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Enhancement of Program Outcomes for Cryptography and Network Security course using Alternate Assessment Tool: An approach towards outcome-based education

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Abstract: Outcome-based education is being practiced across the globe to enhance the employability of the undergraduates by instilling certain domain-specific skills. Evaluation is key in measuring the leaning outcomes of students. Tools such as regular quizzes, assignments, and alternative assessment are in place for continuous evaluation. Alternative assessment tools (AAT) can be modulated to suit the course being taught, and if used properly, it can enhance the attainment of program outcomes (PO). To enhance the coding skills of the students with respect to security algorithms and their real-time applications, for the course "Cryptography and Network Security", in the computer science and engineering branch, AAT was introduced in the assessment process. Students were given a task to develop an algorithm using CryptTool and demonstrate the various attacks on the selected encryption/decryption algorithm. By using AAT, engagement of students was improved due to fortnightly reviews from the teacher, peer reviews, and exchange of ideas to go in the right direction in the work plan. The results show improvement in the attainment of program outcomes PO4 and PO5, which were not mapped when AAT was not yet implemented. In addition, the use of CrypTool as part of AAT helped the students in selecting suitable security projects in their higher semester courses.

Keywords: Alternate Assessment Tool; Bloom's Taxonomy; CO Attainment; CryptTool; Outcome-based Education; PO Attainment

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1. Introduction

Ever since outcome-based education (OBE) started, the focus has shifted from teacher-centric teaching to student-centric teaching. Now, the OBE has been practiced in engineering education, and OBE has modified the teaching-learning process. Notably, the traditional teaching method has many drawbacks, which include the lack of interactivity and critical thinking (Liu and Deng, 2022; Zhao et al. 2022). In this method, the teaching process is focused on completing the syllabus rather than focusing on helping students to understand the concept and apply them. Finally, most importantly, the assessment is based on the grades obtained rather than assessing the skills and knowledge gained during the course continuously. To bring in these important aspects in teaching, a wide variety of approaches have been recently incorporated into the classroom teaching practice (Basavaiah et al. 2021).

OBE is a fundamental strategy that provides a clear picture of what students can demonstrate and an education theory that is centered on outcomes. The OBE mainly focuses on student-centric: skills and demonstration of outcomes by the students. It also organizes the curriculum, assessment, and instruction to measure the skills and knowledge of outcome-based education (Kumbhar, 2020). Presently, the OBE makes learning theories in the education system to be based on the OBE instructional model and Bloom's taxonomies. (Gurukkal, 2020).

In the OBE system, the performance-based assessment is essential in measuring students' skills, knowledge, reflection, and critical thinking (Pradhan, 2021; Eldeeb, 2013). The role of industry collaboration in project-based learning helps students to learn the real-time project experience as well as plays a major role in the OBE system (Akram et al., 2015). Generally, an assessment is a process of documenting students' empirical data as a result of student learning and knowledge usually in measurable terms. The assessment need not be over a paper and pen, alternatively, it can be through demonstration-based, oral questioning, prototype-based, and group activities-based. This alternate way of assessment helps in measuring the students' skills and competency directly, and it is also known as performance-based assessment (Sapawi, 2021).

In this study, the effectiveness of alternate assessment tool (AAT) to enhance the program outcomes (POs) of a course Cryptography and Network Security offered in 6th semester undergraduate programme, Computer Science and Engineering, in B.M.S. College of Engineering, Bengaluru, India, was studied. In this technique, students were given a task to demonstrate the working of any encryption and decryption algorithm or any digital signature algorithm using CryptTool (https://www.cryptool.org/en/). The CryptTool was introduced in 1998 to spread awareness and interest on various cryptology techniques in a simple and user-friendly manner, change various parameters such as the private and public key and analyze the working. Finally, implement the various forms of attacks on the ciphers or vulnerabilities for the cipher. The tool has two versions, that is it can be downloaded and installed on the local system, or it can be used online only.

As part of the tutorial classes, the CryptTool examples were demonstrated in class and students gained confidence in the usage of the tool. Based on the coding examples practiced in class, teams were formed, and each team chose a topic relevant to security applications or any encryption/decryption algorithm for implementation using the tool. Students were fortnightly reviewed for their progress, which helped them to move on the right path by gathering all the feedback from the faculty as well as their peers. This motivated the students to discuss and give suggestions for other team projects as well. Also, after the complete implementation, a final presentation at the end of the 6th semester was carried out for evaluation. Most of the students were able to complete the given task since regular feedbacks and reviews helped them to complete the given task. Along with the presentation by students, a report with all the details of the implementation of the algorithm was submitted for evaluation.

2. Research / Practice

At the beginning of the course, the students were shared the plan of activities to carry out their work for alternate assessment for the course “Cryptography and Network Security”. The main objective here was to make the students implement the project stage by stage during the course. Each group consisted of two students and freedom was given to students to select the topic of their choice, with one condition that the topic selected had to be a real-time application. This condition of real-time application-based topic selection made students to work on their own but not download the projects existing on the web.

The design of the plan used for Alternate Assessment is as follows: Students were supposed to develop a cryptographic algorithm/digital signature without using libraries or built-in functions. Code demonstration along with a report has to be submitted OR Demonstration of Encryption/Decryption algorithms using Tools such as CryptTool or finding vulnerabilities in a website. For example: Implementation of RSA Digital Signature, Elgamal Digital Signature, Diffie Hellman Signature, Modified RSA algorithm for practical purpose, Hybrid encryption schemes. The plan of activities as shown in Table 1. The activity planned was successfully applied in easy execution of the project. Additionally, online quiz was conducted through Social Learning platform Google classroom.

The students were given a demonstration of a few techniques during the class using CryptTool and were

also asked to practice and learn by changing various parameters which helped them to gain confidence for their implementation of the alternate assessment. A few of the exercises discussed during the class are given in Fig. 1.

The faculties evaluated the projects based on the rubrics to maintain fairness and transparency. The quality of learning of the students was greatly improved after the introduction of alternate assessments. The main criteria for the evaluation are based on the User Interface design, Implementation of the algorithm, various test cases, relevance to the current trend, report writing, oral communication and participation in the discussion. Students' exposure to collecting new requirements and designing and developing as per the requirements was the main motive. Reviews given by the faculty helped the students to complete their projects in the right direction and in a timely manner. In addition, the communication and presentation skills of students were enhanced. During the review process, the peers gave additional inputs for further improvements to the project. Fig. 2 illustrates the details of evaluation rubrics designed for the assessment of the AAT.

Meetings were scheduled between the students' team and faculties every fortnight where students presented work done till date. Based on their presentation, suggestions were given by the faculty in-charge. The faculty in-charge seriously reviewed

Table 1: Project Development Plan Of Activities.

Activity	Weeks							
Formation of groups.								
AAT topic selection by each group.								
Student team and topic introduction by each group.								
Design the workflow along with Front-end design.								
Presentation on Front-end design of the application.								
Design and development of the actual algorithm and testing it for various test cases.								
Complete code demonstration.								
AAT Report preparation.								

Tutorial #	Topic
1	**Open SSL Library Features and Application in Cryptography** **https://www.openssl.org/docs/**
2	**Introduction to CrypTool and Installation** **Demonstration of basic features available in CrypTool**
3	**Demonstration of Caesar cipher** In the message to decode, any punctuation is left unchanged in the encoded message, as too are any numbers. To change this **Options > Text Options** and from here you can select what attributes of a message the cipher will alter and which it will leave unchanged. Experiment encrypting the same message with the Caesar cipher with different settings selected from the text options. Decipher each message after doing so and see if the deciphered message still has the same punctuation, spacing etc.
4	**Demonstration of Vigenere cipher** Animal is a tool within the CrypTool that displays the concepts behind a cipher in a user-friendly fashion, by the means of an animation. Demonstrate the use of animal tool for the above cipher.
5	**Demonstration of DES** Open a new file and type a plaintext message. Next click from the menu **Crypt/Decrypt > Symmetric (modern) > DES (ECB)…** This presents a key selection window, this key must be 64 bits long, which equates to 16 hexadecimal figures. For simplicity use the default key of: 00 00 00 00 00 00 00 00 Select **Encrypt** and there should be presented a window showing the data encrypted in hexadecimal form and its corresponding ASCII representation. To decrypt the message again select **Crypt/Decrypt > Symmetric (modern) > DES (ECB)…** Use the same key and select **Decrypt**, and the original message will be displayed in hexadecimal representation. Selecting **View > Show as text** displays it in ASCII; you may also notice some of the formatting is lost in the process or some padding is added. Encrypt the same message using the same process as above only selecting **Crypt/Decrypt > Symmetric (modern) > DES (CBC)…** instead. Compare the two encrypted messages.
6	**Compare ECB versus CBC mode of operation for the following applications:** **a) An online bank statements** **b) An encrypted VoIP session** **c) Viewing of a website using TCP/IP**
7	**Demonstrate DES encryption and decryption using Animal.**
8	**Demonstration of RSA** Now, encrypt a message of your choice using the values: $p = 59$, $q = 71$, $e = 13$ Observe the results. Encrypt the same message with the values: $p = 673$, $q = 619$, $e = 13$
9	**Demonstrate RSA encryption and decryption using Animal.**
10	**Demonstrate RSA implementation using PKI.**
11	**1963497163 is the product of two prime numbers, use tools within the CrypTool to find these two prime numbers. Mention what tools you used to do this.**
12	**Demonstrate hybrid encryption** Combine aspects of AES and RSA algorithm and demonstrate encryption of different plaintext.
13	**Demonstration of** OWASP vulnerabilities

Fig. 1 : Tutorial exercise prepared for the course.

Criteria	Exemplary	Proficient	Partially Proficient	Points
User Interface / Front End Design OR Tool Usage	(1) The designed application has an exceptional design, attractive and usable interface. It is easy to locate all important elements.	(0.75) The designed application has an attractive design and usable interface. It is easy to locate all important elements.	(0.5) The designed application has a usable design interface, but may appear busy or boring. It is easy to locate most of the important elements.	/ 1
Implementation of the Algorithm OR Implementation done in the Tool	(4) Implementation of the algorithm has been done accurately without the usage of any library functions.	(2.5) Implementation of the algorithm has been done appropriately without the usage of any library functions.	(1.5) Implementation of the algorithm has been done with usage of few library functions.	/4
Testing for various cases	(1) The implemented algorithm works for any given valid input.	(0.75) The implemented algorithm works for almost all valid inputs.	(0.5) The implemented algorithm works for any some valid inputs.	/1
Application/Relevance	(1) The designed algorithm has several applications and is relevant in the area of cryptography.	(0.75) The designed algorithm has few applications and is relevant in the area of cryptography.	(0.5) The designed algorithm has few applications and is not very relevant in the area of cryptography.	/1
Report	(1) Clear and Effective writing and adherence to appropriate style guidelines	(0.75) Writing that is clear and effective for the most part and minor errors in adherence to appropriate style guidelines	(0.5) Unclear and ineffective writing and multiple errors in adherence to appropriate style guidelines	/1
Oral communication (presentation)	(1) Clear and effective communication	(0.75) Communication is clear	(0.5) Unclear communication	/1
Participation in Discussions	(1) Provided many good ideas; inspired others; clearly communicated ideas, needs, and feelings.	(0.75) Participated in discussions; on some occasions, made suggestions.	(0.5) Listened mainly; Rarely spoke up, and ideas were off the mark.	/1
Total				/ 10

Fig. 2: Evaluation rubrics for AAT. Evaluation was done for 10 marks.

suggestions given in the previous presentation incorporate and gave them the direction to go ahead in designing wonderful projects. Reviews given by the faculty in-charge really helped the students in completing their projects in the right direction and in a timely manner. Also, active learning approach enhanced communication and presentation skills of students. During the review process, the peers gave additional inputs for further improvements of the project.

The Assessment of the PO of the course "Cryptography and Network Security" based on the Course Outcomes (CO) is shown in Table 2. The CO4 was designed to achieve the PO such as PO4 and PO5 is depicted in Table 3. The mapping of COs to PO4 and PO5 was achieved in the course by the usage of Alternate Assessment Tool: CryptTool. Table 2 illustrates the CO4 pertaining to the CryptTool, and Table 3 shows the mapping to the PO.

Further, the two methods of assessment for computing the CO attainment are direct and indirect: the direct assessment is computed through evaluation of continuous internal evaluation (CIE), which

Table 2 : CO-PO Mapping (3 Being The Highest And 1 Least) For The Course Run In The Year 2021.

CO1	Apply number theory concepts to the field of cryptography
CO2	Analyze various symmetric and asymmetric cryptosystems and types of attacks on these cryptosystems
CO3	Apply the field of cryptography while designing security applications
CO4	Demonstrate cryptography encryption and decryption techniques using CrypTool

Table 3 : Course Outcomes for Cryptography and Network Security for the Course Run in The Year 2021

	PO1	PO2	PO3	PO4	PO5
CO1	2				
CO2		3			
CO3			1		
CO4				2	3

consists of the best 2 out of 3 theory tests and usage of alternate assessment tool (AAT). The sample CIE question paper is shown in Fig. 3. It shows the sample questions framed in the internals evaluation and most of the questions were analyze and apply level of Bloom's Taxonomy. The indirect assessment is carried out through the course end survey (CES) at the end of the semester (Namratha et al., 2018; Shivakumar et al., 2015).

The CES questions are designed to be mapped to the COs and CES rubrics are framed for evaluation of

PART-A

		Questions	Marks
1)	a.	Demonstrate a product cipher made of 2 rounds.	05

PART-B

		Questions	Marks
2)	a.	The ciphertext GEZXDS was encrypted by a Hill cipher with a 2 * 2 matrix. The plaintext is "solved". Find the encryption matrix M.	05
	b.	Demonstrate with a suitable example how monoalphabetic substitution cipher is vulnerable to frequency analysis attack.	05
	c.	Given the plaintext = "cryptography and network security" and the encryption key 3 1 4 5 2, find the cipher text and the decryption key.	05

PART-C

	Questions	Marks
3)	Find the inverse of (x^2+x+1) mod x^3+x+1 in $GF(2^3)$	10
	OR	
4)	Show the steps involved in multiplication of two polynomials: $f(x) = x^6 + x^4 + x^2 + x + 1$ and $g(x) = x^7 + x + 1$ in $GF(2^8)$ using the efficient algorithm for multiplication using n-bit words. Consider $x^8 + x^4 + x^3 + x + 1$ as the irreducible polynomial.	10
5)	Encrypt the message "the house is being sold tonight" using the following ciphers. Ignore the space between words. Decrypt the message to get the plaintext: a. Vigenere cipher with key: "dollars" b. Autokey cipher with key = 7 c. Affine Cipher with key (15,20)	10
	OR	
6)	Given that $Z_7 = \{1, 2, 3, 4, 5, 6\}$ * mod 7 is a group, write all the cyclic subgroups (different orders) of Z_7. Is Z_7 a cyclic group?	10

***

Fig. 3: Sample CIE-1 question paper

Table 4 : Course end survey rubrics.

Course Outcome	Very Good	Good	Satisfactory	Poor
CO1: Able to apply number theory concepts to the field of cryptography?	Able to apply number theory concepts to the field of cryptography for any given problem.	Able to apply number theory concepts to the field of cryptography for most of the given problems.	Able to apply number theory concepts to the field of cryptography for few given problems.	Unable to apply number theory concepts to the field of cryptography for the given problem.
CO2: Able to analyze various symmetric and asymmetric cryptosystems and types of attacks on these Cryptosystems?	Able to analyze various symmetric and asymmetric cryptosystems and types of attacks on these Cryptosystems.	Able to analyze most of the symmetric and asymmetric cryptosystems and types of attacks on these Cryptosystems.	Able to analyze few of the symmetric and asymmetric cryptosystems and types of attacks on these Cryptosystems	Unable to analyze various symmetric and asymmetric cryptosystems and types of attacks on these Cryptosystems.
CO3: Able to apply the field of cryptography while designing security applications?	Able to apply the field of cryptography while designing the given security application.	Able to apply the field of cryptography while designing most of the security applications.	Able to apply the field of cryptography while designing few of the security applications.	Unable to apply the field of cryptography while designing the security applications.
CO4: Able to demonstrate cryptography encryption and decryption techniques using CrypTool?	Able to demonstrate cryptography encryption and decryption techniques using CrypTool for any given problem.	Able to demonstrate cryptography encryption and decryption techniques using CrypTool for most of the given problems.	Able to demonstrate cryptography encryption and decryption techniques using CrypTool for few of the given problems.	Unable to demonstrate cryptography encryption and decryption techniques using CrypTool for any given problem.

the indirect assessment as shown in Table 4.

Following were the challenges faced during the implementation of AAT:

1. Identification of the problem statement that students can understand and implement in stipulated time.

2. Identifying the appropriate parameters for the security application so that the result could be demonstrated easily.

3. Providing required resources (software and materials) to the students for developing projects using CryptTool.

4. Aligning the course content to help the student to learn the concepts faster in implementing the project.

5. Mathematical concepts involved in developing the applications were quite cumbersome for the students initially.

6. The class teacher must provide the inputs or guidance to the entire project groups in a class.

3. Results And Discussion

The introduction of AAT increased the understanding and performance of the students in internal evaluation. Fig. 4 shows the performance of the students in Continuous Internal Evaluation (CIE). The CIE marks distributions were in between 35-50 marks, which was due to the introduction of the practical aspects' implementation during the course. In a batch of 54 students, around 46 students scored more than 40 marks.

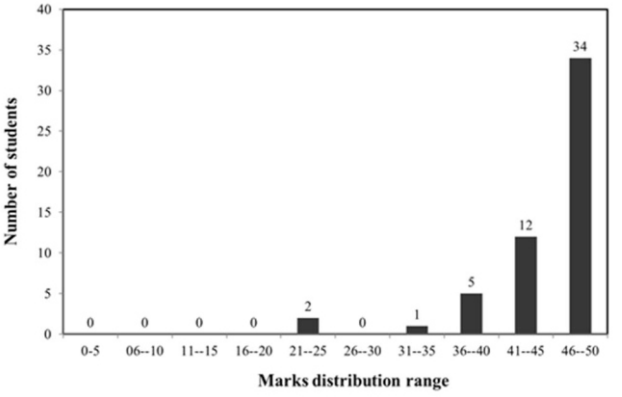

Fig. 4 : CIE mark distribution for the course. Around 46 students scored more than 40 marks.

At the end of the course, CES was taken from the students to adjust the pedagogical methods adopted for the teaching-learning process. The results of CES are illustrated in Fig. 5, Fig. 6, Fig. 7, and Fig. 8. From the corresponding CES results, it is evident that around 85% of the students have given either an "Excellent" or "Good" rating, which in turn reflects that active learning is an efficient method of teaching pedagogy. In the case of CO1, around 81% of the students were confident to apply number theory concepts to the field of cryptography. For CO2, around 86% of students confirmed their confidence to analyze various symmetric and asymmetric cryptosystems and types of attacks on these cryptosystems. Next, an analysis of CES for CO3 revealed that around 83% of students were able to apply the Cryptography concepts to design the given security-related application. Finally, for CO4, around 84% of students were able to apply the CryptTool for future projects.

Student feedback collected during the course is shown in Fig. 9 and Fig. 10 for the two questions. For the question asked if they enjoyed doing the exercises inside the classroom, 58% of students responded positively, whereas no student was unsatisfactory for solving the exercises. For the question asked if solving problems inside the class discussing and presenting the solutions helps them learn the topic better, 64% of students responded positively, while no student was unsatisfactory.

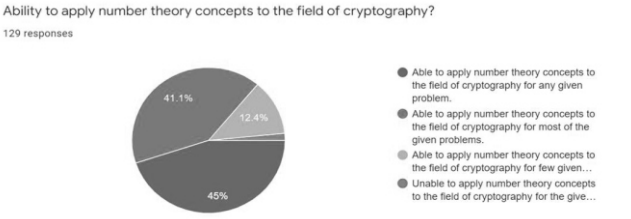

Fig. 5 : Course end survey results for CO-1

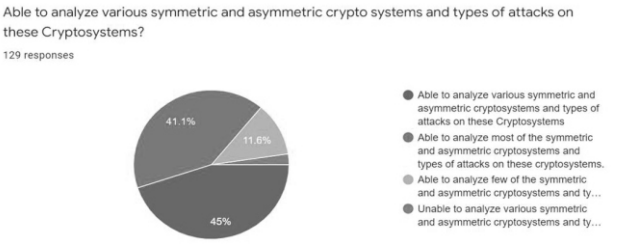

Fig. 6 : Course end survey results for CO-2

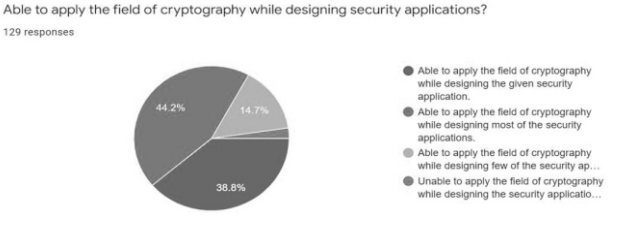

Fig. 7 : Course end survey results for CO-3

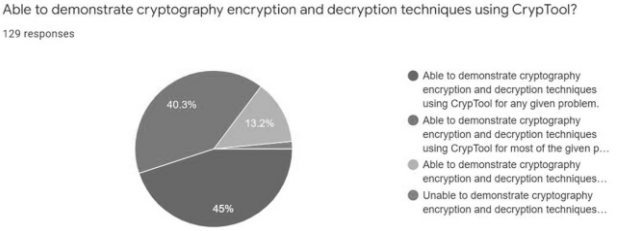

Fig. 8 : Course end survey results for CO-4.

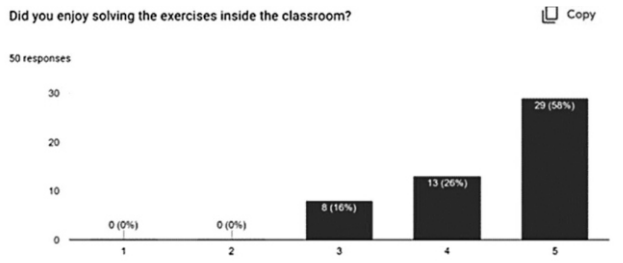

Fig. 9: Student feedback on the question asked.

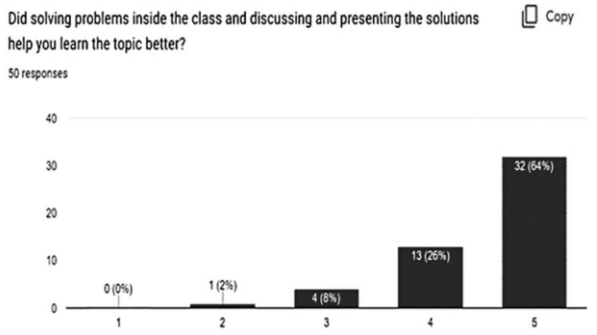

Fig. 10: Student feedback on the question asked.

During the previous run of the course in 2020, since AAT was not applied for evaluation, there were only 3 COs. In 2021, a separate CO was added for AAT, which was mapped to PO4 and PO5.Therefore,

Table 5: Co-po Attainment For The Year 2020.

CO/PO Number	1	2	3
CO attainment	77.0	84.0	83.0
PO attainment	77.0	84.0	83.0

Table 6 : Co-po Attainment For The Year 2021.

CO/PO Number	1	2	3	4	5
CO attainment	78.7	81.7	88.8	88.9	-
PO attainment	78.7	81.7	88.9	88.9	88.9

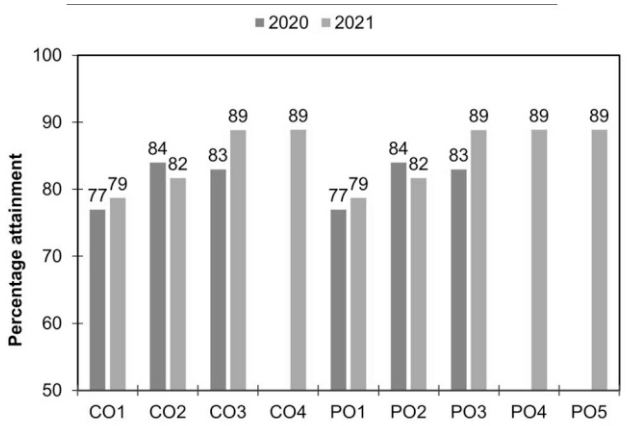

Fig. 11 : Comparison of CO and PO attainment for 2020 and 2021 batch. The percentage attainment is enhanced with the implementation of AAT for the 2021 batch.

the introduction of AAT assisted to attain the higher POs. Table 5 shows the CO-PO attainment for the year 2020 where AAT was not being used and hence no mapping to PO4 and PO5. Table 6 shows the CO-PO attainment for the year 2021 where AAT was introduced with the usage of CryptTool and hence mapping to PO4 and PO5 as well. Furthermore, Fig. 11 clearly shows that the introduction of AAT helped in attaining the PO4 and PO5. The modern tool usage (PO4) and professional engineering practice (PO5), which are very desired to bridge the gap between academia and industry. In addition, attainment of COs was higher in 2021 run, for example, attainment of CO1 increased to 79% from 77% in 2020. In the case of CO3, it raised to 89% from 83%. However, CO2% attainment decreased from 84% to 82%. A similar trend was observed in the attainment of POs as well.

A. Impact on other Courses

As part of the curriculum for 6th semester UG students, a course by title Project Work-4, which includes the implementation of Security related projects. The alternate assessment introduced as part of Cryptography and Network Security course helped students for their security projects as well. Students were well equipped with the knowledge of CryptTool for implementation of encryption and encryption algorithms and the various cipher vulnerabilities and this, in turn, helped them to implement their projects in an efficient manner. Higher-level POs such as PO7, PO8, PO10, and PO12 were also attained as part of this course.

4. Conclusions

An alternate assessment tool (AAT) was implemented for the course "Cryptography and Network Security", using CryptTool that is an open-source software. It was clearly observed that by practically implementing the concepts learnt during the theory classes, students were able to understand the various cryptography concepts in a better manner. The use of AAT has a great impact on learning, and it is reflected in the attainment of course outcomes and in turn, on the programme outcomes. PO1 and PO3 percentage of attainment enhanced from 77% to 79%, and 83% to 89%, respectively. In addition, a couple of new POs were mapped since the implement AAT comprised the use of modern tools. Moreover, the security concepts learnt as part of this course was helpful for students for another course in the subsequent semester. The project design and

implementation were made easier by introducing the AAT as part of the course.

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