Cybersecurity Education Podcasts: A Framework for Effective High School Instructional Design

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ABSTRACT
Podcasts, hosted by industry experts, have emerged as a popular medium for learning, offering valuable insights on various topics. With a growing emphasis on information security and cybersecurity, the demand for educational cybersecurity podcasts is rising. This paper explores the potential of utilizing cybersecurity podcasts as an effective educational tool, particularly for High School students. Recognizing the need for cybersecurity awareness and skills at an early stage, the study presents a learning methodology and framework based on Webb's Depth of Knowledge (DOK). By implementing the four stages of the DOK Framework, the study demonstrates how to create an educational cybersecurity podcast that aligns with educational objectives. This paper serves as a comprehensive guide for developing cybersecurity podcasts as a valuable learning resource in High School education, aiming to equip students for a secure digital future and potential careers in cybersecurity.

Keywords
Cybersecurity Podcasts, Educational Framework, High School Education, Webb's Depth of Knowledge, Learning Methodology

1. INTRODUCTION
The rise of cybersecurity education podcasts is meeting a growing demand for upskilling or reskilling in the secure information profession. This surge underscores the necessity for cybersecurity training, extending even to High School students. The goal is to educate them on maintaining vigilance in the digital realm and to introduce cybersecurity as a potential career path. Extensive research over the years has confirmed the potential of podcasts as effective learning tools in the realm of education.

1.1 Cybersecurity
In the last decade, the significance of cybersecurity has experienced an exponential increase. Cabaj et al. highlight this by stating, "Owing to the huge impact cybercrime has on the economy and safety of organizations and countries, the importance of cybersecurity has grown to such a level that it is now considered an independent discipline" [1]. Despite the soaring demand for skilled individuals in organizations, the available pool of expertise in the field remains relatively small. The National Institute of Standards and Technology (NIST) reports that the cybersecurity workforce comprises over 1 million people, yet more than 660,000 vacant positions need qualified personnel [2].

To bridge this gap, cybersecurity training is crucial in educating individuals across various domains, empowering them to stay vigilant against cyber threats and prevent involvement in such activities. Recognizing the knowledge deficit, engineering colleges have introduced specialized degree programs aimed at preparing students for the workforce upon graduation. Parrish et al. observe in their paper that the recent evolution of cybersecurity indicates its transformation into a genuine academic discipline, moving beyond being merely a training ground for specific specialized jobs [3].

1.2 Podcast
As stated by Sherry et al. Podcasting represents one of the latest applications of Internet technology, with the term itself being a blend of "iPod" and "broadcast," where "iPod" refers to Apple Inc.'s family of portable MP3 players, and "MP3" signifies a common file format for electronic audio files [4]. Podcasts cover diverse genres, such as news, arts, education, comedy, society, culture, medicine, and more. In the last decade, podcasts have experienced exponential success, as noted by Molenaar, K [5].

The podcast landscape now includes over 3 million podcasts with more than 460 million listeners, constituting approximately 22% of all internet users. The most popular global podcast genre is Society & Culture, with over 530 million podcasts, closely followed by Education with over 480 million podcasts [5]. This underscores podcasts as a valuable source of educational content. Pew Research further highlights the changing trends, indicating a decline in radio listenership from 83% in 2020 to 47% in 2022, while podcast listenership has increased from 37% in 2020 to 42% in 2023 [6]. This emphasizes the organic appeal of podcasts and their potential to expand the audience for educational content. Figure 1 provides an illustrative example of a cybersecurity podcast, as referenced in [30]. In this paper, a framework is designed and adopted for podcasts to create an impactful educational podcast, specifically to assist High School students in cybersecurity training.

Figure 1. Example podcast – Hacking Humans [2].

2. PODCASTS IN EDUCATION

Based on the statistics provided by Molenaar, K.'s [5] article in the introduction of this paper, it is understood that the audience is interested in listening to educational podcasts. There is a potential to use podcasts as an educational resource for High School students' cybersecurity training. Further in the article, Molenaar K. mentioned that in a 2022 study on podcast consumption in the US, 59% of millennials reported listening to a podcast in December 2022, and Gen Z also showed a strong interest, with 63% consuming podcasts in October [5]. In another similar study in 2021 in Hungary, Medve, F. says that listening to podcasts was a more popular activity among the younger generations of Hungarians. One-third of weekly podcast listeners were aged between 18 to 29 years old, while only six percent of the weekly podcast audience was over 59 years old [8]. In a survey conducted across eight Asian countries in July 2022, almost half of all millennial respondents stated that they listened to podcasts for at least one hour a day. Among baby boomers, the share of respondents listening to at least one hour of podcasts daily amounted to 37 percent [9]. This confirms that the younger demographic of people is interested in listening to podcasts, and this can be a great source of educational resources. Goldman said in their article about the impact of podcasts in education that "if music is inspiration and radio is theater for the mind, then podcasts are the exploration of the human intellect. In today's world, anyone with the necessary technology can create and consume voice media." [9].

The prominence of digital education has increased in recent times. The world is going digital, and educational institutions prefer online education so that students can learn the latest technologies, stay up-to-date, and be ready for their future. The digital revolution has enhanced distance education opportunities. Institutions are also encouraging online studies for maximum participation of students. In their empirical study, Merhi mentions that "online and mobile learning (m-learning) tools have become widely applied forms of e-learning and/or hybrid learning by educational institutions" [10]. With the increase in the popularity of digital education, podcasts can be used to create engaging and lively course content for High School education. Tavales & Skevoulis said, "Podcasts are better e-learning tools" [11]. This digital resource can be accessed from anywhere and from any device. Podcasts can help in the student's general and domain knowledge development. With several podcasts created to serve the interests of various cognitive complexities, this tool can be a solution to enhance the education system. Vodcasts or video podcasts have also gained popularity due to the mix of video and audio content that appeals to the audience. According to Judge A. L. in their article say that "The Annual Report from Riverside. fm disclosed that 85.4% of businesses are utilizing video in their podcast productions"[12] which shows that digital medium is being widely used and accepted. Podcasts are popular and have an audience and hence can be utilized as a medium for High School Education.

Podcasts are a great alternative to the standard "online-focused" teaching approach where the course is delivered using online lecture videos and the student's understanding is tested using online quizzes and assignments. This is because podcasts allow students to engage in passive learning, where they get to grasp knowledge without demanding their active engagement, which can be overwhelming for them. Podcasts enhance imagination and critical listening skills, which will play an important role in the student's higher studies or professional development. This learning resource can be more relatable due to its storytelling and self-paced learning methodology and will help students understand concepts using real-world examples.

3. WEBB'S DEPTH OF KNOWLEDGE

Webb's Depth of Knowledge, commonly referred to as DOK, is a framework developed by Norman L. Webb in 2002, utilized in curriculum development and student assessment. While Benjamin Bloom's taxonomy has been the predominant framework since 1956, the DOK framework by Norman L. Webb has garnered attention from High School educators since the late 1990s. Unlike Bloom's taxonomy, which is rooted in the psychology of the student, Webb's framework is centered on the curriculum of the subject [7].
This framework aids in classifying the complexity and cognitive requirements of various learning tasks and objectives. In their paper, Hess et al. discuss the comparison between Bloom's and Webb's frameworks, noting that "Webb's work has compelled states to reconsider the meaning of test alignment, encompassing both the content assessed in a test item and the intended cognitive demand, or the depth at which we expect students to demonstrate understanding of that content" [7]. Webb characterizes his framework as nominative rather than taxonomic, wherein the complexity of the content and the task determine the DOK levels (Figure 2).

Webb's Depth of Knowledge Framework consists of four levels, each representing a distinct degree of cognitive complexity. Learning objectives, content, activities, and assessments are organized according to the appropriate level.

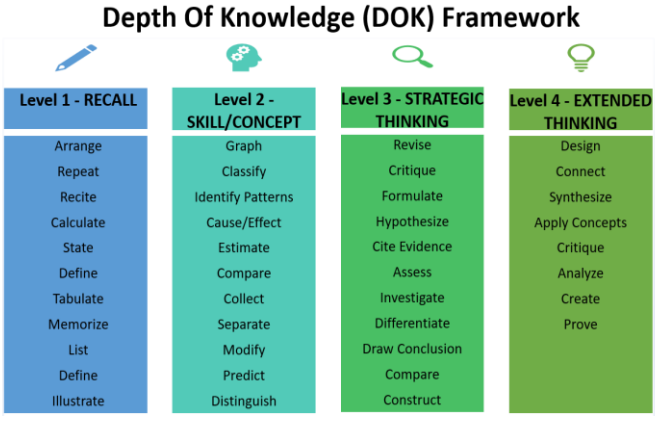

Figure 2. Depth of Knowledge (DOK) Framework

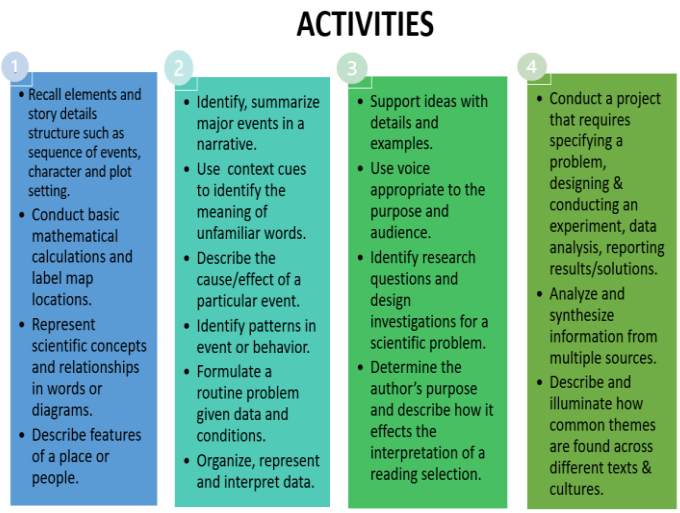

Figure 3. DOK Activities in different levels

3.1. DOK-Level 1: Recall and Reproduction

This level entails the retrieval of information, facts, terms, concepts, and routine procedures. It involves tasks that can be answered through reference, requiring a low level of information processing. The expectation is that students should perform these tasks automatically, making up to 30% of the curriculum, depending on the grade.

3.2. DOK-Level 2: Skill/Conceptual Understanding:

This level demands a deeper comprehension of concepts, involving responses to routine queries by connecting more than one idea in familiar situations, such as interpreting simple graphs. It requires the use of information and conceptual knowledge to select an appropriate procedure involving two or more steps to complete a task. Skill constitutes 40% of the curriculum.

3.3 DOK-Level 3: Strategic Thinking/Reasoning

This level necessitates complex thinking for justifying responses to solving non-routine problems. Students are required to develop a plan or sequence of steps to approach a problem, often with more than one possible answer. Strategic thinking, covering about 20% of the curriculum, involves applying knowledge to solve new challenges.

3.4 DOK - Level 4: Extended Thinking:

This level represents the highest cognitive complexity, demanding creative and critical thinking to address multiple conditions of a problem or task. It involves research, reflection, and time to consider all potential options while solving projects or research assignments. Tasks at this level have high cognitive demand and typically involve collaboration with others to explore solutions, covering about 10% of the curriculum.

Key insights validating the effectiveness of this framework include:
(a) All levels are significant, and they do not follow a linear progression.
(b) Each level holds its importance.
(c) DOK emphasizes cognitive demand rather than difficulty.
(d) DOK is contextual and focuses on the depth of thinking, as opposed to relying on verbs as seen in Bloom's Taxonomy.

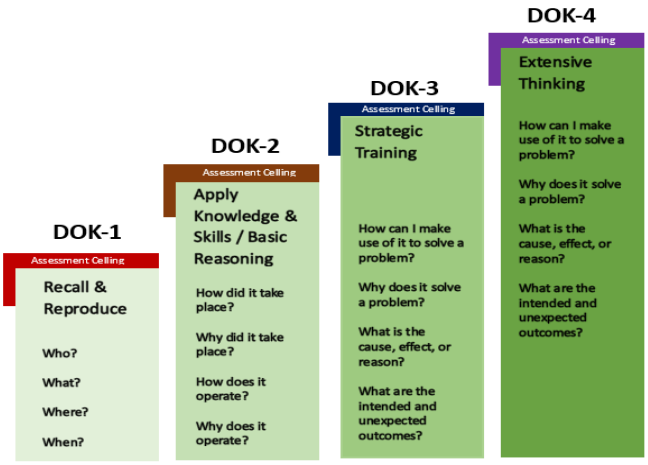

Figure 4. Illustrates distinct levels alongside learning analytics questions

4. PODCASTS: SELECTION AND ANALYSIS

While numerous cybersecurity podcasts are available on the internet, the careful selection of podcasts is crucial for analyzing the current topic. Nine articles from reputable websites were chosen, providing insights into popular cybersecurity podcasts. The selection criteria included the following conditions: a podcast was chosen if it met at least two of the following criteria:
1. Provides information about the cybersecurity field.
2. Conduct an in-depth analysis of a topic, news, or concept related to cybersecurity.
3. Recommend solutions for the career development of cybersecurity professionals.
4. Produced or hosted by a reputable organization or institution.
5. Promotes representation, ethics, and credibility.
6. The podcast is recommended by at least two websites as a popular choice.
The sources used for selection and analysis are referenced in the reference section, identified as [13], [14], [15], [16], [17], [18], [19], [20], [21], and [24]. The list of podcasts analyzed to identify improvement areas in cybersecurity podcasts is presented below, arranged in decreasing order of the total number of episodes for clarity. The evaluation focused on the episode format, podcast type, concept connection, approach taken by the hosts, and episode organization. However, a detailed assessment of content correctness and authenticity was not conducted, as this paper specifically concentrates on the podcast's model and structure.

Table 1. Selecting and Analyzing Podcasts

#	Podcast	Description	Weblink	Host	Total Episodes
1	CyberWire Daily	Published each weekday, this podcast provides daily news of cybersecurity and host	https://thecyberwire.com/podcasts/daily-podcast	Dave Bittner	1883

		interviews with experts from industry, academia, and research organizations across the world.			
2	Security Now	Discussion of the latest topics in security today.	https://twit.tv/shows/security-now	Steve Gibson and Leo Laporte	934
3	Risky Biz	A weekly podcast that features news and in-depth interviews with security industry luminaries.	https://risky.biz/	Patrick Gray	718
4	7-Minute Security	A weekly podcast that focuses on penetration testing, blue teaming, and building a career in security.	https://7ms.us/	Brian Johnson	584
5	Unsupervised Learning	A Security, AI synergy podcast that explores the intersection of security, technology, and society.	https://podcasts.apple.com/us/podcast/unsupervised-learning/id1099711235	Daniel Miessler	393
6	Smashing Security	A weekly podcast that discusses cybercrime, hacking, and online privacy.	https://www.smashingsecurity.com/	Graham Cluley and Carole Theriault.	334
7	The 443	As part of the WatchGuard brand, this podcast provides simple, clear, and understandable information to IT professionals and business leaders.	https://www.secplicity.org/category/the-443/	Marc Laliberte	254
8	Hacking Humans	A weekly podcast that details social engineering scams, phishing schemes, and criminal exploits that are affecting organizations around the world.	https://thecyberwire.com/podcasts/hacking-humans	Dave Bittner and Joe Carrigan	254
9	Malicious Life	A podcast by Cybereason explores cybersecurity incidents from history with comments and reflections by real hackers, security experts, journalists, and politicians.	https://malicious.life/	Cybereason	221
10	The OWASP Podcast Series	A non-stop cybersecurity podcast that hosts interviews with volunteers and security leaders provides education and thought leadership for better web app security	https://soundcloud.com/owasp-podcast	Jim Manico and Mark Miller	184

5. CYBERSECURITY EDUCATION PODCAST FRAMEWORK

In an article from the University of New England, it is noted that Bloom's work primarily focuses on student action, addressing the "what" of learning, while the Depth of Knowledge (DOK) framework, specifically Webb's DOK, emphasizes the "how" [22]. This section explains the DOK framework for cybersecurity education.

5.1 DOK Framework for Cybersecurity Education

This framework aligns with Webb's Depth of Knowledge and serves as a guide for creating a High School cybersecurity educational podcast. It is designed based on a curriculum that assesses and enhances various levels of cognitive complexity in learning cybersecurity concepts, aiming to enhance students' overall cybersecurity knowledge. All four stages of this

framework can be implemented within a single episode, or each stage can be dedicated to a separate episode, with progression from one stage to the next in subsequent episodes. Adhering to this framework ensures a structured approach to imparting knowledge, providing students with a comprehensive understanding of a specific topic or cybersecurity as a whole – the ultimate goal of cybersecurity training and education.

The first level aims to make students cyber-aware, and the second level provides a comprehensive knowledge of the field, aiding in better understanding and facilitating career decision-making in cybersecurity. The third level helps students grasp organizational management processes, preparing them to think about an organization's overall cyber posture. The fourth and final level serves as a pathway to comprehend and advance in academia and research studies within the realm of cybersecurity.

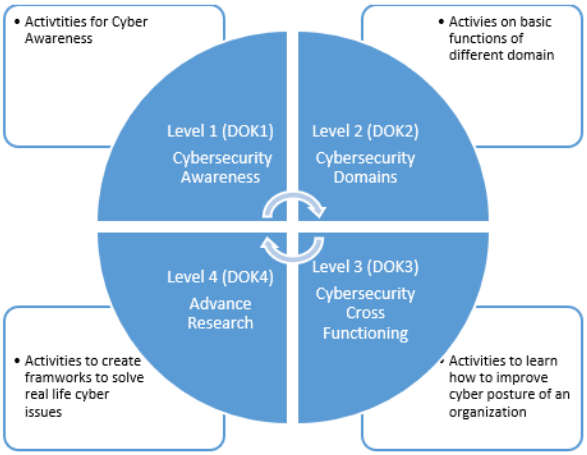

Figure 5. Cybersecurity Education Framework for Podcasts

5.1.1 Level 1 (DOK1) - Cyber Awareness

In this initial stage, the podcast should focus on topics related to cybersecurity awareness. This encompasses fundamental terms used in cybersecurity, such as definitions, phishing awareness, social media security, encryption, safe internet usage, malware and ransomware, data privacy, and other foundational concepts within cybersecurity education. Given the basic nature of these concepts, the cognitive effort required is minimal. The host can employ various approaches, such as storytelling or interviews, using question stems to address different aspects and facilitate easy understanding and recall. Activities can include questions that prompt internet research for answers or provide open resources for testing knowledge on cybersecurity awareness. Engaging in activities like fun games, crosswords, word games, and basic quizzes can effectively convey the required knowledge.

5.1.2 Level 2 (DOK2) - Cybersecurity Domains

In the second stage, the podcast should delve into overall cybersecurity domains. This involves imparting information about various domains, covering their functions, processes, procedures, and products in cybersecurity. Students will gain a holistic understanding of the differences between concepts, exploring how these domains interconnect to form a cohesive whole. While the complexity surpasses the awareness level, it doesn't require extensive thinking. Activities can include questions that demand the use of information and conceptual knowledge and selecting an appropriate procedure involving two or more steps to complete a task. This stage may feature comparison questions, domain quizzes, constructing concept maps, and identifying patterns based on open-source incident data sets. Open-source materials challenge students to interconnect concepts, necessitating interpretation rather than simple online searches.

5.1.3 Level 3 (DOK3) - Cybersecurity Cross-Functioning

In the third stage, the podcast should cover the interrelationship of different domains and their role in maintaining an organization's cyber posture. This includes information about frameworks, methods, and processes ensuring smooth interoperability across domains. Students will learn to secure organizational networks, address diverse scenarios, and think like cybersecurity professionals to uphold the cyber posture. Activities at this level may involve advanced questions requiring the use of various knowledge sources to solve non-routine problems. This can include formulating strategic plans, constructing designs, and developing logical arguments to address scenarios or situations. Advanced question stems, quizzes, performing proof of concepts (POCs) for different products, conducting assessments, and implementing cybersecurity processes are valuable activities for this stage.

5.1.4 Level 4 (DOK4) - Advanced Research

The fourth and final level focuses on instilling a research-based approach in students. This involves identifying gaps in the cybersecurity field and exploring ways to address them. Students engage in discussions with peers to devise solutions, build models, and develop new frameworks. This level demands the highest cognitive effort from students, fostering an understanding of how to innovate in addressing cybersecurity challenges. Activities may include analyzing existing models, identifying gaps, and synthesizing approaches or new frameworks to create innovative solutions. This level provides students with insights into the workings of cybersecurity academia and research, helping them determine if this could be a potential career path. Considering the high school context, the framework need not be exhaustive but should present a foundational idea with a detailed plan, outlining the technologies used to address cybersecurity challenges.

Based on this framework, sample stem questions are created by the authors and published on the web so that they can be used in structuring and providing an effective cybersecurity podcast that can be utilized for high school cybersecurity education. [31]

The Course Learning Objective (CLO) of a high school basic cybersecurity course are as follows:
CLO1. Foster interest in innovative cybersecurity and secure computing topics.
CLO2. Enhance awareness of cybersecurity to ensure that all students grasp appropriate and safe online behavior.
CLO3. Promote diversity within the cybersecurity workforce.

According to [23], it is emphasized that the depth-of-knowledge (DOK) demands for these CLOs should be regarded as the "ceiling" rather than the "target." Table 1, based on the CLOs for a basic cybersecurity course designed with precision, illustrates the alignment of CLOs with the high DOK levels at which the learning objectives will be assessed.

The table below illustrates how the DOK(s) can be referred to different activity levels.

Table 2. Course Learning Objectives

CLOs	Ceilings		DOK (s)
1	Increasing interest		1
2	Ethics, safe online use		1, 2, 3
3	Improving diversity in the cybersecurity workforce		1, 2, 3, 4

6. USE CASE

This case study was conducted in a high school in India, with about fifty students participating in a survey. Most students indicate familiarity with terms like "cybersecurity," "cyber-attack," "hacking," "virus," and "malware." They answered five questions related to the podcast, summarized in Table III. To enhance usability, responses were measured on a Likert scale (very easy to very hard), as shown in Table IV. Table V presents the frequency of student responses. Data analysis produced a radar plot (Figure 6) and box plots (Figure 7). These figures indicate that students found the learning activity highly relevant and focused (Q4, Q5). The survey form and the podcast based on the DOK framework used for this use case can be accessed as they are open source [25][26][27] [28] [29] [30]. While the timeframes for the list of podcasts provided earlier in this paper are varied, it is observed that listeners prefer shorter podcasts if they want to get a quick overview of a topic, while listeners prefer elaborate podcasts if they seek a detailed perspective from a subject matter expert in the field. For this case, we focused on providing an overview of a topic and used a podcast with a short timeframe.

Table 3. Cybersecurity Podcast Questions

Question numbering	
Q1.	How difficult did you find learning cybersecurity through this framework?
Q2.	How complex did you find learning cybersecurity concepts?
Q3.	How clear did you find the learning process?
Q4.	How relevant was the learning to your current studies?
Q5.	How focused were you while completing this activity?

Table 4. Variable Likert Scale

Response Criteria	
Criteria A	Very Easy/Very Clear/Very Relevant/ Very Focused
Criteria B	Easy/Clear/Relevant/Focused
Criteria C	Neutral
Criteria D	Difficult/Complex/Slightly Confused/ Slightly Relevant/Slightly Focused
Criteria E	Very Difficult/Very Complex/Very Confused/ Not Relevant /Not Focused

Table 5. Selecting and Analyzing Podcasts

	Criteria A	Criteria B	Criteria C	Criteria D	Criteria E
Q1	12	15	18	3	4
Q2	10	15	21	3	3
Q3	13	17	15	5	2
Q4	9	23	9	5	6
Q5	14	24	9	3	2

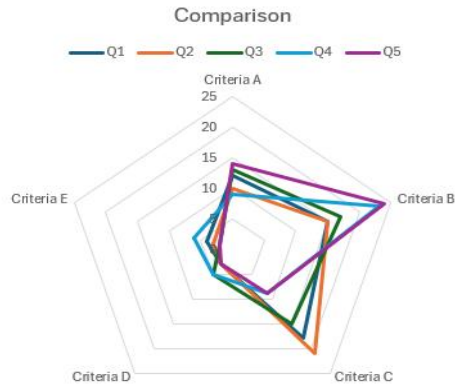

Figure 6. Radder plot on Students' Responses

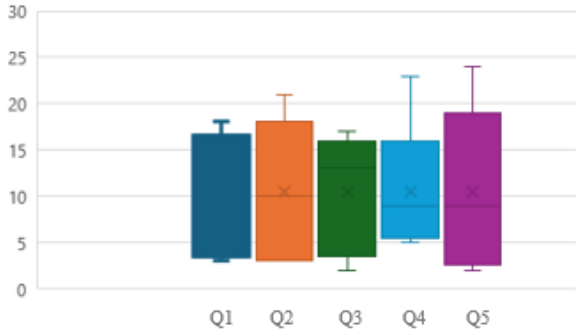

Figure 7. Box Plot of Students' Responses

7. DISCUSSION

Upon reviewing the aforementioned cybersecurity podcasts and student responses to the survey questions, as mentioned in the above use case, several areas for improvement in the overall organization of podcasts have been identified:

7.1 Structure

Many podcasts lack a consistent format or structure. Only a few present their content in a sequential, chronological, or easily understandable format for listeners.

7.2 Connecting to Concepts

Podcasts tend to be more experience-driven without connecting back to fundamental concepts. While organizational terms may vary, the underlying concepts are often universal. Connecting terms back to these concepts enhances overall understanding and illustrates their application in various organizational contexts.

7.3 Future Trends and Innovation

While information on topics is provided, in-depth discussions on future applications and how to achieve them are often lacking. Delving into these aspects can foster a research-oriented thought process among listeners, leading to innovation for improved solutions in the cybersecurity field.

7.4 Credibility of the Podcast

The absence of a reference framework makes it challenging to assess the credibility of podcasts. Establishing a framework for evaluation can help determine whether podcasts meet the educational requirements of cybersecurity training.

7.5 Simplicity in Technical Topics

Conversations within podcasts are often intricate and may not address basic technical topics. This complexity hinders understanding, impacting the learning experience. Podcasts should strive for simplicity in presenting technical topics, making them easy to understand and connecting them to different concepts to provide a comprehensive understanding.

7.6 Engagement with Audience

It is vital for recognizing and understanding the target audience. Tailoring the content to meet the needs and understanding ability of the audience is essential to guide the depth, flow, and humor in the podcast. This also arouses interest and increases the likelihood of a transition toward digital education learning platforms.

7.7 Adapting Content for the Platform

Educational podcasts significantly differ from traditional classroom teaching. It is essential to leverage its unique strengths by utilizing vivid imagery, compelling audio elements, and thought-provoking questions. The content and delivery must create a clear picture.

The study was primarily focused on evaluating the effectiveness of the framework in teaching cybersecurity to high school students and created cognitive mapping questions to evaluate the student's preferences for using this framework.
From the real-world use case that was conducted based on the online survey of high school students, we can see that on average, more than 85% of the students did not find learning through this framework difficult or very difficult and have agreed that this learning process helps them and is relevant.

8. CONCLUSION

In conclusion, podcasts have emerged as a popular and growing medium, with research indicating an increasing listenership that positions them as valuable sources of educational content. This paper has contributed by introducing a cybersecurity education framework designed for podcasts, grounded in the well-established educational framework, Webb's Depth of Knowledge, along with an empirical study evaluating the effectiveness of this framework in implementing within a podcast for high school cybersecurity education. The development and operationalization of this learning methodology to improve student engagement through multimedia elements, interactive learning, and utilizing gamification techniques, such as will be presented in the upcoming extension of this journal paper. This research intends to further validate and refine the proposed framework for other subject domains while also providing valuable insights for the ongoing evolution of cybersecurity education through podcasting

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