

# Toward Effective Cybersecurity Introduction for High-school girls

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**Abstract.** The gender gap is one of the main concerns in the IT sector, in general, and in cybersecurity, in particular. In the last years, many initiatives were proposed targeting high-school students that may be interested in cybersecurity. Most of them rely on capture-the-flag (CTF) competitions to gradually form technical skills in an entertaining way. Despite these efforts, however, the number of girls that effectively complete these programs is still negligible. In this work, we present the results obtained by CyberTrials, a CTF-based cybersecurity program for high-school girls. The two main novelties of CyberTrials are its peculiar organization and gaming platform, which substantially differ from other similar initiatives. The preliminary results show that our methodology could effectively engage the participants

**Keywords.** education, hands-on training, cybersecurity, Capture the Flag, gender gap

## Introduction

Gender disparity in STEM fields, driven by societal stereotypes (A. H. Master et al, 2020), a lack of role models (S. González-Pérez et al, 2020), and gender-based expectations (C. Riegle-Crumb et al 2017), is a well-documented issue (D. N. Beede et al, 2011; M. Wang et al, 2017). High school experiences contribute significantly to this gap, as studies reveal obstacles faced by young women considering STEM careers (D. Card et al, 2021; J. Legewie et al, 2014). Italy exemplifies this pattern, with 56.3% female university admissions in 2020/2021, but only 21% choosing STEM courses, perpetuating this gap post-graduation. The gender gap in cybersecurity, a STEM subset, is more pronounced, with women comprising just 25% of the workforce. This hampers innovation, necessitating diverse competencies and perspectives.

To address this, diversity initiatives must begin in high school. Mentorship programs (H. Stoeger, 2013), outreach campaigns (E. Prieto-Rodriguez et al, 2022), and tailored courses (J. M. Bystydzienski et al, 2015) are vital. Yet, cybersecurity's technical nature poses challenges for hands-on experience.

We introduce CyberTrials, an entry-level, game-based cybersecurity program for high-school girls. It introduces various research areas, allowing participants to grasp technical concepts. CyberTrials incorporates hands-on Capture The Flag (CTF) sessions alongside lectures, using gamification elements to enhance engagement (F. Fui-Hoon Nah et al, 2014).

Our results show CyberTrials effectively engages participants, imparting technical skills in Linux terminal usage, network scanning, and steganography. This approach aims to bridge the cybersecurity gender gap by inspiring the next generation of female professionals.

## 1. Preliminaries

Capture The Flag (CTF) competitions involve IT challenges where individuals or teams earn points for solving security-related tasks, like decrypting ciphers or bypassing authentication. Success yields a flag submitted for scoring, with the highest scorer winning. CTFs come in various formats, primarily jeopardy-style where each challenge is independent, and flags can have fixed or dynamic values. Attack-defense (AD) style has teams managing vulnerable systems, earning points through offense and defense. Quest-style CTFs, less common, integrate challenges into a narrative storyline. Solved challenges impact the game, unlocking hints or new challenges, enriching the narrative and complexity.

## 2. The CyberTrials Program

The CyberTrials program is designed as an entry-level cybersecurity training initiative tailored for high-school girls. The program's inception occurred approximately one year ago, and the second edition has just been concluded. Here, we do not report any details from the first edition, as it is a light-weight edition of the second one.

Enrollment in the program was open to high school students affiliated with CyberHighSchools, a nationwide network of educational institutions. The entirety of the program was conducted remotely, with the exception of the final challenge, which was hosted in Turin. Participants were not required to possess technical competencies, and notably, programming skills were not a prerequisite.

### 2.1 Program Structure

The CyberTrials program aimed to provide high-school girls with foundational cybersecurity skills and a comprehensive understanding of various cybersecurity aspects. The curriculum covered areas like ethics and legal considerations, computer networks, open-source intelligence, threat modeling, digital forensics, cryptography, and social engineering. Soft skills and teamwork were also emphasized.

The program began on January 30, 2023, with an introductory meeting where participants were grouped into four-member teams. The first week focused on team-building activities to help participants get acquainted and included introductory challenges to familiarize them with the platform. From the second week, weekly two-hour online lectures covered the designated topics. Expert speakers from academia and industry led each module, and recorded sessions were provided to participants.

The theoretical aspects were complemented by hands-on training, featuring a continuous CTF competition throughout the training period. Each week introduced three new challenges of varying complexity, from easy to difficult.

A unique aspect of CyberTrials was its integration of continuous storytelling, particularly evident in the second edition's quest-style CTF. The narrative centered around an anonymous web artist seeking validation of authorship for stolen and misattributed artworks. All challenges were intricately linked to this narrative, incorporating references, descriptions, hints, and additional materials. External activities, like an Instagram account associated with the fictional web artist, contributed to the narrative's development.

## 2.2 Program Timeline

CyberTrials began on October 10th, 2022, with online registration, closing on January 15th, 2023, with 941 enrolled students. The training phase ran from January 30th to April 15th. The CTF scoreboard froze on March 13th, ending on March 27th after Module 8. Final rankings used the CTF scoreboard with tiebreakers based on the ratio of correct to incorrect submissions and the total submission time, favoring teams with fewer incorrect submissions.

The top 20 teams, announced on March 28th, participated in the final event on September 7th, 2023. This included an in-person CTF and a write-up session where teams presented their approach to solving a CTF challenge, with a committee evaluating presentations. Final rankings incorporated CTF scores and write-up points to determine the program's winner.

## 2.3 Platform

The comprehensive platform architecture is depicted in Figure 2 and incorporated the following components:

- Moodle (M. Dougiamas, 2002): Serving as an e-learning and classroom management tool, It facilitated the dissemination of training materials, including slides and recorded lessons.
- Discord (J. Citron, 2015): Employed for communication and support. After receiving invitations to join the CyberTrials Discord server, participants were randomly assigned to four-member teams upon their initial access by a Discord bot. Teams were afforded exclusive access to private Discord channels.
- CTFd: Responsible for CTF hosting and challenge provisioning.
- Instagram: Leveraged as an integral element of the quest-style CTF and for social announcements.
- WebTops: Deployed to provide all teams with a standardized, lightweight Linux environment hosted within Docker containers (S. Hykes, 2013).

Upon registration, participants received access to Moodle and Discord. Each team, through its private Discord channel, was furnished with access credentials for both the CTF platform and the dedicated Linux environment, ensuring a uniform, tailored environment conducive to their hacking activities.

## 3. Results

Edition

|    | Origin |     | High School year |     |     |     |     |     |     |     |
|----|--------|-----|------------------|-----|-----|-----|-----|-----|-----|-----|
|    | NW     | NE  | C                | S   | I   | 1st | 2nd | 3rd | 4th | 5th |
| I  | 17%    | 39% | 28%              | 6%  | 10% | 13% | 18% | 29% | 29% | 11% |
| II | 23%    | 23% | 16%              | 28% | 10% | 6%  | 8%  | 43% | 29% | 14% |

Table 1: Participants data of the two editions.

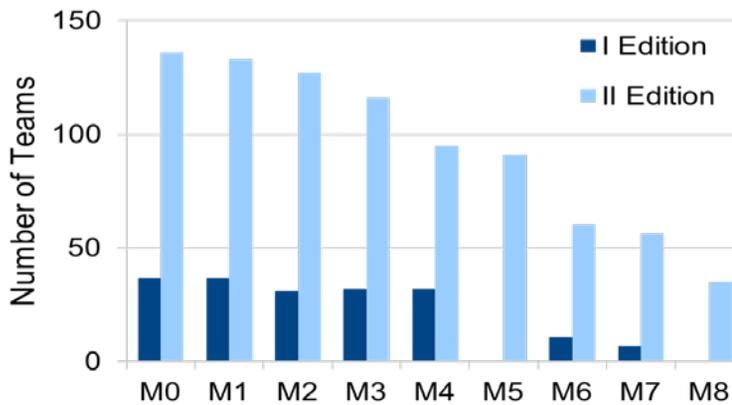
Table 1 presents aggregated data on program participants. In the second edition, participants were more evenly distributed across regions, whereas the first edition had a concentration in the northern part of the country (56%). Finally, 51% comes from a lyceum, while 49% is from a technical institute. Participation in challenges was monitored first with weekly reports on inactive members, then with warnings for inactivity, and finally excluding repeat offenders. Teams with two or fewer members were merged weekly.

| Edition | Enrolled | Lecture |      | Challenges |      |
|---------|----------|---------|------|------------|------|
|         |          | First   | Last | First      | Last |
| I       | 378      | 189     | 51   | 181        | 31   |
| II      | 941      | 557     | 340  | 440        | 379  |

Table 2: Number of participants in the two editions.

Table 2 compares attendance in last year's (I) and this year's (II) CyberTrials editions. Initial dropout matched the expected 40%, with 41% in the last edition. Lecture attendance increased from 26.9% to 61%, while challenge participation remained stable at 86%. This supports the proposition that the competitive aspect (challenges) was more engaging than lectures, as seen in the drop in participation (16.5%) after the qualification for the final.

Fig. 1  
Students attendance during the two editions.



Overall, 139 teams participated, with 26 teams merging and 4 disbanding due to member defection. Figure 1 illustrates the active teams' engagement across program weeks. A notable difference between editions is the dropout rate. The first edition saw a stable participation until week 5 (M4), whereas the second edition had a more uniform decline, with the highest reduction between M5 and M6 (-23%).

Program effectiveness was assessed through pre-and post-program questionnaires. Most participants found lectures (92%) and challenges (90%) interesting and challenging (92% and 81%, respectively). Notably, 65% considered the challenges to be moderately com-

plex, aligning with participants' initial skills.

To conclude, 12,467 flags has been submitted through the CTF competition, equivalent to 9.5 flags per hour, considering day and night, weekdays and holidays.

#### 4. Conclusion

In this article, we introduced the CyberTrials program, its gaming infrastructure, and the key outcomes observed in its initial two editions. Despite being in its second iteration, CyberTrials has demonstrated remarkable promise in terms of its appeal and efficacy in acquainting high-school girls with the field of cybersecurity. This achievement is the result of a methodical examination of the program's content and meticulous planning of its gameplay, centered around a quest Capture The Flag (CTF) format.

In conclusion, we emphasize the significance of initiatives like CyberTrials, not only for fostering interest and proficiency in cybersecurity but also for addressing the broader skill gap in computer science.

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