scores of the online segment of the course and found that blending the two modes of learning was significantly more effective in learning application skills (2013).

Ma and Nickerson (2006) reviewed the importance of laboratory work and hands-on experiments in science education. The study addressed questions on the effectiveness of different laboratory techniques and the beneficial areas for future scientific research. The researchers reviewed 60 articles focused on three laboratory types from a journal based on education: real, simulated, and remote (conducting a real experiment via the internet). They did not know the reasons for an existing debate on laboratory technology, but they stated that it might be the differing support for multiple teaching methods or students' preference in learning methods. Their study observed that students learn from both equipment and interactions with peers and/or teachers (2016).

Other scholars have studied the benefits of computer simulations such as Sahin (2006), who reviewed research on implementing computer simulations in science-based courses. The main argument for implementing the computer-simulations was that they allow students to conduct labs that were too expensive, time consuming, or dangerous to conduct in real life. Sahin stated that one method of computer simulation methodology was having students participate in the simulation and then complete a quiz to reinforce the information. The study concluded that simulations were better than hands-on labs: the opposite of Heise's previously mentioned findings. Despite this conclusion, reports reviewed by Sahin (2016) state that computer simulations lacked clear evidence to support changing students' attitudes towards the subject. Although the computer simulations replaced expensive and dangerous laboratories, little research indicates that students learn better with the simulations (Sahin, 2016).

Many online laboratory kits are sold for use in classrooms or at home. The eScience Labs kits for forensic science costs about $198 each for 13 labs that cover different topics within forensics. These kits were designed specifically for introductory college courses. Flint Scientific, Inc. and Home Science Tools sell individual kits in sets for whole classrooms, but mostly for high school and middle school courses. Forensic science kits from Flint Scientific, Inc. range from $30.00 for single subject kits for 15 pairs of students to $274.49 for a 6-kit bundle. Home Science Tools provides both kits for a classroom and for a single student. Kits may range from $15 for an individual to $350 for a small classroom bundle. Carolina is a supply company that also sells forensic laboratory kits for all grades and college students. The kits can provide materials for whole classrooms to perform a single exercise or for multiple exercises pertaining to a single case. The prices range from $12 for a basic firearm identification kit to $1,015 for a whole mystery series. Some other kits were available for purchase but did not include a manual because they are meant for a forensic science course at a specific institution (Quality Science Labs, LLC, 2016).

Materials and Methods

The forensic science laboratory kits from eScience Labs included 13 activities and each activity was completed for evaluation purposes. Additional materials used but not provided by the kit were a lab notebook and stopwatches. The notebook was used to write notes and observations of each activity, including forensic knowledge required to understand the purpose and objective of each activity. Two stopwatches recorded the elapsed time of an individual activity. One stopwatch recorded the total time of the activities, including the time spent for writing notes and observations. The second stopwatch recorded the elapsed time of the activity without time spent for writing side notes and observations.

Kit Content

The kit provided a booklet with instructions to begin an experiment. The first set of instructions involved checking inventory and contacting the company if an item was missing or damaged. The students were then asked to register for an account using the company website and the access code found on the box. The last set of instructions told students to plan experiments using the estimated times as a reference and the list of extra household items needed that the kit did not provide. The booklet also contained a safety protocol when working with chemicals, flames, or sharp items and suggestions for cleaning and disposing of an experiment.

The kit contained an electronic lab manual in the form of a CD. The lab manual provided some background information on each experiment: questions within the literature (before and after the lab) and the steps to complete experiments. The manual seems like it would be a great addition to assist student learning despite the presence of minor typos and errors. The minor typos included "tjat" instead of "that" or stating "the other one" when referencing both a first item and second item. A few items were misplaced or the manual stated the wrong location of the items. For example, the plastic bag labeled "Fingerprinting" stated the fingerprint card was in this plastic bag, but it was located with the other printed materials in a folder.

Every item needed to complete each lab activity in the inventory list was in the kit as well as safety goggles, gloves, underpads, and an apron. The safety equipment was not necessary for all activities, but the manual still emphasized wearing safety equipment before and during an experiment. Some items in the kit were never used or there were too many included: a thermometer, a sharpie, beakers, and plastic pipettes. The kit provided plastic items and tools designed for safe use to perform each activity with the exception of the glass sheet, scalpel, alligator clips, and hammer. All the tools were fully functional and intact. However, the butane lighter broke and leaked after using it for only one experiment but it was needed for two other experiments.

Lab 1: Evidence and Crime Scenes

Lab 1 consisted of three activities. The first activity allowed students to collect and process evidence using proper collection methods and a main chain of custody form. A short summary of a mock crime scene was provided in the manual. Materials for the activity included lifting tape, plastic bags, a chain of custody sheet, a photomacrographic scale, and other essential tools to collect a sock marked as evidence and process it for trace evidence. The second activity allowed students to complete a crime scene diagram. Materials included an incomplete crime scene diagram, protractor, ruler, and instructions on completing the diagram. In addition to the diagram, students were required to create a legend of the evidence and non-evidence items found at the crime scene. The third activity was designed to introduce students to the capabilities of a compound light microscope using a simulated microscope with a series of steps to properly set the parts to observe different virtual samples.

All three activities met the learning objectives for the lab; however, a part of one objective was to prevent contamination and the manual failed to instruct the student to wear full personal protective equipment (PPE). The protocol stated to wear gloves but did not state to wear the apron. Students may have easily contaminated the sock if they were not wearing the full appropriate PPE. A post-lab question asked students about other attire (besides gloves) that a crime scene investigator (CSI) should wear to collect crime scene evidence. This allowed students to think of the importance of PPE during an examination of a crime scene and evidence.

During collection of the evidence the protocol said to "use your knowledge of crime scene photography to take the most reliable picture" (eScience Labs, 2015, p. 31). A figure of a photomacrographic scale and description of the figure stated the circles on the scale were to "ensure a camera lens is perpendicular to the ruler," but further details of proper CSI techniques to develop a good picture were not found within the literature (eScicnce Labs, 2015, p. 24).

Lab 2: Fingerprinting

Lab 2 included two activities. The first activity provided a fingerprint card and inkpad to allow students to simulate rolling fingerprints onto a card. For each finger, students were asked to identify the basic pattern of each finger, minutiae points, and any scars or creases. The second activity was lifting fingerprints from two different surfaces using fingerprint powder and a fingerprint brush and lifting-tape sheets were also included. Through activities and questions students would have the opportunity to determine the importance of fingerprints in forensics. One question asked for the types of surfaces a CSI would test for fingerprints and another question asked for ways to prevent losing or contaminating prints while lifting latent fingerprints.

Three basic fingerprint patterns and the percentage of the population with each fingerprint pattern were provided within the literature. It did not show the subclass patterns that may also be found. For example, the manual stated a whorl might be a central pocket whorl with a ridge that completed a circuit without touching another ridge. While completing the activity, one of the fingerprints was a loop with a central pocket, but the manual did not include this pattern or a picture of it. Students were asked to determine the basic fingerprint pattern, but if they had no knowledge of the various fingerprint patterns, the pattern found may appear as a loop or a whorl.

The kit only provided one fingerprint card with room for only one print per finger. This did not allow for error. If students had too much ink on a finger or a sweaty finger, the print may be blurred and no pattern would be identified. Allowing no opportunity for error would show students the importance of performing fingerprints correctly the first time to obtain identifiable prints from victims and suspects.

Lab 3: DNA

Lab 3 included two experiments. The first activity asked students to extract deoxyribonucleic acid (DNA) from a soft fruit of their choice, such as strawberries, grapes, or bananas, by squishing the fruit and then adding solutions to isolate the DNA. The first experiment was completed using a banana but DNA was not successfully isolated. This experiment was followed by questions regarding DNA structure and its importance in forensic science. The second experiment allowed students to set a gel electrophoresis mechanism using the following materials: 0.8% agarose; a mini gel electrophoresis chamber; alligator clips; carbon fiber; Tris base, boric acid, and EDTA (TBE) buffer; and four different colored dyes. The dyes represented known and unknown polymerase chain reaction (PCR) products.

This second experiment allowed a visual representation of DNA separation based on size. Instead of using DNA different dyes representing DNA samples were placed in the agarose gel wells and the separations of the unknown dye samples into separate colors were compared to the separation of the known dye samples. A follow up question asked about the use of an electrical current during electrophoresis and how it worked. It did not state that DNA is negatively charged and therefore travels towards the positive electrode with the help of a current running through the gel.

Lab 4: Blood

Lab 4 included two activities. For the first activity students were asked to produce many forms of bloodstains. The first type was a single drop from various heights, the second was multiple drops from a single height, and the third was a single bloodstain using force. The force behind the third bloodstain was achieved by filling a transfer pipette with about 2 mL of red solution and quickly squeezing the pipette to allow the solution to transfer onto the paper with pressure. The second activity asked students to produce bloodstains at various angles from the same height using a protractor and a clipboard to produce the angle.

The pre- and post-lab questions allowed students to determine the role of bloodstain analysis in forensics and the information they may obtain from the analysis. One pre-lab question asked students to determine the number of stab wounds from the bloodstain patterns in the image, but the literature in the manual did not explain the steps to accomplish this.

While completing the first part of the experiment, an unintentional drop fell onto the sheet, but the sheet had enough space to continue the experiment. After completing the steps, the simulated blood soaked the cardstock paper and the paper towels underneath leaving small puddles of simulated blood on the floor. The manual did state that a mess may occur and students should choose a surface wisely to avoid staining it.

Lab 5: Fiber and Hair

Lab 5 included a single activity that involved using a butane lighter to burn five different known fibers (cotton, nylon, polyester, wool, and one unknown fiber) to perform a fiber analysis. Since the activity involved a flame the protocol emphasized lab safety before using the butane lighter and during the activity. Questions throughout the activity allowed students to think of the limitations of this type of analysis. At the end of the activity the manual provided tables to note the results of the analysis. The manual contained some errors in the post-lab section. For example, the protocol asked to add pictures of the results into the table, but the spaces in the table were only tall enough for two lines of text. The manual also contained a post-lab question that referenced “pre-lab question 2” (eScience Labs, 2015, p 106), but it only had one pre-lab question listed and it did not correspond to the post-lab question. After completing the lab, a conclusion was difficult to generate and required repeating the analysis.

Lab 6: Impression Evidence: Shoes, Tires, Tools

Lab 6 included one activity involving a toy car, construction paper, and ink to perform a tire track analysis. Students were asked to make tire tracks in a straight line, curving from left to right, and curving from right to left. Questions within the activity allowed students to explain the importance of shoe, tire, and tool marks in forensics.

The manual stated the use of a photomacrographic scale, but it did not tell students to take a picture of the tire tracks with a scale. Analysis of the tire tracks included counting how many tracks were visible and which tires were on the outside or inside based on the curve direction. This was difficult to analyze since the wheel axis of the toy car shifted from side to side.

Lab 7: Fractography and Glass

Lab 7 consisted of a single glass activity, which involved cracking a taped glass using a nail and hammer. Students were asked to analyze the pieces of glass for fracture patterns and radial fractures. Questions within the activity prompted further analysis of the impact hole and emphasized the importance of glass evidence in forensics.

The glass was difficult to break and required multiple hits to stress the glass enough to create fractures. Literature in the manual stated the 90-degree angles from the radial fracture lines were located on the opposite edge from the side of impact. However, some of the radial lines observed did not correspond to this information and the manual did not include an explanation for this occurrence. The protocol emphasized safety while working with broken glass and asked students to list a few safety guidelines. Students were also reminded before and during the activity to wear PPE at all times.

Lab 8: Autopsy and Time of Death

Lab 8 included one activity that allowed students to perform a mock autopsy on a frog using dissection tools and a miniature scale to weigh the organs of the frog. Post-lab questions asked students to analyze frog characteristics that would help pathologists estimate a time of death. The final steps asked students to open the stomach of the frog and draw conclusions based on the contents (or lack of contents) in the stomach. As students follow the protocol, the manual asks students to take pictures of the frog, which would require students to take off their gloves and hold the camera. Other lab activities required gloves, but the kit only included three pairs.

Lab 9: Body Identification

Lab 9 included two experiments. The first experiment asks students to measure their height, foot length, ulna length, and femur length using a tape measure and masking tape. After measuring all the body parts the protocol asked students to calculate their height based on the measurements taken and to compare the calculated height to the actual height. This experiment allows students to determine the variance in measuring limbs to calculate a body height if a whole body is not available at a crime scene and it allowed students to explain other factors that may alter the accuracy of height calculation.

The second experiment asks students to cut a Styrofoam plate into pieces small enough to bite on and obtain indentations from all the teeth. After biting into the plates, the protocol asks students to label the teeth using the universal numbering system stated in the literature. Some post-lab questions ask for details on students' dental impressions and other post-lab questions ask students to analyze digital dental X-rays. This activity would help students determine identifying factors from bite impressions and help students practice the universal numbering system. The universal numbering system further helped students visualize a bite mark based on the dental X-rays.

Lab 10: Questioned Documents

Lab 10 was composed of two activities. The first activity had students forge three different signatures using exemplars and note observations of each signature, such as the–variance between the forgery and the exemplar. During the handwriting analysis students were able to observe the difficulty and variance in forging a signature. The second activity involved comparing chromatography results of multiple known ink samples and one unknown ink sample to determine the potential source of origin. The pre- and post-lab questions allowed students to know which features and characteristics are important for handwriting analysis and the tools that may be used to examine evidence of questioned documents.

Lab 11: Fire Investigation

Lab 11 consisted of one activity involving manipulating a candle flame using a metal mesh and a glass test tube to observe the essential element required for a fire to continue burning. Since the experiment included fire the protocol emphasized safety in a pre-lab question before and during the experiment. Some pre- and post-lab questions allowed students to explain the different properties associated with fire, such as backdraft, flashover, and combustion.

For this activity, manipulations of the flame isolated one of the three essential elements required to keep a flame burning. Following each manipulation, the post questions asked the students to determine which element was eliminated. Some of the elements were difficult to distinguish based on the manipulation the protocol asked students to perform; therefore, guesses were written as answers for some of the post-lab questions. The overall concept of this activity required chemistry knowledge.

Lab 12: Toxicology

Lab 12 contained one activity involving analyzing reaction characteristics of three known substances and an unknown substance to determine the identity of the unknown. Students accomplished the identification of the unknown substance by observing the combination of the known and unknown substances with vinegar, potassium iodide, and hot water. Students were asked to note observations of all 12 reactions and to then presume the identity of the unknown substance.

Students learned about other techniques available to determine the identity of various substances, such as chromatography and mass spectroscopy. Students also learned the difference between a presumptive and confirmative test. Post-lab questions allowed students to relate this activity to actual crime scene tests of unknown substances by asking them what the unknown and known powders of the activity would represent in an actual crime scene. Other post-lab questions asked students to analyze a theoretical chromatography test on known drugs and an unknown substance. The students were then asked to identify the unknown substance based on the test results. Information taught in the literature of this activity involved many chemistry concepts.

Lab 13: Firearms

Lab 13 included one activity involving the analysis of a bullet hole. The literature taught students that there are many class and individual characteristics that may be found on a gun or bullet. The literature also discusses the different parts involved in the mechanics of guns and ammunition. Using this information, pre- and post-lab questions allowed students to explain the information that a gun and/or bullet may provide a forensic scientist, such as an estimated shooting distance based on the presence or absence of gunshot residue (GSR).

The activity allowed students to analyze a bullet trajectory path using a printed bullet hole, measuring tape, and string provided by the kit. After measuring the axis and angle of the bullet hole, the protocol asks students to calculate the shoulder height using the equation provided, which required knowledge of geometry to understand the meaning of the angles calculated.

Discussion

The kit was completed without simultaneous enrollment of an introductory forensic science online course. The evaluation of the kit was performed to decide if it should be incorporated into an online science course, but there was no suggested course content that students should have encountered before starting an experiment. Completion of each activity determined that the manual did not contain enough information for a student new to forensic science to fully comprehend some of the topics solely using the kit. Professors should review or complete the experiments to determine the information they should include in the lecture.

All the experiments were easy to complete and the concepts behind them were not difficult to understand. The easier experiments, such as labs 1 and 10, contained less information in the evaluation as compared to the more complex experiments, such as labs 3 and 8, which involved more knowledge. The experiments were able to provide students with examples of the precision and patience required in many forensic science techniques to obtain reliable results. Many of the experiment questions asked students for different circumstances where a CSI or a forensic analyst may use the technique. This allowed students to visualize using actual evidence for the experiments.

The kit provided plenty of references for students to work with but most of the experiments did not depict a real-life situation. The figures and images were mostly illustrations instead of pictures of real objects. These figures and images minimized the capability of a student to learn the characteristics and details to be aware of in blood spatter or minutiae fingerprint characteristics. The manual should use real images instead of graphic illustrations when possible to assist students' understanding of real results versus ideal results.

In addition to the PDF manual used throughout completion of the activities the kit also provided an online manual. The online manual was only used once to provide a short PowerPoint at the beginning which was a condensed version of the literature within the PDF manual. The online manual also had additional quizzes after the literature sections to prepare students for the experiments.

Conclusion

After completing the 13 experiments, the kit was determined to be a good addition to an online introductory forensic science course. The kits alone may not be enough to teach students, especially those fairly new to forensic science, the knowledge required to fully understand the concepts behind each application and technique. However, combining online lectures from a college professor with the kits may help students fully grasp more complicated concepts, such as the geometry necessary for ballistics, spatter analysis, or DNA analysis.

Professors may compile a series of lectures with videos and PowerPoints to introduce a forensic science topic, such as fingerprinting. These lectures would allow students to know details and different learning methods about the topic that the eScience Labs manual does not provide. The professor may then assign the eScience Labs activity that corresponds with the lecture to provide students with visuals of the topic and basic experiences of procedures and techniques. The professor may further use concept check questions and the pre- and post-lab questions in the eScience Labs forensic kit manual as quiz or test questions or use them as guidelines to create new questions. The professor may also request lab reports after the completion of a lab activity to emulate the full effect of proper scientific work.

All the activities were well structured and interactive enough to understand the theory and mechanism behind each forensic topic. The labs were not difficult experiments, which ensures that a student would be capable of completing the experiments at home safely while still understanding the importance of each technique for forensic science. Completion of the kits also exposed students to the tedious work involved to obtain reliable and admissible results for use in the courtroom.

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