Utilization of the 'World of Guns' in Firearms Examination Courses

Jamie S. Spaulding[1]*

[1]*Department of Criminal Justice and Forensic Science, Hamline University, 1536 Hewitt Ave, Saint Paul, MN 55104, *corresponding author: jspaulding02@hamline.edu*

Abstract: Delivery of a comprehensive firearm and toolmark examination course is often challenging because few universities are able to maintain extensive reference collections such as those found in crime laboratories. These reference collections are essential to understanding the functionalities of various firearms and in the developmental training of apprentice/entry level firearm and toolmark examiners. Several sections of the Association of Firearm and Toolmark Examiners (AFTE) Training Manual and the National Firearms Examiner Academy (NFEA) curriculum, including numerous training exercises are dedicated to field stripping, disassembly, and assembly of firearms to develop a comprehensive understanding of their operation. To overcome a limited reference collection, a major assignment utilizing the 'World of Guns: Gun Disassembly' was integrated into an undergraduate course to enhance student learning, provide active learning opportunities for students, and align the course with several learning outcomes of the AFTE Training Manual and the NFEA. Students were expected to 1) use the game to field strip, disassemble, and reassemble a series of assigned firearms and 2) draft a paragraph description of the firearm and the mechanism by which it operates. The integration of the game resulted in improved exam scores on questions about firearm mechanism recognition and student understanding of how markings are transferred to evidential samples. Furthermore, the application demonstrates the effectiveness of game- based learning in a forensic science course.

Keywords: firearms examination; game-based learning; student engagement

Introduction

Forensic firearms examination, like other pattern evidence analysis disciplines, is reliant on examiner proficiency to draw comparisons between questioned samples recovered from crime scenes and known test fire exemplars. During comparison, the examiner evaluates the similarity of impressed and striated features on cartridge cases and bullets using comparison microscopy.

As with other pattern disciplines, the assessment of individual characteristics is paramount to a conclusion regarding source attribution. Per the Association of Firearm and Toolmark Examiners (AFTE) (1), individual characteristics are "marks produced by the random imperfections or irregularities of tool surfaces. These random imperfections or irregularities are produced incidental to manufacture and/or caused by use, corrosion, or damage." As these toolmarks are created on the firearm incidental to manufacture, the examiner must have a comprehensive understanding of the manufacturing process as well as mechanisms within the firearm to articulate the transfer of toolmarks to evidential samples. Firearm design and manufacturing technologies are integral to the firearm examiner because this is where class and individual characteristics originate. A key learning objective in training is for examiners to identify the parts of a firearm that can produce identifiable marks for firearms identification (2). This understanding is necessary to assess the significance of the toolmarks encountered during initial examinations, during comparison examinations, and when rendering source conclusions (3).

Firearms sections of crime labs also maintain reference collections with a vast array of different firearms to demonstrate different action mechanisms. Examiners use reference firearms in function testing to evaluate the condition of evidence firearms. Maintenance of such a reference collection for teaching purposes is rarely feasible for a university which greatly restricts students' understanding of firearm development and operation, essential elements in the evaluation of firearm related evidence.

The aim of this article is to illustrate the utility of an online simulation game in a forensic firearm and toolmark examination course. The 'World of Guns: Gun Disassembly' (WoG) game (4) is available on Steam (5), a digital distribution service and was integrated into an undergraduate course to enhance student learning, provide active learning opportunities for students, and facilitate several learning outcomes associated with the training of firearms examiners in the field.

AFTE Training Recommendations

The AFTE Training Manual (2) is a modular guide which contains a syllabus outlining the best practices for the training of new firearm and toolmark examiners. This is reaffirmed by the Firearm and Toolmark Subcommittee of the Organization of Scientific Area Committees (OSAC) for Forensic Science who proposed a standard for the Requirements and Recommendations for a Firearm and Toolmark Examiner Training Program (3). Sections C–E of the AFTE Training Manual outline training on historical and current trends in the development and manufacture of firearms and ammunition (2)*. Additionally, ten of the sixty-six training exercises are dedicated to field stripping, disassembly, and assembly of firearms to develop a comprehensive understanding of their operation. An additional six assignments relate to development of firearms, mechanisms, and the cycle of fire. In practice, the National Firearms Examiner Academy (NFEA) provides apprentice/entry level firearm and toolmark examiners developmental training (6). This NFEA curriculum is very similar to that outlined in the AFTE Training Manual including many of its exercises Additionally, the National Institute of Justice online firearm training program (7) outlines the AFTE Knowledge and Ability Factors associated with the sections on firearms manufacture as follows:

- Knowledge of the historical development of firearms design
- Knowledge of machining and finishing processes of tools, guns, barrels, breechfaces, extractors, ejectors, firing pins, and silencers (with emphasis on working surfaces and edges) and their effect on individuality.
- Knowledge of sources of information regarding identification markings and serial numbering systems in firearms (including locations of serial numbers, part/assembly numbers, proof marks on firearms, and the locations of hidden numbers)
- Knowledge of internal ballistics: ignition, pressure, function of chamber design, chamber and cartridge dimensions, headspace considerations
- Ability to recognize: (1) those attributes or characteristics of a particular firearm design which are reflected in the fired projectiles and fired cartridge cases; and (2) non-firearm caused toolmarks on ammunition components
- Ability to determine the source and uniqueness of various striated and/or static marks on bullets and cartridges

Without a comprehensive reference collection, such as those maintained in crime laboratories, these objectives are simply not possible. Nor are students able to understand the terms “field strip”, “detail strip” and “disassembly” for the range of firearms (2). It is also difficult for students to understand the internal and external safety mechanisms found in different firearms and learn the manufacturer’s nomenclature for each safety mechanism without visualization of said firearms, essential knowledge prior to function testing.

Educational Benefit of Interactive Simulation Games

Many learners generally perceive traditional instructional methods as ineffective, unengaging, and insipid (8). Game-based learning is the intentional use of digital or non-digital games or simulations for the purpose of fulfilling one or more specific learning objectives (9–11). Gamified learning in science, technology, engineering, and math (STEM) is rapidly growing as an educational strategy that incorporates gaming principles into the classroom (12). Game-based learning has been shown to inspire learners to ingest more by boosting enjoyment and engagement (10–13). In addition to providing a compelling interactive stimulus for students, a game can provide students the chance to “own” and self-direct their learning through hands on involvement with the material (14). Furthermore, game-based learning has been shown to have beneficial effects on student learning outcomes in STEM where students develop embodied understandings that serve as a solid foundation for other content in the course (11,15,16). Furthermore, the utilization of a game within coursework mirrors the impact of the video gaming industry on the everyday lives of students. Approximately 73% of Americans aged 2 and above play video games every day (17).

Methods

A major assignment for an undergraduate firearm and toolmark examination course was developed which utilized the WoG game as an interactive three-dimensional firearms reference source. WoG is a simulation video game that allows the player to operate and disassemble various firearms (4). Full access to the game can be purchased for fifty dollars, or the game can be played for free with objectives which unlock more content progressively. Full access to the game immediately unlocks all 257 firearm models and 30,600 parts which span 200 years of firearm history (4). All of the mechanical aspects of the firearm are very detailed and interact with one another when the firearm is fired. As an illustration of the level of detail, the trigger mechanism including the sear and disconnector of an AK–47 is shown in **FIGURE 1**. The Steam platform fosters accessibility for students as the platform is operating system agnostic; accessible for Windows, macOS, Linux, iOS, and Android. Accessibility is a major consideration for students who employ a variety of technologies.

* See **SUPPLEMENT 1** where explicit reference is provided for the training exercises.

FIGURE 1 Screen capture from the WoG demonstrating the level of detail in the trigger mechanism of the AK–47.

Gameplay includes various modes which enable students to learn the operation, handling, and field stripping the gun. The armorer mode allows for complete (dis)assembly of firearms. In each of the modes, the user has full control of the camera and can view the firearm in layered X-Ray or a Cutaway mode. Both reloading and firing of the firearm have complete time control with slow-motion down to 50x. In gas operated firearm mechanisms, the gas pressure animations are visible. An example test fire of the Colt Model 1911 in the cutaway mode is shown in **FIGURE 2**. Another screen capture taken in the WoG program is shown in **FIGURE 3**. The direct impingement mechanism of the Colt M16 A1 is shown in x-ray mode where the user can see the interaction of the trigger with the sear and hammer which then moves to strike the firing pin discharging the chambered cartridge.

FIGURE 2 Screen capture from the WoG mid-discharge of the Colt Model 1911 in cutaway mode. Observable is the gas pressure, shown as a color gradient, behind the projectile which has just been expelled from the muzzle.

FIGURE 3 Screen capture from the WoG of the Colt M16 A1 in one of the x-ray modes where some parts are still visible. Observable are the trigger mechanism, gas tubes for the direct impingement into the bolt carrier group, and the cartridges in the magazine and chamber.

The assignment had students examine, analyze, and describe a series of ten assigned firearms with two main learning outcomes. The first objective of the assignment is to develop an understanding of the interrelationship between the parts and mechanisms within the firearm. The second objective is to determine how the firearm mechanism operates, creates the markings observed during forensic analysis, and whether a firearm has been purposefully altered by a user, or if the wear in the firearm is due to normal use. In combination these objectives directly apply the course content with a simulated reference collection. Using the software, the assigned firearms are given in **TABLE 1**. The report requirement for the assignment has students include a screenshot of the completion message from the game indicating the student had successfully field stripped, disassembled, and reassembled the assigned firearm with a paragraph description of the firearm and the mechanism by which it operates. An example of the Colt M16 A1 completely disassembled is given in **FIGURE 4**. To completely disassemble the firearm, the user needs to click on the part to select it, then the specific area to initiate an action such as a roll pin to remove it and the part selected. The parts must be removed in the appropriate order to complete the (dis)assembly.

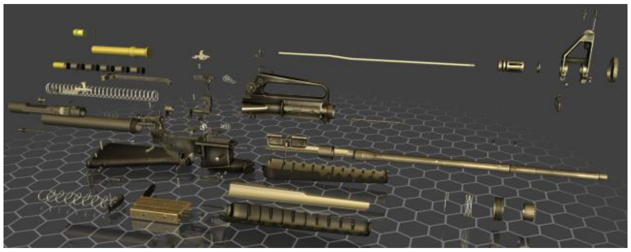

FIGURE 4 Screen capture from the WoG of the Colt M16 A1 completely disassembled as required by the assignment. This firearm is comprised of 156 parts.

To determine the effectiveness of the WoG game, an evaluation between two semesters were in the course, one prior to and one after implementation. In the semester prior to implementation, solely videos and images were presented to the class and uploaded to the learning management system (Canvas) for the course to introduce these mechanisms. Exam questions were held consistent between the semesters as were the lecture slides and related course materials. These scores were compared to determine the contribution of the WoG to student understanding. Furthermore, course evaluations and other comments on the assignment were included as a qualitative evaluation of the assignment.

TABLE 1 *Assigned firearms to field strip, disassemble, and reassemble in the WoG software.*

Firearm Manufacturer and Model	Mechanism
Browning Auto–5	Short recoil
Colt M16 A1	Direct impingement
Colt M1911	Short recoil
Glock 19	Short recoil striker
Izevsk Machinebuilding AK–47	Piston driven gas system
Magnum Research Desert Eagle .44	Piston driven gas system
Marlin 336 Deluxe	Lever action
Remington 700	Bolt action
Colt Single Action Army*	Single-action revolver
Beretta 92FS*	Short recoil
Izevsk Machinebuilding Tokarev pistol*	Single action short recoil
Mossberg 500 SPX*	Pump action
Springfield XDm*	Short recoil striker
Hi-Point C9*	Blowback

*denoted optional firearms for bonus points

Results

Comprehension of Course Content

In the semester where the WoG was implemented, students grasped the course material easier and showed more engagement. In their submissions for the assignment tasking students to field strip, disassemble, and reassemble the assigned firearm; the paragraph descriptions of the firearm mechanism contained rote details about the operation of the firearm. Two example paragraphs from student submissions are provided in **SUPPLEMENT #2**. The descriptions provided illustrate that the students are carefully watching the animations of the firearm operation and taking detailed note of the parts and their interactions. This understanding of the material was also evident through performance on the final exam for the course. The exam has a multiple part question: "State the action type and provide an example firearm with the illustrated mechanism." The students are presented with two to three images captured from video animations, not from the WoG, of the Colt 1911, AK–47, Glock 19, and an AR–15. The screenshots provide an overall of the firearm, a close up of the trigger mechanism, and visualizations of the gas system if applicable. These images were from when the course was not taught using WoG and were held consistent in both exams. For each section of the multiple part question, an improvement in student scores was observed after the implementation of the WoG. These average scores for each firearm in the question are provided in **TABLE 2**. It is noteworthy that the class size for each semester was sixteen students. In **TABLE 2**, the column of scores with the WoG demonstrates perfect scores for the Colt 1911 and AK–47. The sample size is significant here because the 94% scores for the Glock 19 and Colt M16 A1 indicate that one student got both of those questions incorrect; furthermore, it was the same student who incorrectly answered both of those parts of the question. These results are improved from the semester prior to implementation.

TABLE 2 *Average exam scores for questions where students have to identify the firearm mechanism and provide an example. The 'Firearm' column denotes the example firearm assigned in the World of Guns and presented in the question images.*

Firearm	Mechanism Type	Score without WoG	Score with WoG
Colt 1911	Short recoil	88%	100%
Glock 19	Short recoil striker fired	81%	94%
Colt M16 A1	Direct impingement	75%	94%
AK–47	Piston driven gas system	88%	100%

Student Engagement

Student engagement is typically difficult to quantify, especially in terms of an assignment that was primarily completed outside of the classroom. The only quantitative metrics which suggest effectiveness of the assignment are that the student evaluations of instruction (SEI) scores were slightly higher across all categories during the semester where the WoG was implemented. Additionally, in the SEI question “what features of this course most effectively helped you to learn?”, three of sixteen students specifically mentioned the assignment. Additionally, eleven of the students completed additional firearms in the section for bonus points, which might indicate engagement with the material. Anecdotally, two students mentioned that they still play the game from time to time in the semester succeeding the course.

Discussion and Conclusion

This paper introduced an assignment from an undergraduate forensic firearm and toolmark examination course which implemented the WoG game. The usage of the WoG software demonstrates the utility of game-based learning as a means to develop critical skills required for forensic science students. The usage of the WoG does not replace practical experience with firearms nor cut away guns used during the typical training of firearms examiners. However, the interactive nature of the game is an alternative in situations where the specific firearm is not in a reference collection, or an extensive reference collection is not possible. Unlike guides or videos on firearms, the method of using a simulation is much more interactive and preliminarily appears to foster deeper understanding. Merely observation of images or a video may not let the concepts be retained by the student as well as playing an active role in their own learning.

The application of the WoG enables students to digitally handle firearms, interactively view them in multiple manners (x-ray, cutaway, etc.), and fire the firearm. There are additional features within the game such as timed game modes and a high scores table which can help student master the material in a competitive way.

The results of the assignment presented show that the use of game-based learning has a positive impact on students' motivation and interest in learning, as well as increasing learning effectiveness. These findings are similar to those in the literature across other domains (9,10,12). The WoG also records user activity within the game. Steinkuehler and Squire (16) note that the ability for students to objectively track their progress through accumulated points and achieved milestones in the game is a vital concept to game-based learning known as progression. Coupling experiential learning with progression can also foster intrinsic motivation, as students have the opportunity to appreciate and acknowledge their own skill development by reflecting on their progression (16).

There are two primary limitations of this work. Firstly, there is limited supporting information as the students were not surveyed about the assignment. In the future, it would be helpful to gather additional student input on the assignment and what improvements could be made to how the WoG was utilized. It would also be useful to explore how students felt that the knowledge helped build a more concrete understanding of other course material. Secondly, the findings here are a comparison between two semesters which is a limited sample size. While it appears that the students learning was enhanced with the implement of the WoG, it must be considered that this particular course section was more engaged with the material or concept of game based learning.

As the potential need for remote or hybrid learning continues, there remains a need for alternatives to traditional course formats. These results preliminarily indicate that there is a unique opportunity to leverage technology to power new forms of game based learning in forensic science efficiently and easily. Another implication is that students have the freedom to fail in this experiential learning without consequences. For example, if a student were disassembling an actual firearm, the potential to drop a pin or lose a spring that is decompressed across the classroom is real. Finally, the usage of game based learning in this format provides immediate feedback to the students.

The demand for student-centered teaching methods to develop highly qualified learners, capable of learning in an active and collaborative environment, calls for the deployment of game-based activities and simulations. These strategies will enhance their critical thinking and develop more detailed understanding which will enable them to face contemporary challenges of the field.

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Supplement 1: Training Exercises

Reference was drawn in text to several sections and training exercises in the AFTE Training Manual (2) and the NFEA where the World of Guns software was employed to further student understanding. "*(list omitted)"* was added to several sections below with large enumerated lists for brevity by the author. These are explicitly defined below:

AFTE Training Manual

Section C. FIREARMS AND AMMUNITION DEVELOPMENT AND CURRENT TRENDS

1. Review the history of early firearms and ammunition development up to the advent of metallic cartridges, with particular emphasis on lock mechanisms, early rifling techniques, percussion systems, priming methods and pre-metallic cartridges. Prepare a chronological outline of this early development. (Training Assignment #3)

2. If possible, visit the firearm collection of a museum to observe examples of early firearms and ammunition development, paying close attention to firearms that are developmental benchmarks. (Training Assignment #1)

3. If possible, tour a laboratory's firearms reference collection noting, in particular, commercial and military firearms since the development of metallic cartridges.

Section D. MANUFACTURE OF MODERN FIREARMS

3. Select firearms from the laboratory Firearm Reference Collection (if available) to demonstrate each action listed below. Define each action and be familiar with any additional firearm actions found in the AFTE Glossary.
(list omitted)

4. Define each of the following types of firearms and explain in detail the cycle of fire. The operation of each type of firearm, including the loading of cartridges and the subsequent movement of the cartridge case and/or bullet after firing should be documented. (Training Assignment #11)
(list omitted)

5a. Explain the difference between manual, semi-automatic, and automatic operation of firearms. Give an example of each.

5b. Explain the difference between a handgun and long gun.

6. Define the following firearms parts:
(list omitted)

7. Explain and illustrate the differences between the following types of actions (Training Assignment #12)
(list omitted)

8. Numerous manufacturing methods are used in the forming of modern firearm parts. Research, identify and briefly define the listed processes using the AFTE Glossary and other reliable references. Be familiar with the tool mark patterns (both striated and impressed) that some of these processes leave on the bearing surfaces of a firearm that are in direct contact with ammunition prior to and after discharge. In addition, you are encouraged to view on-line videos for these manufacturing processes, if available. (Training Assignment #6)
(list omitted)

22. Demonstrate knowledge of the basic nomenclature of handguns, rifles, and shotguns by defining the words and terms in the list below. Discuss the manufacturing methods that may have been used to fabricate and finish each part. (Training Assignment #7)
(list omitted)

23. Research and be able to explain the various types of firing mechanics, specifically hammer and striker mechanisms found in open and closed bolt designs. Learn the internal safety mechanisms associated with these assemblies and how they function. Learn the manufacturer's nomenclature for these parts, when available, using the AFTE Glossary as needed.

27. Select a firearm and identify how the following parts of that gun may have been made. Identify high stress and low stress parts paying close attention to those areas that are in direct contact with ammunition components during cycling and firing.
(list omitted)

30. Demonstrate and explain the "cycle of fire" for each type of firearm action. Include loading, firing and unloading procedures. Attempt to use the manufacturers' specific nomenclature for each step.

31. Learn the meaning of the terms "field strip", "detail strip" and "disassembly". While in training, it is recommended that each firearm examined be field stripped. (Training Assignment #15-25)

32. Research and define the following as they relate to firearm accessories and attachments:
(list omitted)

33. internal and external safety mechanisms found in pistols, revolvers, rifles, and shotguns. Learn the manufacturer's nomenclature for each safety mechanism. The AFTE Glossary may be used when needed. Classify each safety as active or passive. Include the following:
(list omitted)

34. Research and be able to comprehensively explain to a layman the manufacturing methods of common firearm parts that are in direct contact with ammunition during cycling and firing (barrel, breech face, chamber, extractor and ejector).

National Firearms Examiner Academy
MODULE C – Evolution of Early Firearms
MODULE E – Modern Firearms Development and Operating Systems
MODULE F – Manufacture of Modern Firearms
MODULE J – Test Firing for Known Specimens and Operability

Supplement 2: Example Student Submissions

The following is a description of the operation of the Colt M16 A1 from a student for the developed assignment using the WoG.

Student #1
"The M16 A1 is a direct impingement mechanism, where the trigger interacts with the sear, which releases the hammer that strikes the firing pin through the breech face aperture and interacts with the primer of a cartridge. When the propellant is ignited, the projectile travels through the barrel in which the pressure inside of the barrel increases, and there is a compartment for the gas to travel upwards and rearward into the bolt carrier group, which separates a gas tube from the barrel and drives a spring operated slide rearward, compressing the spring and the spring drives the slide forward which strips a new round. The space created by the gas tube and the barrel allows for a lot of the pressure and gas to escape that way, allowing for easier control of recoil. Additionally, when the firearm is set to automatic, the disconnector allows the sear to move out of the way of the hammer, allowing the firearm to engage in an automatic fashion."

Student #2
"The M16 A1 was designed in 1959 and went into production in 1963. The M16 A1 was used for many years by the US military during the Vietnam War and later became the standard service rifle due to its efficiency and accuracy. The M16's A1 mechanism is a direct impingement gas system. When the trigger is pulled, the hammer is forced upward hitting the firing pin (located in the bolt carrier). The firing pin hits the bullet's primer igniting the propellant. The pressure built from the propellent forces the bullet forward through the barrel. The high-pressure propellant gasses travel down the gun barrel, through a gas block, and then through a gas tube into the bolt carrier which unlocks the bolt to cycle the action rearward. The case is them moved backward by the extractor (when the ejector spring is compressed) and then is ejected out through the hole in the upper receiver. As the bolt carrier is forced backwards it pushes the buffer back and compressed the action spring. When the action spring moves forward, the bolt carrier and buffer are also pushed forward. A new cartridge moves upward into the chamber and the gun is ready to be fired again."