Active Learning to Find the Key to Unlock Your Laptop

Marián Queiruga-Dios
Universidad Francisco de Vitoria
Pozuelo de Alarcón, Madrid, Spain
marian.queiruga@ufv.es

Farrah Kristel Battista, María Jesús Santos Sánchez, Araceli Queiruga-Dios
Universidad de Salamanca
Salamanca, Spain
farrah.batista, smjesus, queirugadios@usal.es

***Abstract*—Higher education students are usually not familiar with active learning, especially students from degrees not related to education. This is not the case of primary and secondary education students, that have been involved in several active methodologies during their studies. This paper presents a game-based learning proposal that was implemented during a cryptography outreach session with high school students and with third-year students from computer science undergraduate degree. Both groups were separately involved in the activity, and they found the solution of all riddles and problems. Students' behavior was similar, as all of them were engage with the game, where they learnt cryptography, while they were engaged in the active learning session acquiring transversal and specific skills.**

I. Introduction

The use of different pedagogical approaches, active methodologies, or efficient ways to involve students are widely spread in pre-university education [1]. This is not the case of undergraduate degrees at university, where such proposals are common in some degrees but less extended in science and engineering. These methods could help in the development of students' learning processes.

The common European higher education area implies a way of teaching and learning where competencies represent the central axis of the new system that promote student-centered learning. This means that it is no longer enough for a student to only learn technical or specific contents. In this framework, students must also acquire a series of competencies that guarantee that they are capable of effectively and adequately engage in the work for which they are prepared. Competencies could include essential skills, knowledge, and attitudes that students would require in their future careers and their professional development [2]. In any case, specific contents are of course still necessary and essential, although they acquire a practical and applicable nature. To achieve such a transformation in the educational system, teachers must adapt their way of teaching to the new needs. Moreover, the European common space defined the students' qualifications in terms of learning outcomes but not contents.

In education, as well as other contexts, a meaningful experience can remain in the student's memory and heart for much longer than the time performing the activity. In experiential learning or experience-based learning, students experiences occupy a central place in the entire teaching and learning processes. The experience may come from events in years prior to university studies or from the current moment in their lives or from their participation in activities with teachers and other students. Activities that are done out of classes are part of student's contexts [3].

Students, teachers, and any person are learning all the time. Students and faculty learn inside but also outside of classrooms, and during and after training activities; they learn from books written by scholars but also from conversations during their leisure time, from watching an instructional tutorial but also from looking at a painting or observing nature or playing a video game [4]. Several learning styles allow the achievement of competencies, which constitute a motivational force and is limited by individual's perceptions [2].

The use of technology, such as computers or mobile devices, and the implementation of active methodologies or pedagogical approaches such as game-based or service-learning for educational purposes enhance cognitive processes and provide competency-based learning [5].

Active learning pedagogy is a student-centered process where students are engaged in activities and tasks that pushes them to be active, to think and reflect about what they are doing and how they are learning and acquiring competences. This approach forces students to be involved in their own learning process. Students establish their own goals for learning in student-centered learning opposite to traditional teacher-centered instruction [6].

Teamwork, problem and project-based learning, or technology-enhanced learning are some approaches that promote active learning while students work to solve a problem, question or issue established by the teacher who acts as guide and facilitator. These activities engage students and lead to students' interaction in a collaborative environment, where they must take decisions increasing their self-governance and autonomy. Engineering and science students are familiar with collaborative work while learning in a laboratory, solve problems using a specific software or trying to understand a difficult concept. These students use to ask for help from their fellows and on less occasions to teachers [7].

From existing knowledge, students go step-by-step actively constructing and increasing their own knowledge [8].

Game-based learning (GBL) is an active-learning method that is widely used in primary and secondary education, but this is not the case of higher education, where most of the teachers prefer traditional classes. Depending on the degree and the course, it is gaining ground because teaching-learning methods are changing, and current students are different every new year

ISSN 2305-7254

(with different needs from students from 5, 10, 20, etc., years ago).

Engagement could be defined as the simultaneous occurrence of absorption, concentration, attention, interest, and enjoyment. The engagement includes behavioral, cognitive, and emotional dimensions. Learning performance is highest when students are motivated and with the desire of being involved in learning activities. To increase students' engagement and immersion in GBL becomes a way to optimize learning elements such as challenges and skills [9], [10]. Interesting activities lead students to concentrate and elevate enjoyment during those activities. Furthermore, cognitively complex, and challenging activities engage students more deeply and reflection lead to long-term learning [11].

The type of game including in this study belongs to escape games, which offers an immersive experience working in groups in a cooperative manner. This game promotes and improves creativity, learning immersion, leadership behavior, problem-solving skills, etc. The game can be organized in different ways. The most common way is a sequential or chain structure in which a linear flow allows go one step further after solving one puzzle, until the final challenge can be solved. Other structures go from the open one where different riddles can be solved at the same time, to a structure with several independent paths or a complex pyramidal structure [12].

The game defined in this paper was conducted with two different groups of students. The first group was made by high school students as part of the research and excellence baccalaureate (BIE in Spanish). Within the different baccalaureate modalities, the BIE has been launched in 2013. Its main difference with other baccalaureates is the close collaboration with different university departments. The purpose of the BIE developed in the community of Castilla y León is to stimulate autonomous learning, teamwork and interest in knowing different methods and techniques of research, in direct collaboration with university teaching and research staff. The BIE incorporates one course per year subjects (in a two-years Baccalaureate), the first one is an initiation to research and a research project in the second year. Conferences, workshops, laboratory practices, visits to centers, etc. are the different formats of the courses [13].

The second group that participated in this game was made by students from the 6-credits course of cryptography, an optional subject for third-year Computer Science undergraduate degree students. This course content is the following:

- Introduction and preliminary concepts
- Mathematical fundamentals
- Private key encryption protocols
- Public key encryption protocols
- Digital signature and hash functions

The remainder of this paper follows the following organization: Section II include a brief overview of related work, Section III introduces some topics and history about cryptography, which will help to understand the game proposed to students, Section IV is about all aspects of the game, how it was designed, and which encryption methods were used. Finally, conclusions of a game-based learning session were included.

II. Related work

The use of games for learning brings several positive behaviors: students combine topics and competencies from different areas of knowledge, which allows them to find a solution to a given problem; they can test how changes during a game cause changes in the outcomes; they work and discuss with their fellows to win the game achieving the goal, while improving their social and teamwork skills [14].

Creative and innovative teaching, such as GBL is used in nursing professional development practitioners [15], surgical education [16], computer science [17], mathematics [18], physics [19], etc. We have noticed that in recent years, the use of games for educational purposes is increasing, even at science and engineering subjects. Creativity, interactivity, rules, goals and overcome the challenges while learning are some characteristics of GBL. The level of difficulty depends on the students' level and the learning outcomes that are integrated in the riddles [14].

The use of riddles and puzzles based on cryptography and information coding is really useful when proposing a game. Currently, and due to the widely use of smart devices for digital communication and electronic data exchange, security threads and the importance of protecting devices is on everyone's lips. To avoid loss of information or devices damage, cryptography emerges as the desired solution. On the other hand, this field has been always known as the way to hide "things", i.e., messages and information that must be invisible to eavesdroppers. The need for cryptography to provide procedures and keys to protect information becomes vital [20].

Several papers can be found in the literature about serious games to learn cryptography and data security. An online escape game where students must escape from a room containing a trash can, a printer, a laptop, and other objects, was proposed in [21]. Student's avatar moved along the room interacting with those objects.

In the case of Borrego et al. [22] students use their knowledge about cryptographic protocols and security in computer networks to find a password to unlock a laptop. They found part of a private key that allowed them to decrypt a message and they had another challenge about network sniffing.

QuaSim is an online 3D-game with tutorials and quizzes related to quantum cryptography, with lessons about quantum communication and quantum key exchange protocols [23].

A different type of games for learning is Crypto Go, a card game lo learn symmetric cryptography. With a set of 108 cards, the goal of the game is to collect certain special sets of cards, about one cryptographic protocol (stream or block ciphers, hash functions, message authentication codes, etc.) [24].

Recenty, a 2D top-down puzzle adventure called SherLOCKED was proposed to practice about data confidentiality, integrity, and availability. In this game students have the role of a detective that moves inside a house interacting with the objects and looking for clues. They have to answer questions related to the course contents and solve several riddles and try to solve a crime [25].

III. Some tips about cryptography

As is well known, cryptography includes methods and techniques to create confidential messages that could be sent through secure communication systems. Cryptography aims to safeguard confidentiality, data integrity, authentication, and non-repudiation of information. Usually, the terms cryptology, cryptography and cryptanalysis are often confused. In this sense, cryptology is the science of secret communications, i.e., the discipline that takes care of the study of hidden messages. It is divided into cryptography and cryptanalysis; whereas cryptography is dedicated to the creation of secure messages, cryptanalysis focuses on the breaking of such messages [26].

Historically, cryptography has been used at least 2500 years ago up to the present, and this history could be divided into four periods, pre-scientific, classical science, transition phase from classical to modern science, and modern cryptography [27]. In each of these periods, cryptosystems have been created, starting with the most basic ones to the most complex ones today.

A cryptosystem, also known as cypher method or encryption algorithm, consists of the encryption and decryption algorithms used to transform a plain text into a cypher text, and vice versa, using a secret key [28].

The pre-scientific period extends from the ancient civilizations of Egypt, Mesopotamia, China, Greece, and Rome, to the end of the 17th century. The cryptosystems of this period were empirical and very simple; the best known is the Julius Caesar monoalphabetic shift cypher, a type of a substitution cypher, which consists of replacing a letter by the letter three positions ahead in the alphabet order; this cypher was very useful in the wars of Emperor Julius Caesar, but nowadays it is effortless to decipher [29]. At this stage, modular arithmetic is useful to understand shift ciphers, which are obtained by shifting the alphabet by a fixed amount.

Later, substitution cyphers appeared, replacing one, two or three letters for any other letter or symbol. The Pigpen is a geometric simple substitution cypher; the alphabet is distributed in two grids and several patterns, the first pair is simple, and the second pair is dotted. This cypher may have been used by the Hebrew rabbis and in the Christian Crusades [30].

The next period, the classical science period, covers the period until the Word War I, where the scientific basis of cryptography appeared. At this time, encryption techniques became more complicated, and the Alberti, Vigenère and the permutation cyphers were created. The Alberti and Vigenère cyphers are based on polyalphabetic substitution, many variants of this technique were defined. However, in the permutation cypher, the order of positions of the letters changes.

After the World War I different teams in different countries developed electro-mechanical devices that would generate polyalphabetic ciphertext. All of them were relatively small and based on standard typewriter keyboards. The mechanism was called rotor and works in such a way that when a plaintext letter was introduced the machine changes it to an encrypted one [31], [32].

The transition phase starts at the end of the 19th century to the beginning of the 20th century. This period is characterized by the invention of the cipher machines [28].

Finally, the modern cryptography period spans from the second half of the 20th century to the beginning of the 21st century. The emergence of computer equipment has made it possible to incorporate new methods such as symmetric and asymmetric cryptographic protocols; in addition, standards such as DES (Data Encryption Standard) and AES (Advanced Encryption Standard) were adopted [33].

Most of the encryption algorithms can be decrypted quickly due to the advancement of computer technology. Therefore, new, and increasingly complex encryption and decryption methods, such as quantum cryptography, continue to be sought [34].

Every day some forms of cryptology are used in education. When login to a smartphone, cryptology is involved in the form of a one-way hash function that protects passwords. In the process of buying something over the Internet, two different forms of cryptology are used (public key cryptography to set up the encrypted network connection and a symmetric key algorithm to finish the transaction). These are two examples of the importance and use of cryptography [32].

IV. Game design and materials

The goal of the game was to motivate students about cryptography, which is an optional course in both groups of students. This activity was proposed as a breakout game, i.e., a game similar to an escape room, where participants must find the key to open a box, or a padlock, or unlock a laptop in the case of this proposal, with limited time. To escape from a fictitious situation or to find a key, players must solve chain challenges contained within the room [11], [15], [35].

The great advantage of cryptography is that this matter offers several opportunities to define a riddle or a puzzle encrypting and decrypting messages [21].

Fig. 1 shows the main part of the game. Students where split into groups made of 4-5 persons and they worked together, in a collaborative manner, to solve the challenges and win the game. They must find four numbers to unlock a padlock that could open a box that contains the password of a laptop. From a QR code they got an url (https://bit.ly/3aifx6X) with a Google form. They must write the correct password and try if it was possible to unlock the laptop.

As all the game information was put together in a unique paper, it was sometimes difficult to separate useful information from what does not add any relevant information, or worst, may be confusing.

There are three parts that include non-useful information:

1) The blue rectangle at the top with the following text: “gnikool peek dna riapsed ton od ,erehwon sdael txet sihT .acnamalaS ed dadisrevinU eht fo scitamehtaM deilppA fo tnemtrapeD eht yb dezinagro pohskrow yhpargotpyrc eht ot emocleW”. This was difficult to decode. Students leave this till the last moment of the game and they did not realize that it is mirror writing. The original text is: “Welcome to the cryptography workshop organized by the Department of Applied Mathematics of the Universidad de Salamanca. This text leads nowhere, do not despair and keep looking”.

Fig. 1. Poster about cryptography used during the game-based learning session

2) Information about Alberti disk:
"The Alberti disk is a simple device, made up of two concentric disks, which allows us to choose the translation we want" and the corresponding figure.

3) The last one is the Scythela of Sparta.
Students know about the Scythela because it was included in the course introduction.

On the other hand, general information about cryptography and some definitions such as plain alphabet (to write original messages), encrypted alphabet (signs that replace the plain alphabet), encryption protocol (a cryptographic algorithm to encrypt messages), plain text (initial and clear message), cryptogram (encrypted message), was added in a rectangle in the central part of the poster. Furthermore, in the blackboard, on the right, the goal of the game is clear: "The key to unlock the computer is inside the box. We need to find the 4 numbers to open the padlock. There must be a way to fight against Wannacry".

At this point, gamers are able to find the four-numbers key. The signal showing several directions includes the most important information of the paper: "Decrypt the final key: South - East - West - Southeast", so, these are the places to find the clues and finally the key digits.

At the south (bottom part of the poster) there is a Pigpen cipher made of symbols such as: ⊏, ⌜, ⊡, ⊐, etc. This is decoded as "Find what number corresponds to the letter E in the Spanish alphabet", so, the solution is number 5.

Then, the east. There are two figures at this side: The American National Security Agency (NSA) logo, and a traffic signal with number 27. In this signal, the text says that "these are not keys", so, this is discarded. The NSA is not the original one because at the bottom part students could read "Part of the key: number one", son the second number of the key is one.

There are three rectangles on the east, all of them related to Caesar cipher. The first one shows how this encryption method works, the second one is a credit card with the following text: "RQH RI WKH QXPEHUV RI WKH NHB LV QLQH", whose decryption corresponds to "One of the numbers of the key is nine". Finally, moving to the southeast, there is computer screen with a riddle with a long text whose solution is eight. Gamers use to think that hackers use the half of the number mentioned in the story, because eight divided by two is four, fourteen divided by two is seven, etc. But the solution is to count the number of letters of each number. Thus, the number of letters of forty in Spanish ("cuarenta") is eight, and not 20.

Thus, the team that found the key of four numbers (5 – 1 – 9 – 8) won the game.

In addition to having this poster, students receive a small box with several rolled papers as is shown in Fig. 2.

Fig. 2. Rolled papers with some clues and additional information to solve the riddle

These papers include useful and non-useful data, such as the following:

- Keys and algorithms are used to encrypt messages and hide information
- QR codes (quick response code) can be read by any multimedia device
- To encrypt a message with public cryptographic protocol two keys are needed
- ASCII code: Collection of 8 zeros or ones that encode the most common symbols and that allow communication with the computer
- To decrypt a message such as “YHPL YLGL YLPFL” with Julius Caesar cipher, each letter must be change to the next third in the alphabet and thus, the decrypted message is VENI VIDI VINCI
- A transposition is to change the place that the letters of the original message occupy
- Substitution is to change some letters for others or for numbers

With this additional information, gamers were able to find the solution.

In the case of undergraduate or graduate degree students, an additional challenge was added. When they got the key to open the box, they found a new riddle inside and a decoder wheel. With this wheel they must find the solution of the riddle shown in Fig. 3.

This step of the game was very easy to solve, and students quickly found the solution. They found numbers 5, 16, 26 and 18 that corresponds to letters E, P, S, Z and R, respectively.

V. Conclusion

Game-based learning and serious games in education involve students in their own learning. This active pedagogy promotes teamwork, reflection, creativity, leadership, communication, and critical thinking, between others.

This paper presented the implementation of an escape room in a course about cryptography. As digital natives, students have heard a lot about cryptographic protocols and security aspects. The use of games for learning engages them and make them participate in a real situation, which it is difficult to replicate in traditional sessions.

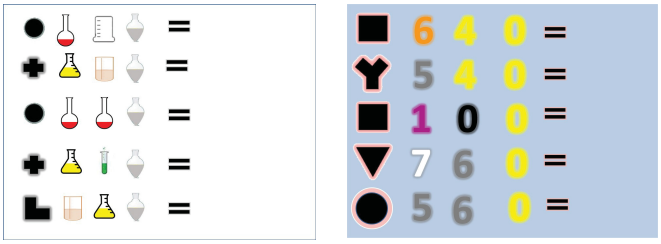

Fig. 3. Riddles for two groups of students that can be solve with a decoder wheel

The Breakout session was conducted with two groups of students that attended a course about cryptography. After each session a debate was proposed to discuss about the activity. The total amount of students participating in the Breakout was 38 (20 from high school and 18 undergraduate degree students from Computer Sciences).

Only 3 students had previously participated in an escape game in non-academic contexts. The rest of students has never tried such an activity for entertainment. They share with teachers the following appreciations:

- I like very much to participate in this game. In this way I can learn by doing thing
- I was fantastic, I have learned how to decrypt messages by doing it, and I have collaborated with my classmates in a very funny activity
- I would like more classes like this. We could learn in a different way. I wonder if this method could be used in difficult subjects like statistics or linear algebra.
- I have heart about escape games, I will try it out of classes
- I felt that I was learning while playing. This leads me to think about other classmates that don’t understand some problems. With this type of activities, we could learn teamwork and acquire knowledge about the subject

Participants think that it is possible to improve the teaching-learning process through games in the classroom.

After preparing and conducted several breakouts with students from different levels, another conclusion was reached: when confusing information is including in the game, this becomes more difficult. In the case of this cryptography-based game, students spent too much time trying to solve the initial riddle (the blue rectangle at the top with the mirror writing). Moreover, the rolled papers with some help were sometimes confused, and they spent time looking the place where this information could be used.

The proposal to improve this game-based method is to implement a similar game with a group of students and maintain a second group with traditional classes. Then, the results of the game session could be analyzed, and some quantitative results could be reached.

ACKNOWLEDGMENT

This work was partially supported by Fundación Samuel Solórzano under grant no. FS/26-2020, and by the Spanish State Research Agency (AEI) of the Ministry of Science and Innovation (MICINN), project P2QProMeTe (PID2020-112586RB-I00/AEI/10.13039/501100011033), co-funded by the European Regional Development Fund (ERDF, EU).

REFERENCES

[1] M.C. Sáiz Manzanares, S. Rodríguez Arribas, C. Pardo Aguilar, and M.Á. Queiruga Dios, "Effectiveness of self-regulation and serious games for learning STEM knowledge in Primary Education", *Psicothema*, 2020.

[2] S. Hackett, "Educating for competency and reflective practice: fostering a conjoint approach in education and training", *J. Workplace Learn.*, vol. 13 no. 3, 2001, pp. 103-112.

[3] L. Andresen, D. Boud, R. Cohen, *Experience-based learning. understanding adult education and training*. Sidney: Allen & Unwin, 2000.

[4] B.D. Ruben, "Simulations, games, and experience-based learning: The quest for a new paradigm for teaching and learning", *Simul. Gaming*, vol. 30 no. 4, 1999, 498-505.

[5] S. Tobias, J.D. Fletcher, A.P Wind, *Game-based learning. Handbook of research on educational communications and technology*, New York: Springer, 2014.

[6] J. Michael, "Where's the evidence that active learning works?", *Adv. Physiol. Educ.*, vol. 30, 2006, pp. 159-167.

[7] S. Pedersen, and M. Liu, "Teachers' beliefs about issues in the implementation of a student-centered learning environment", Educ. *Technol. Res. Dev.*, vol. 51 no. 2, 2003, pp. 57-76.

[8] M. Ben-Ari, "Constructivism in computer science education", *J. comput. math. sci. teach.,* vol. 20 no. 1, 2001, pp. 45-73.

[9] J. Hamari, D.J. Shernoff, E. Rowe, B. Coller, J. Asbell-Clarke, and T. Edwards, "Challenging games help students learn: An empirical study on engagement, flow and immersion in game-based learning", *Comput. Hum. Behav.*, vol. 54, 2016, pp. 170-179.

[10] N. Pellas, "Exploring interrelationships among high school students' engagement factors in introductory programming courses via a 3D multi-user serious game created in open sim", *J. Univers. Comput. Sci.*, vol. 20 no. 12, 2014, p. 1608e1628.

[11] P. Fotaris, and T. Mastoras, "Escape rooms for learning: A systematic review", *in Proc. European Conf. on Games Based Learning*, Oct. 2019, pp. 235-243.

[12] M. Grande-de-Prado, S. García-Martín, R. Baelo, and V. Abella-García, "Edu-Escape Rooms", *Encyclopedia*, vol. 1 no. 1, 2021, pp. 12-19.

[13] A. Hernández Encinas, A. Martín del Rey, J. Martín Vaquero, A. Queiruga Dios, G. Rodríguez Sánchez, "Bachillerato de Excelencia, Criptografía y Seguridad de la Información: una oportunidad", *in Proc. I JNIC2015 Conf.*, Sept. 2015, pp. 190-194.

[14] M. Pivec, O. Dziabenko, and I. Schinnerl, "Aspects of game-based learning", *in Proc. 3rd International Conf. on Knowledge Management*, Jul. 2003, pp. 216-225.

[15] V. Adams, S. Burger, K. Crawford, R. Setter, "Can you escape? Creating an escape room to facilitate active learning", *J. Nurses Prof. Dev*., vol. 34, 2018, pp. E1–E5.

[16] A.E. Kinio, L. Dufresne, T. Brandys, P. Jetty, "Break out of the classroom: The use of escape rooms as an alternative teaching strategy in surgical education", *J. Surg. Educ.*, vol. 76, 2019, pp. 134–139.

[17] S. López-Pernas, A. Gordillo, E. Barra, J. Quemada, "Examining the Use of an Educational Escape Room for Teaching Programming in a Higher Education Setting", *IEEE Access*, vol. 7, 2019, pp. 31723–31737.

[18] A. Queiruga-Dios, M.J. Santos Sánchez, M. Queiruga Dios, V. Gayoso Martínez, and A. Hernández Encinas, "A virus infected your laptop. Let's play an escape game", *Mathematics*, vol. 8 no. 2, 2020, p. 166.

[19] M. J. Santos, M. Miguel, A. Queiruga-Dios, and A.H. Encinas, "Looking for the Antidote for Contaminated Water: Learning Through an Escape Game", *in Proc. International Joint Conference: 12th International Conference on Computational Intelligence in Security for Information Systems (CISIS 2019) and 10th International Conference on EUropean Transnational Education (ICEUTE 2019)*, May 2019, pp. 217-226. Springer, Cham.

[20] M.T. Gençoğlu, "Importance of Cryptography in Information Security". *IOSR J. Comput. Eng*, vol. 21 no. 1, 2019, pp. 65-68.

[21] F.A. Deeb, and T.J. Hickey, "Teaching Introductory Cryptography using a 3D Escape-the-Room Game", *in Proc. 2019 IEEE Frontiers in Education Conference (FIE)*, Oct. 2019, pp. 1-6.

[22] C. Borrego, C. Fernández, I. Blanes, and Robles, S. "Room escape at class: Escape games activities to facilitate the motivation and learning in computer science", *JOTSE*, vol. 7 no. 2, 2017, pp. 162-171.

[23] S. Vadla, A. Parakh, P. Chundi, and M. Surbamaniam. "Quasim: A multi-dimensional quantum cryptography game for cyber security", *Journal of The Colloquium for Information Systems Security Education*, vol. 6 no. 2, 2019, pp. 1-19.

[24] A.I. González-Tablas, M. I. González Vasco, I. Cascos, and Á. Planet Palomino. "Shuffle, cut, and learn: Crypto go, a card game for teaching cryptography", *Mathematics*, vol. 8 no. 11, 2020, p. 1993.

[25] A. Jaffray, C. Finn, J.R. Nurse. "SherLOCKED: A Detective-Themed Serious Game for Cyber Security Education". in *International Symposium on Human Aspects of Information Security and Assurance*, July 2021, pp. 35-45. Springer, Cham.

[26] H. Niederreiter, and A. Winterhof, *Applied number theory*. Cham: Springer, 2015.

[27] S. Zapechnikov, A. Tolstoy, and S. Nagibin, "History of Cryptography in Syllabus on Information Security Training", *in Proc. IFIP World Conf. on Information Security Education*, May 2015, pp. 146-157. Cham: Springer.

[28] N.P. Smart and N.P. Smart, *Cryptography made simple*. Springer, 2016.

[29] D.K. Sharma, N.C. Singh, D.A Noola, A.N. Doss, and J. Sivakumar, "A review on various cryptographic techniques & algorithms", *Materials Today: Proceedings*, in press.

[30] D. Davies, "A brief history of cryptography", *Inf. Secur. Tech. Rep.*, vol. 2 no. 2, 1997, pp. 14-17.

[31] M.R. Adhikari and A. Adhikari, *Introduction to Mathematical Cryptography*, Basic Modern Algebra with Applications, pp. 517-584. New Delhi: Springer, 2014.

[32] J.F. Dooley, *History of cryptography and cryptanalysis: Codes, Ciphers, and their algorithms*. Cham: Springer, 2018.

[33] G.R. Blakley, "Twenty years of cryptography in the open literature", *in Proc. IEEE Symposium on Security and Privacy*, May 1999, pp. 106-107.

[34] G. Alagic, J. Alperin-Sheriff, D. Apon, D. Cooper, Q. Dang, J. Kelsey, et at. *Status report on the second round of the NIST post-quantum cryptography standardization process*. US Department of Commerce, NIST, 2020.

[35] M. Wiemker, E. Elumir, and A. Clare, "Escape room games", *Game based learning*, vol. 55, 2015, pp. 55-75.