A flipped classroom approach: Enhancing critical thinking with Poll Everywhere and question dissection techniques in undergraduate forensic science education

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Abstract: Critical thinking and question dissection techniques are important but often under-taught skills emphasized for undergraduate students. This study aims to determine if the addition of a question-based activity can improve these skills. Undergraduate students in an entry-level criminalistics laboratory course were given interactive polls consisting of definition-based "simple" questions, followed by application-based "complex" questions. The initial two sessions included guided instruction on breaking down complex questions into manageable components, then subsequent sessions were independently performed by students. Data were collected measuring student response speed and accuracy throughout the semester. Students completed a self-assessment before and after the course reflecting on perceived critical reading/thinking ability and value of the activity. A student t-test was used to calculate statistical significance for all self-assessment data. Over the semester, accuracy of simple questions was maintained, while, for complex questions, the response accuracy increased, and response time decreased. Self-assessment surveys administered pre- and post-intervention revealed significant improvements in the students perceived critical reading ($p = 0.002$) and thinking ($p = 0.029$) abilities. Students also rated the activities as highly valuable, with scores averaging 8–9 on a 10-point scale. Our findings suggest that targeted 10-minute question dissection activities can measurably improve analytical skills at an undergraduate level in a forensic science laboratory. This approach offers a scalable, low-barrier strategy to build core competencies in critical thinking across criminal justice or forensic science and is abstractable to any discipline.

Keywords: critical thinking, student engagement, flipped classroom, active learning

Introduction

At every education level, student engagement is a recognized goal with many possible solutions. Active engagement is essential because it improves student retention and perceived value of learning (1). The fundamental purpose of higher education in STEM is to provide a student with enough knowledge and skills in a subject area to make educated inferences, judgements and actions independently. In order for students to operate autonomously, they first have to build a knowledge base and be able to apply that material. Compiling information requires students to engage and in the post-pandemic era of innumerable online resources accompanied by countless distractions, achieving and maintaining engagement can be difficult (1-3). In forensic science, innovative strategies to promote student engagement have been widely explored. For example, a college anthropology course incorporated hands-on interactive modules in osteology, odontology, skeletal examination, and mock scene processing to increase engagement (4). Another approach involved high school students participating in an extracurricular activity at a local university to form personal connections and a sense of identity as forensic scientists (5). Some universities offer crime scene houses, allowing students to apply their skills in real-world laboratory activities (6). These approaches can boost engagement inside and outside forensic science programs by involving students from other majors or high schools in crime scene investigations. However, some institutions find these initiatives prohibitive due to limited resources or time to support such programming.

Building on the importance of engagement, fostering critical thinking is also key in education. While didactic lecture-based teaching is common in college settings, it often leads students to rely heavily on instructors for information. In contrast, self-directed learning encourages students' independent critical thinking (3). Critical thinking, defined as the ability to reflect and apply knowledge to make informed decisions, is an essential life skill. It is particularly important in forensic science and criminal justice, where employers expect strong critical

thinking skills (7). Time, space and examples are necessary for students to practice and apply these skills to effectively develop them (8).

One approach that promotes self-directed learning and critical thinking is the "flipped classroom" design. Supported by educational system literature, this method has shown success in both undergraduate and professional settings (3, 9). Flipped classrooms are associated with improved and more effective learning (10). However, in entry-level collegiate courses, students may lack the background knowledge or skills necessary to succeed in entirely independent learning environments. Importantly, research indicates that combining flipped classroom activities with traditional lectures results in higher student satisfaction and grades, compared to classes relying on lectures alone (11). Many instructors use online class polling software to provide self-directed learning during class. These programs allow instructors to upload questions, which can be answered anonymously by the class. Poll Everywhere, one such program, has been shown to be an effective method to improve student engagement and increase critical thinking skills (2). This program is specifically advantageous because of its simple user interface (professor and student), flexibility of response devices, ability of polling questions to be seamlessly incorporated in power-point presentations and the option of turning responses into a competition for speed and accuracy of responding (not done in this study, but a perk for those interested in gamification).

Inspired by this, we designed a Poll Everywhere activity that focused on question dissection techniques. Individuals within the forensic science field come from a variety of backgrounds including criminal justice, biology, chemistry, or sociology, all of which stand to benefit from improved critical thinking skills. The study design includes exposing students to simple questions about the definition of terms that contribute to and build their knowledge. They are then asked more complex questions whereby the definition of terms used are implicit and without that knowledge cannot be answered. When the students are exposed to complex questions during the first-class session, they are instructed on how to dissect the question into its most basic form to determine what the question is asking. This novel, and underexplored, method of question dissection incorporated into a classroom engagement tool, teaches forensic science educators a method to build their student's skill on how to section long questions into less intimidating pieces, improving their critical reading and thinking while empowering them to succeed.

To assess the validity of the activity, we evaluated the accuracy and speed at which undergraduate students answered the questions, along with their self-reported improvement. Overall, our goal is to provide instructors with a flipped classroom activity that is simple to incorporate into laboratory or lecture environments that is focused on enhancing students' critical thinking.

Methods

Question Dissection Activity

The question dissection activity involved reviewing the previous lecture with a focus on 1 to 3 topics. For every topic, a question set of 2 questions was asked. Each question set included a "simple" question focused on the definition of a term. This was followed by a "complex" question on the same topic that required application of the simple questions' definition to answer correctly. Examples are shown in **TABLE 1**, which precedes Appendix A. After each question was answered by the class, the correct answer was discussed by the class. These sessions lasted no longer than 10 minutes per class period and incorporated 2 to 6 questions. They were conducted every other lab for the duration of the semester (14-15 weeks).

Course Information and Class Breakdown

Criminalistics I is an introductory lecture course covering various crime scene investigation techniques and methods of pattern analysis; in the laboratory component students gain hands-on experience with each technique discussed in class. The polling activity was tested in 2023 and 2024 over three laboratory sections. The study met Arcadia University IRB exemption criteria involving "no more than minimal risk" and student anonymity was preserved throughout the data collection process.

The question dissection activity was incorporated into the beginning of every laboratory class. When students arrived at class, they were first given time to ask questions on prior material. Afterwards, students logged into Poll Everywhere from their devices (i.e., cell phone, laptop, or tablet) and anonymously answered the question sets provided that reviewed information on the previous class's information. Once the activity was completed, students then received a brief introduction to the laboratory they would be performing that day. They then participated in their laboratory, recording observations, measurements and outcomes as necessary before adjourning. This was repeated bi-monthly across the semester, the laboratories occurred weekly.

Methodology

Throughout the semester, this activity slightly evolved to reflect the students' understanding. The activity was started during the second class. The first time students engaged in this activity, the students were instructed on how to break down the complex question prior to answering it. This provided a framework to students on

how to determine what topic the question is asking about, what outcome the question is looking for, and what information is "extra", distracting, or descriptive. During all sessions following the initial set there was a discussion about question breakdown after the complex question was answered to improve student comprehension and skill application over time. The last session did not include any simple definition questions and instead only incorporated complex questions covering topics from the semester. This allowed students to showcase the skills they built over the semester without being primed by the topic the question was centered on.

Evaluation of Actual and Self-Reported Learning

On the first meeting of class, students filled out a self-assessment of their critical reading and thinking strength, topic comprehension speed, and novel topic application speed on a numerical scale 1 to 10 (Appendix A). The survey also included demographic information: class year, sex, and major (Appendix A). They repeated this self-assessment during the last class period where they were additionally asked to evaluate the question activity by reporting how the basic definition and complex applicational questions improved their understanding of the topics covered and whether they found the question dissection helpful to improve their understanding (Appendix B). A student t-test was used to calculate statistical significance of differences between the start and end of the semester. P-value <0.05 was considered significant.

As activities were conducted throughout the semester, Poll Everywhere logged students' time to respond and accuracy for each question which were then exported into Excel and analyzed. Averages and standard deviations of the time and accuracy were taken for each question and plotted using GraphPad Prism 10.4. A trend line was calculated where appropriate, with a reported slope including standard error of the mean (SEM) where appropriate.

Results

In total, 43 students took this course within this study period. The student population had a sex ratio of about 3:1 female to male (**FIGURE 1A**) and was composed of a balance of class years with additional juniors (**FIGURE 1B**). First year students are freshmen, second year students are sophomores, third year students are juniors, fourth year students are seniors (**FIGURE 1B**). A wide variety of majors were represented, more than half were criminal justice, with biology or psychology next and a plethora of others (**FIGURE 1C**). Majors are as reported when class was taken.

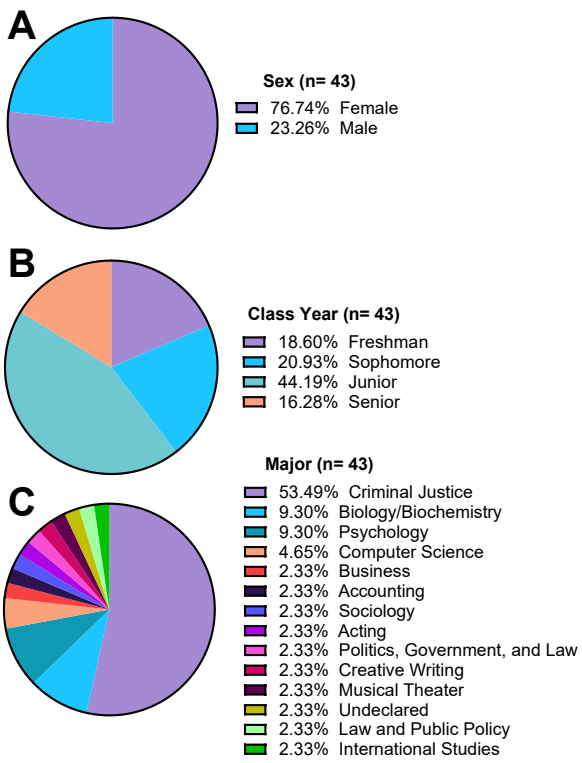

FIGURE 1 Demographics of Student Population. (A) Sex, (B) Class Year and (C) Major. Percent of each displayed.

Evidence of Learning

The length of time needed for students to answer the simple definition questions decreased early from just under 2 minutes to about 1 minute for the rest of the semester with a slope of -0.03min/question (**FIGURE 2A**). The simple question accuracy did not have an appreciable change over time, with a slope of only +0.561% per question asked (**FIGURE 2B**).

The speed at which the complex questions were answered decreased over time, finishing at about 1 minute, while the start of the semester began at about 1.5 minutes with a negative slope of -0.02 min/question (**FIGURE 2C**).

The accuracy of the complex questions improved over the course of the semester with a positive slope of about 2.9% per question asked (**FIGURE 2D**). The first 2 complex questions were walked through by the instructor and the answers were provided to the students therefore they were dropped from the correlation curve. The accuracy of complex questions began at about 30% in week 2 and increased to about 80% in week 13. (**FIGURE 2D**).

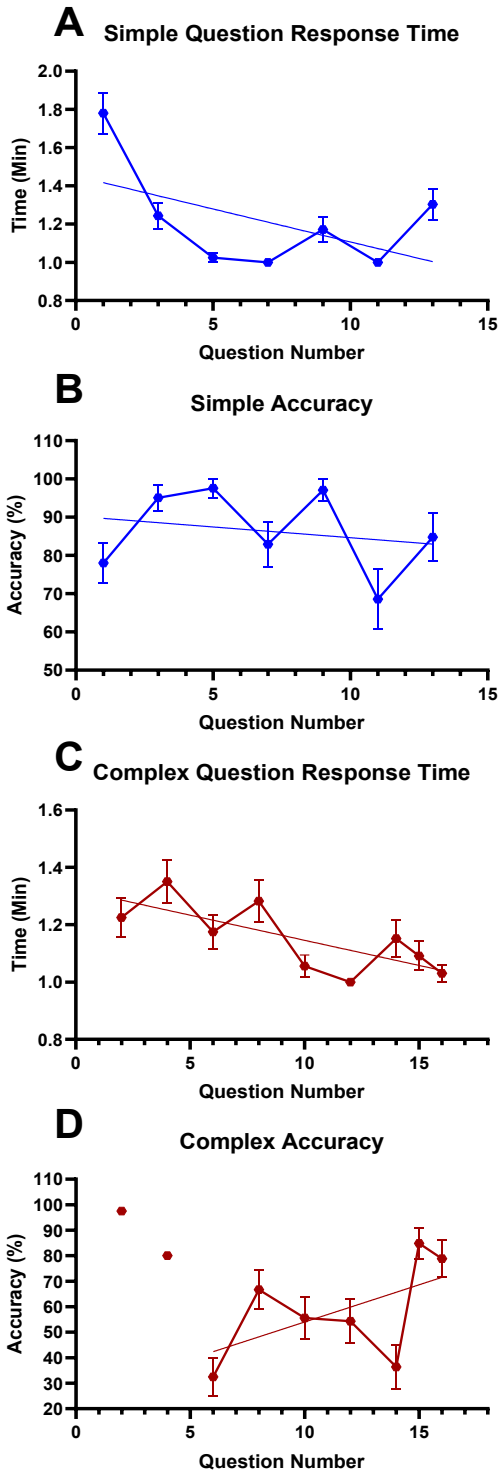

FIGURE 2 Speed and Accuracy of Question Answering Overtime (A) Time spent answering simple questions (B) Accuracy of answers to simple questions (C) Time spent answering complex questions (D) Accuracy of answers to complex questions. Mean values graphed with SEM errors.

Student Self-Assessments

Students rated the basic definition "simple" questions, the complex questions, and the question dissection technique as all relatively helpful, averaging between 8-9 in value (**FIGURE 3A)**. All self-assessment scores improved from the start evaluation to the end of course, with a statically significant increase in the student's evaluation of their critical reading and critical thinking skills, p = 0.002 and p = 0.029 respectively (**FIGURE 3B**). In addition, their self-reported speed of comprehension and speed of topic application each displayed a positive trend (**FIGURE 3B**). This correlates well with the shown improvement in complex question speed and accuracy.

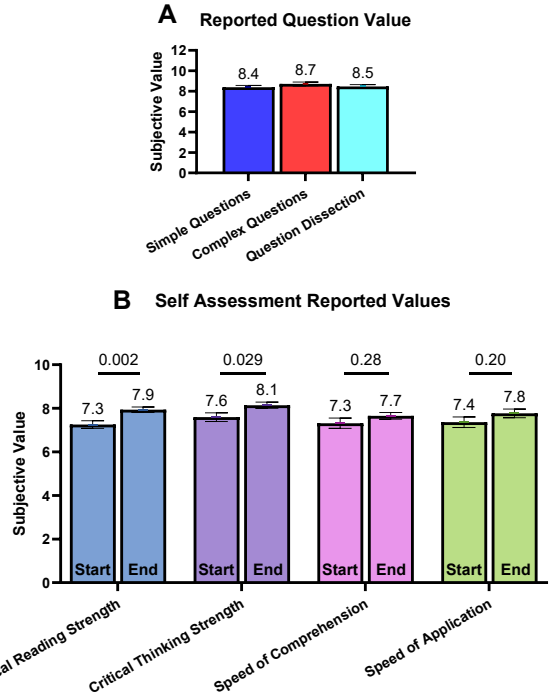

FIGURE 3 Self-Assessment and Reported Value. Means were taken from reported Likert scale values and displayed above the bar. (A) n = 39 (B) n = 43 for starting bars (left) and n = 39 for ending bars (right), not all students filled out exit survey. Error bars are SEM. P-value computed from student t-test; values displayed above bars.

Discussion

This study demonstrated a Poll Everywhere, or question-based class engagement activity, has the potential to improve students' critical reading, critical

thinking, question response accuracy and question answering speed. Our diverse sample suggest that, regardless of sex, major, or class year, students can benefit from participating in these activities. Providing didactic learning through a standard lecture course and incorporating flipped classroom activities, in entry level classes, can be beneficial for student learning regardless of background the students may have.

Students displayed improvement in complex speed and accuracy over the course of the semester and reported higher confidence in their own critical reading and critical thinking strengths. They felt their speed of comprehension and application was faster. Though this was a trend and not a significant comparison to the values reported at the start of the semester, the quantitative data reflected these feelings. Also, the accuracy of the answers to the complex questions did improve relatively drastically from on average below 50% to about 80% (**FIGURE 2D**), which corresponds to the students' response of improved reading and thinking. The response time taken to answer complex questions decreased from 1.3 minutes to a little over 1 minute. This also corresponds well to the self-report from the students about their speed, even though the difference between the start to end values were not statistically significant they were experientially relevant.

Alignment with Other Studies and Resources

These results aligned with other studies that have demonstrated increased engagement and success with flipped classroom approaches and utilization of Poll Everywhere (2, 3, 9-11). The efforts engage students studying forensic science through a novel method of interacting with complex questions (1). Similar question-based activities can be incorporated into lab settings and formal classrooms of all levels. With only approximately ten minutes of class time and formal prepping of 2-6 questions per activity, this is an accessible way to increase critical thinking skills, aligning with calls for evidence-based teaching practices in STEM fields.

Limitations

There are multiple potentially confounding effects present. Firstly, these activities were carried out over the course of semesters during which students were building knowledge. In addition, information presented in the questions may be overlapping with information they were reviewing in class. Therefore, scores in general are expected to increase. The professor of the course designed the questions, while attempting to balance how challenging they were. Some question sets may have been more difficult than others. While beyond the scope of this study, this increased question-to-question variability in question response and accuracy. Additionally, students were primed with background knowledge since they answered the simple question immediately prior to the complex question, except for the last two class sessions that did not have simple questions. While not necessarily noted, slight drops in the accuracy of complex questions without priming would not be unexpected. Finally, this study is constrained by a limited sample size. Although the student population comes from diverse educational backgrounds and experiences and generally improved with the activity, further use of the activity with more students could better elucidate the study results.

Conclusion

In all, this activity displayed promise and was well received. Critical reading and critical thinking are skills widely applicable to the field of forensic science and beyond. Any educational setting where students use definitions or facts as the background for complex questions, stand to benefit from learning through question dissection. For example, in the field of medicine, knowledge of side effects may inform the patient presentation of a reaction to prescribing a medication. This study shows that easily implementable technology can teach undergraduates to develop a core skill to benefit and service them well for the rest of their education and career journey.

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TABLE 1 Representative Examples of Question Sets Used for Skill Building

Topic:	Simple Question	Complex Question	Dissection
Crime Scene Sketch	A "birds eye view" is used for crime scene sketching. This view is like: (A) taking a picture with a camera placed on the floor (B) a view from high up showing every aspect of the room, including vertical objects like posters or cabinet surfaces **(C) a layout seen from overhead** (D) a mirror image of what you see with your eyes	You are investigating a crime scene; in a dusty drawer you discover a blueprint. You see an overhead map with a compass on the side. There are alphabet letters throughout the rooms and a key written on the back. Using this image where is the gun? [Image provided] (A) Northeast corner near the window (B) Southeast area near the plant **(C) Southwest area behind the couch** (D) Northeast area on the table	What is this question really asking? Do you understand how to read a map? What is the purpose of the letters? How to key items, can you read a key? Are you able to orient yourself? Task: Use the key, map and compass to find the gun's location Demonstrates understanding of a crime scene sketch
Blood Spatter Analysis	When analyzing a drop of blood spatter, the tips of the tails tell you? (A) Speed (B) Height **(C) Direction** (D) Velocity	While investigating a crime scene, you find a pattern of blood cast on the wall. There is a long tear drop with the rounded edge facing the door and the sharp point aimed at a broken window. Which direction was the blood drop traveling? (A) Toward the door **(B) Toward the window** (C) Perpendicular to the window (D) Perpendicular to the door	What is this question asking you to know? What does the tip of the tail of a blood drop tell you? Can you orient the drop in space and apply direction to a situation?
Tool Mark Analysis	Class characteristics are features all things of a kind share – hammers have flat heads to strike nails, while individual characteristics are: **(A) Unique marks that are transferred when using tools** (B) Uniform throughout manufacturing (C) The same for all specific tools (D) Will not change with time	During investigation of a murder case, 3 screwdrivers were found outside the back door on the ground, only one was used to pry the lock off the door. One of the three had the corresponding blade width to the marking on the frame. This is a: (A) Individual characteristic (B) Manufacturers characteristic **(C) Class characteristic** (D) Unique characteristic	What does this question want me to know? How do you categorize blade width? Is that something other tools share? If they share could that be unique? Would it be particular to a manufacturing company? Do you know that it will not change with time?

APPENDIX A: Beginning of Semester Evaluation

What's your Major?
What's your class year?
How would you rate your critical reading strength? 1-10
How would you rate your critical thinking strength? 1-10
How would you rate your speed of comprehending new topics? 1-10
How would you rate your speed of applying a new topic to a scenario? 1-10

APPENDIX B: End of Semester Evaluation

How would you rate your critical reading strength? 1-10
How would you rate your critical thinking strength? 1-10
How would you rate your speed of comprehending new topics? 1-10
How would you rate your speed of applying a new topic to a scenario? 1-10
How much did the basic definition questions improve your understanding of the topics we covered? 1-10
How much did the applicational example questions improve your understanding of the topics we covered? 1-10
How helpful were the question dissections for improving your understanding? 1-10