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Silos to Synergy: Harnessing Integrated Learning for Improved Outcomes

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Abstract— **In recent days, integrated learning emerges as a potent pedagogical approach, intertwining diverse subjects to foster comprehensive education for millennial learners. Its benefits span across enhanced learning outcomes, improved critical thinking, creative problem solving, and engaged learning. The research study aims to create an effective integrated learning experience for the undergraduate students of information technology program. Around 65 students of fifth semester B.Tech IT program and three faculty members have participated in the research study. Project-Based Learning (PBL) has been adapted to creating meaningful cross-curricular experiences. The proposed PBL enables the learners to develop simulations for various cryptographic algorithms which were learnt in the course on Information security. The project also intertwines the concepts covered in other courses like Web Technologies, Software Testing and System Thinking. The PBL has been carefully designed with focus on problem statements, learning goals, project milestones, calendar and rubrics for assessment. Simulations developed by the learners in teams are integrated to create a complete software package which could serve as a virtual lab for cryptography and information security course. The experimental study on integrated learning has resulted in a usable educational software product for teaching cryptographic algorithms. Also, there is a significant enhancement in the attainment of course outcomes and satisfaction index of the learners. The positive outcome in learning achievements and student engagement affirm integrated learning's value. Various plans to address the implementation challenges in integrated learning are also discussed in the research article. The authors believe that the manuscript will serve as a beginner's guide to academicians wishing to practice integrated learning in their classrooms.**

***Keywords*—Integrated Learning, Project Based Learning, Rubrics, Comprehensive Learning, Learning Outcomes, Product building skills.**

***JEET Category*—Practice**

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I. INTRODUCTION

Integrated Learning is a pedagogical approach that involves connecting different courses in a curriculum to create a more comprehensive and holistic educational experience. It promotes communication, creativity, collaboration and critical thinking amongst millennial learners by elucidating connections and interrelationships across multiple courses. Integrated learning also termed as cross disciplinary learning, primarily deals with problem solving and is capable of accommodating a wide range of learning theories, learning styles and multiple intelligences. The various forms of integrated learning are as follows:

Interdisciplinary Learning: This involves blending two or more distinct disciplines to explore connections between them. For example, a project on designing a dancing Robot includes Mechanical Engineering, Electronics and Information technology.

Cross-Curricular Projects: Instructors design projects or activities that incorporate concepts and skills from multiple courses. Learners work on tasks that require knowledge and skills from different areas, encouraging them to see the relevance of each subject. Learners engage in projects that require them to research, analyze, and solve complex problems. These projects often encompass multiple courses and encourage critical thinking and collaboration. The characteristic features of integrated learning are as follows:

- Breaks the monotony of traditional single-subject instruction and allows learners to connect with material in ways that resonate with their interests and learning styles.
- Encourages learners to think creatively and come up with innovative solutions.
- Nurtures students' problem-solving skills as they draw on knowledge and techniques from various disciplines.

Other significant benefits include includes increased engagement and motivation, effective time management, development of transferable skills, better preparation of the graduating students for the real world with a greater sense of community and purpose. As integrated learning is a relatively newer approach, there is an increasing need for well-

established role models, teaching methodologies, and sharing of best practices.

II. Related Works

Educationists have experimented integrated learning in their domains and have analyzed the impact on learning outcomes and on transferable skills. A framework for the integration of art in pedagogy to create an atmosphere of "experiential and joyful learning" in the classrooms has been proposed by the National Council of Educational Research and Training (NCERT) (Bau, 2020). The proposed framework has been tested in primary school education and has been reported to be effective in creating a room for happy learning. Generally, the course map of all undergraduate and postgraduate programs is carefully designed in such a way that technical skills acquired in particular courses gradually build on each other. Integrated learning involves establishing links between skills and knowledge derived from different curricular sources and experiences. This approach bridges the gap between theoretical concepts and practical application, employing diverse perspectives to enhance students' comprehension of various issues. (Huber & Hutchings, 2004; Huber, Hutchings, Gale, Miller, & Breen, 2007). However, there exists a common challenge that learners view the curriculum as a stack of multiple courses with disjointed learning outcomes in spite of the traditional existence of prerequisites and co-requisites. This pedagogical challenge has been addressed by combining various courses into an integrated learning block (ILB) with a unified mission and objective. (Usmeldi, 2019). Research study has been conducted using quasi experiment method with pre-test and post-test group control design. Experimental results confirm that there is a significant difference in the competence of learners exposed to integrated learning and learners exposed to conventional learning methods.

An educational approach that combines academic learning with real-world work experiences is called as Work-Integrated Learning (WIL). It aims to bridge the gap between theoretical knowledge gained in the classroom and practical skills needed in the workplace. WIL programs are designed to provide students with the opportunity to apply what they learn in a real work environment, thereby enhancing their employability and preparing them for successful careers. The overall impact of WIL and its impact on potential employability on Operations Management Engineering students have been investigated (Agwa, 2017). The learners have enjoyed the work experience and developed skills, attitudes and behaviors essential to improve employability. Integrated Learning aims to mimic real-world scenarios, where problems and challenges are rarely confined to a single domain.

In the present situation, any industry increasingly values professionals who possess both technical prowess and a broader skill set. Information Technology based companies seek employees who can not only code or engineer but also communicate effectively, think critically, and understand the societal impact of their work. Integrated learning has proven to be a promising solution as it aligns with these industry demands, producing graduates who are better equipped to tackle multifaceted challenges.

However, it could be inferred from the literature that there is a limited study on integrated learning especially in the field of computer science and information technology programs. Curriculum design complexities, innovative assessment methodologies, faculty collaboration, resistance to change, time management and resource constraints are considered to be the major reasons for limited implementation of integrated learning experiences.

The increasing demand for a well-structured instructional design and the need for exploring ways to mitigate the challenges in creating an integrated learning experience have motivated the authors to conduct this experimental study. The authors have developed an integrated instructional design for B.Tech Information Technology Program for the courses on Web Programming, Information Security and Software Testing which were offered in the fifth semester of study. The instructional design has been centered on Project Based learning and active learning approaches. (Fusic, 2020). The impact of integrated learning on learning outcomes has been analyzed based on the performance of the learners in respective examinations.

III. Research Objectives

The motivation for the research is supported by the following research questions:

- RQ1 How to effectively create an integrated learning experience that combines multiple courses in a curriculum and promotes product building skills?
- RQ2 What is the impact of integrated learning in enhancing the learning outcomes of a specific course?
- RQ3 What are the common ways to mitigate the risks and challenges involved in planning such integrated learning experiences?

IV. Materials and Methods

An integrated curriculum is built upon educational encounters that result in the attainment of individual and social abilities, as well as the development of skills in creating products, processes, systems, and services. This encompasses both the understanding of concepts and the mastery of competencies relevant to sustainable development. (CDIO Standard 2). The curriculum must be interwoven with the learning of disciplinary knowledge and its application in professional engineering (Malamqvist, 2020). When disciplinary courses establish clear connections between related content and learning objectives, they synergistically reinforce each other. A well-defined instructional design outlines how the blending of skills and interdisciplinary links will occur. This might involve aligning specified learning goals with individual courses and supplementary activities within the curriculum.

The curriculum of B.Tech Information Technology of our institute has been prepared in accordance with ACM Computing Curricula and Conceive Design Implement Operate (CDIO) standards. The curriculum is well balanced with a nice blend of courses on Humanities and Social

Sciences, Engineering Sciences, Basic Sciences, Program Core Courses, Program Specific Electives, interdisciplinary electives, industry supported courses, internships and capstone projects. The proportion of each of the curricular components is illustrated in the figure 1.

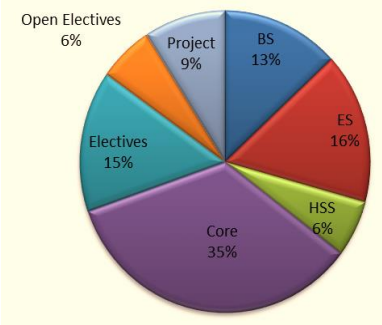


Fig 1 – Curricular Components in B.Tech IT program.

Programming, Data Engineering, Cyber Security and Privacy, Distributed Systems, Mobile Technologies, Cognitive sciences are the chosen specializations for the Information

TABLE I
FIFTH SEMESTER COURSES

Course Code	Course Name
21IT511	Web Technologies
21IT520	Information Security
21IT530	Data Mining
21IT540	Accounting and Finance
21IT571	Web Technologies Lab
21IT580	Information Security Lab
21ES590	System Thinking
21ITPQ0	Software Testing

Technology Program. The fundamentals of each of the specialization are covered in program core courses and the advanced concepts are covered in program elective courses. The list of courses as presented in Table 1 are offered during the fifth semester of the program.

Integrated Learning has been planned for the courses on Web Technologies, Information Security, Software Testing and System Thinking through a cross curricular project. The integrated learning is promoted through Project Based Learning which involves the application of various concepts such as cryptographic algorithms, HTML, Client side scripting languages (Java Script) and software testing tools. The instructional design for integrated learning with PBL is designed with major subsections as follows:

- Project Overview
- Learning Goals
- Project Milestones
- Project Calendar
- Rubrics for Assessment

A. Project Overview

The major outcome of the proposed instructional design is to develop a web application for demonstrating the working of various cryptographic algorithms. The project is done in teams of maximum size as four. Heterogeneous teams are formed by the instructors. Academic proficiency, programming expertise, leadership and team management skills are taken into consideration for the formation of teams. The overview of the project is illustrated in Table II. The individual web application created by all the teams will be integrated together, thereby resulting in a virtual lab for Cryptography. The integrated web application shall be used as a teaching aid by the academic community to teach the course on Cryptography in the future. It has been well proven that simulations arouse curiosity amongst learners. Creating

TABLE II
PROJECT OVERVIEW

Parameters	Description
Project Title	Integrated Learning Experience on Design and Development of Virtual lab for Cryptography
Project Duration	6 Weeks
Courses Intended	Web Technologies, Information Security, System Thinking and Software Testing.
Driving question	Can my students' team design and develop a web application for simulation of various cryptographic algorithms? Can all these applications be integrated and developed as a virtual lab for academic purposes? .
Year Level of Students	Third Year B.Tech IT Students
Projects Identified	1. Implemetation of RSA 2. Primality Testing and Factorization 3. AES Key Generation 4. Implementation and Cryptanalysis of Hill Cipher 5. Elliptic Curve Cryptography - Encryption 6. Elliptic Curve Cryptography - Key Exchange 7. Simulation of Dictionary Attack for password cracking 8. Modular Arithmetic Calculator 9. Digital Signature Staandard 10.Secure Hash Algorithm 11.Implementation and Cryptanalysis of Caesar Cipher 12.DES Key generation 13.Diffie Hellman Key Exchange 14.Vignere and Vernam, Ciphers 15.Knapsack based Cryptography 16.Playfair Cipher and Transposition Cipher 17. One Time pads, Primality Testing and Factorization Calculator
Related concepts from other courses	Information Security: Symmetric and Asymmetric algorithms, Hash functions and Digital Signatures. Web Technologies: HTML, CSS, Client Side Scripting(Java Script) Software Testing: Web application Testing System Thinking: Functional and Logical Requirements, System Modeling

simulations by learners themselves shall enhance their higher order thinking skills. The entire class of strength 65 has been

divided into seventeen teams and each team is assigned with a cryptographic algorithm for simulation. The list of cryptographic algorithms are presented in Table-II.

B. Learning Goals

The pedagogical approach of PBL has been chosen for creating an integrated learning experience with cross curricular projects. Further, this experience will prepare the learners to design and develop projects using the concepts learnt and enable to meet the requirements of real time applications. Design and implement experiences gained through PBL will be an enabler for building confidence among the students in engineering practices. Upon completion of this integrated learning, learners will be able to

- Design an interactive web application for cryptographic algorithms
- Handle exceptions effectively through a responsive webpage
- Write test cases and perform unit testing/ integrated testing using appropriate testing tools.
- Develop UML diagrams for visualization of the project flow
- Participate in team and contribute individually
- Communicate the technical and managerial information verbally, visually and on written form

C. Project Milestones

Various phases of the proposed integrated learning experience is represented in the figure -2

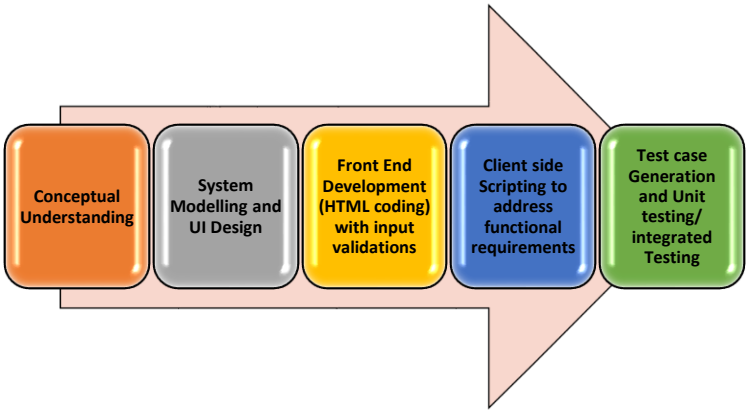


Fig 2 – Project Milestones.

In the first phase on Conceptual Understanding, learners are provided with appropriate reading materials and useful internet resources to understand the assigned cryptographic algorithm. Learners also utilize the office hours for clarification of doubts. Learners also search the existing web applications for demonstrating the chosen crypto algorithm. If such an application already exists, they explore the possibilities of adding new features. Exclusive Worksheets are developed to test the conceptual understanding.

In the second phase on System Modeling and UI Design, learners apply the concept of system thinking and identify the physical and functional requirements of the chosen web application. To visualize the flow of the project, use case diagram, class diagrams and activity diagrams are drawn. A storyboard is a visual representation illustrating the sequence of screens comprising a system's user interface and the associated navigation pathways. Even if the system fulfills the user's functional requirements, if the progression across screens does not align with their preferred workflow, it can result in a significantly vexing experience. Hence Storyboards are used in UI Design for visualization and enhancement of this facet of the system prior to the commencement of the actual construction process.

In the third phase on Front end development, HTML codes are developed to convert the storyboard into a real web page. Appropriate input validations are done to avoid exceptions and runtime errors.

In the fourth phase, client side scripts to execute the identified functionalities in the browser are developed. A modular design is adopted and each team member contributes to the development of at least one module. Each module is tested independently with suitable test cases.

In the fifth phase, integrated testing has been carried out to test the complete project using appropriate testing tools.

D. Project Calendar

The pedagogy for integrated learning experience is planned for duration of 6 weeks and the detailed plan is presented in Table III.

TABLE III
PROJECT CALENDAR

Week	Assessment and Activity
Week 1	Conceptual Understanding Assessment: Worksheets for Problem Solving
Week 2	System Modeling and UI Design Assessment: Peer review
Week 3	Front End Development Assessment: Review -1
Week 4 and Week 5	Scripting Assessment: Report on debugging
Week 6	Unit Testing and Integration Testing Incorporation of Testing comments Assessment: Review -2

E. Rubrics for Assessment

Rubrics are essential for assessment of the project work as it addresses higher order cognitive levels. Exclusive rubrics for Review -1 and Review -2 are presented in Table-IV and Table –V respectively. Review -1 is conducted for the assessment of user interface design and Review-2 is conducted for the assessment of functional requirements.

TABLE IV
REVIEW 1- ASSESSMENT RUBRICS FOR USER INTERFACE DESIGN

Parameters	Excellent (4)	Good (3)	Fair (2)	Need Improvement (1)
Visual Consistency	Highly consistent use of	Generally consistent use of	Some inconsistencies in the use of	Inconsistent use of colors,

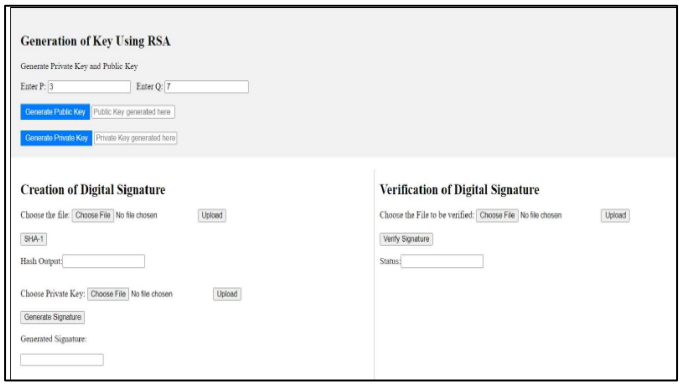
	colors, typography, and visual elements throughout the interface.	colors, typography, and visual elements	colors, typography, or visual elements.	typography, and visual elements.
Content Hierarchy	Excellent content hierarchy, important elements are clearly and effectively highlighted	Clear content hierarchy, important elements are appropriately highlighted.	Somewhat unclear content hierarchy, important elements are somewhat highlighted	Unclear content hierarchy, important elements are not highlighted.
Spacing and Layout	Excellent spacing and well-balanced layout, contributing to a clean and organized interface	Adequate spacing and balanced layout, ensuring clarity and organization, Few elements are missed out	Some issues with spacing and layout, leading to slight clutter	Poor spacing and unbalanced layout, causing clutter and confusion.
Alignment	Exceptional alignment, contributing to a visually pleasing and harmonious interface.	Elements are generally aligned properly, enhancing the overall visual harmony	Some misalignment issues, but overall alignment is passable	Elements are misaligned, causing visual discomfort and confusion.
Usability and User Experience	Excellent usability, interactions are highly intuitive, providing a seamless and enjoyable user experience.	Reasonable usability, interactions are generally intuitive with few minor issues.	Some usability issues, interactions are somewhat confusing.	Poor usability, confusing interactions, and a frustrating user experience.

TABLE V
REVIEW 2- ASSESSMENT RUBRICS FOR FUNCTIONAL REQUIREMENTS

Parameters	Excellent (4)	Good (3)	Fair (2)	Need Improvement (1)
Completeness of Features	All required features are present, well-implemented, and fully functional.	Most essential features are present and functioning properly.	Some missing or incomplete features, affecting core functionality.	Major functional gaps, core features missing or incomplete.
User Interaction and Navigation:	Highly intuitive navigation and smooth user interaction	Generally intuitive navigation and user interaction design.	Some navigation issues and suboptimal user interaction design.	Confusing and frustrating navigation, poor user interaction design.
Data Input and Output	Data input and output processes are seamless, efficient, and user-friendly.	Data input and output processes are reliable and moderately efficient.	Some data input and output issues affecting user experience.	Data input and output processes are error-prone and inefficient.
Performance and Loading Times:	Excellent performance, fast loading times, and smooth operation.	Acceptable performance, with occasional minor delays in loading.	Noticeable performance issues and occasional slow loading times.	Unacceptable performance issues, slow loading times, frequent crashes.
Error Handling and Feedback	Comprehensive error handling and informative user feedback.	Adequate error handling and user feedback mechanisms.	Some errors are not properly handled, limited feedback to users.	Poor error handling, lack of user feedback on errors.

V. IMPLEMENTATION

The proposed instructional design has been implemented successfully in the academic year 2022-23. Sample projects on the development of Digital Signatures, Elliptic curve encryption, Password cracking, Diffie Hellman Key exchange are illustrated in Figures 3 to 6 respectively. The projects developed were hosted in github repository of the learners. The Continuous assessment for the course on Information Security is normally evaluated for 200 marks out of which 80 marks is allotted for assignments and 120 marks is allotted for written examinations. This integrated assignment is given a weightage of 50% in assignment and contributes towards 20% of the total internal assessment.



. Fig 3 –Digital Signature

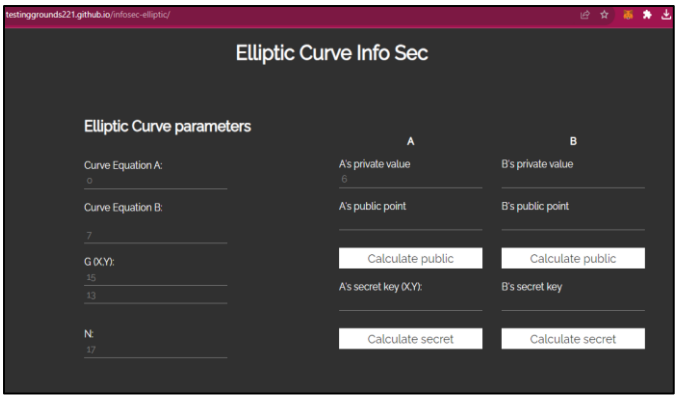


Fig 4 – Elliptic Curve Encryption

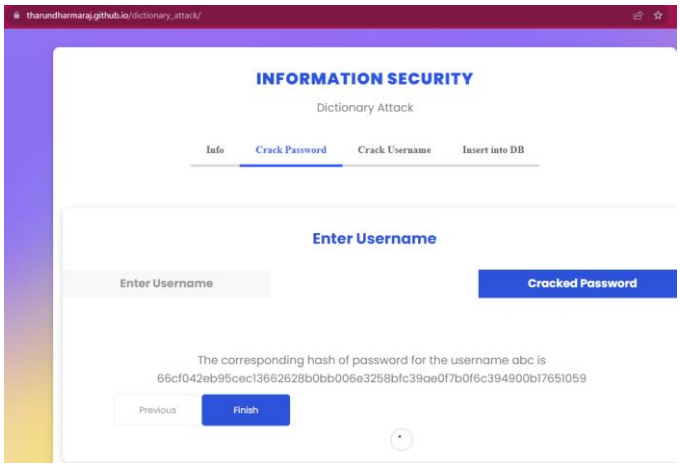


Fig 5-Password Cracking using Dictionary Attacks

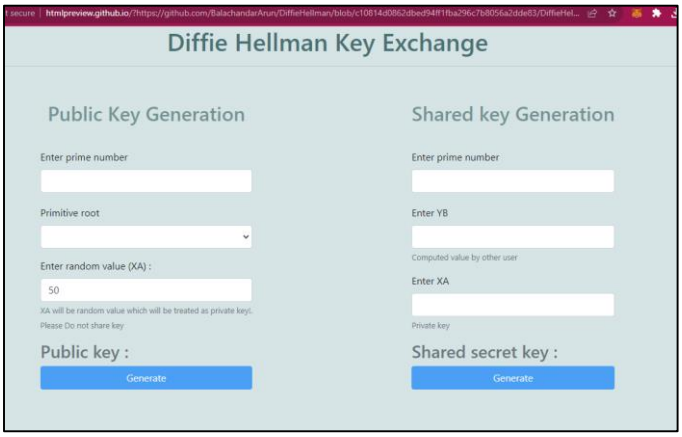


Fig 6 –Simulation of Diffie Hellman Key Exchange

VI. Results And Discussion

Discussion on RQ1:

RQ1 explores the possible ways to design integrated learning experiences in a timely and effective manner. From the experience of the authors, project based learning which involves multiple courses offered in the same semester seems to be a viable solution. Use of PBL templates have helped the authors to come up with a better instructional design with emphasis on Problem statements, learning goals, Milestones, Project Plan and Rubrics for assessment. The success of the integrated learning experience is dependent on the chosen problem statements. If the problem statements are interesting and the project is useful for the academic community, learners show a lot of interest in the project. Course Committee Meetings and problem statements posted in Smart India Hackathon and Kavach etc shall be used in the future offerings of the course. It could be inferred form the quality of the project implementations, PBL is most appropriate for creating an integrated learning experience.

TABLE III
Project Calendar

Week	Assessment and Activity
Week 1	Conceptual Understanding Assessment: Worksheets for Problem Solving
Week 2	System Modeling and UI Design Assessment: Peer review
Week 3	Front End Development Assessment: Review -1
Week 4 and Week 5	Scripting Assessment: Report on debugging
Week 6	Unit Testing and Integration Testing Incorporation of Testing comments Assessment: Review -2

Discussion on RQ2:

The impact of the proposed instructional design has been analyzed based on the performance of the learners in continuous assessment test (CAT), terminal examinations and attainment of course outcomes respectively. Also, the learner satisfaction index is used to analyze student involvement and engagement. It could be inferred from the figure 7 and 8 that the proportion of students who have secured the top 2 grades(S and A) in CAT and terminal examination is 61% and 52% respectively. The experimental group includes 65 Learners in the academic year 2022-23 and the control group includes 68 learners in the previous batch 2021-22. The comparative performance of the learners in CAT and Terminal Examinations are presented in figures respectively. It is evident that there is a significant increase in the count of students who have secured top 2 grades and a decrease in the count of failures (U), thus demonstrating the effectiveness of the integrated learning experience in enhancing the learning outcomes.

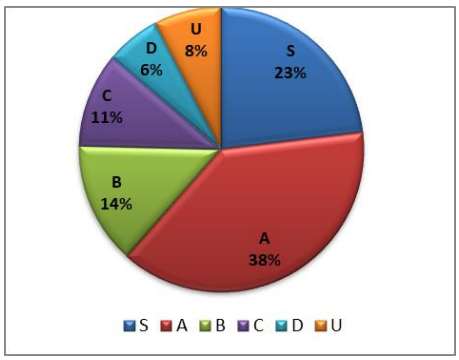


Fig 7-Performance in Continuous Assessment Test

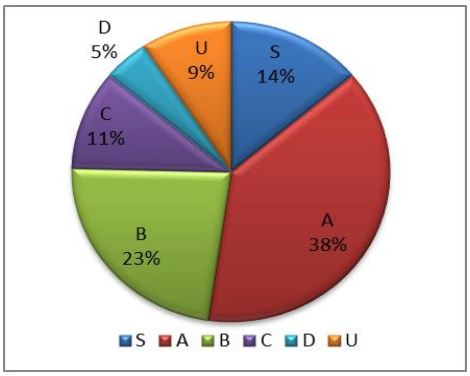


Fig 8-Performance in Terminal Examinations

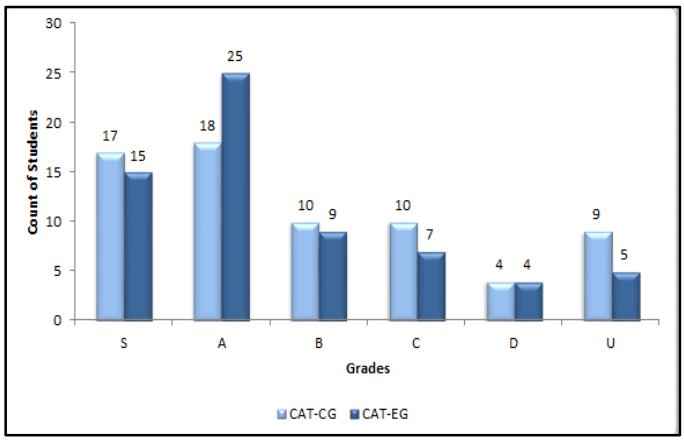


Fig 9- Comparative Performance in Continuous Assessment Test

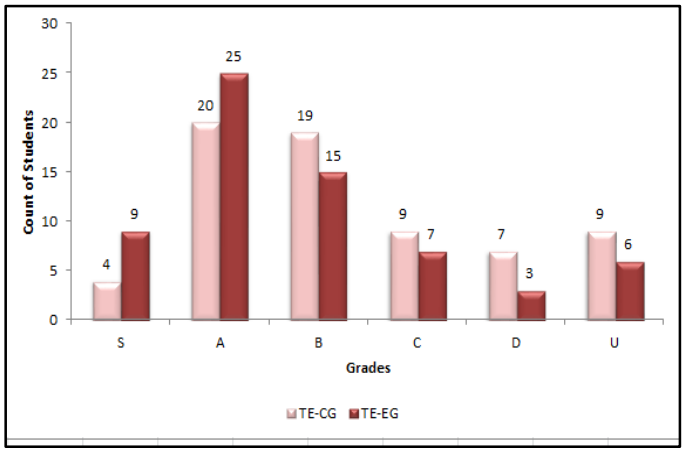


Fig 10- Comparative Performance in Terminal Examinations

In the information Security course with six learning outcomes, the attainment of three course outcomes related cryptography is analyzed. The expected proficiency (EP) and expected level of attainment (ELA) is fixed based on the history of the academic performance of the last three batches in the respective course and a 20% increase for continuous improvement. It could be inferred from table VI, that the actual attainment is greater than the ELA.

TABLE VI
ATTAINMENT OF COURSE OUTCOMES

S.No	CO	EP	ELA	Actual Attainment
CO1	Perform Encryption/ Decryption of text using symmetric and asymmetric crypto algorithms to provide confidentiality.	A	75	84.05
CO2	Compute hash and digital signature for the given message to provide integrity and non-repudiation	A	75	85.16
CO3	Examine the strength of any cryptographic algorithm by crypt analysis	B	70	84.63

An exclusive questionnaire has been designed to get feedback on the integrated learning experience from the learners. The analysis of the feedback is presented in figure 11 . It could be inferred that on an average, more than 70% of the learners have found the activity to be useful and relevant. Sample responses for qualitative feedback are as follows:

- The activity helped us to see the practical applications of what we are learning.
- It helped us to analyze, synthesize, and evaluate information across courses, fostering a deeper understanding of concepts.

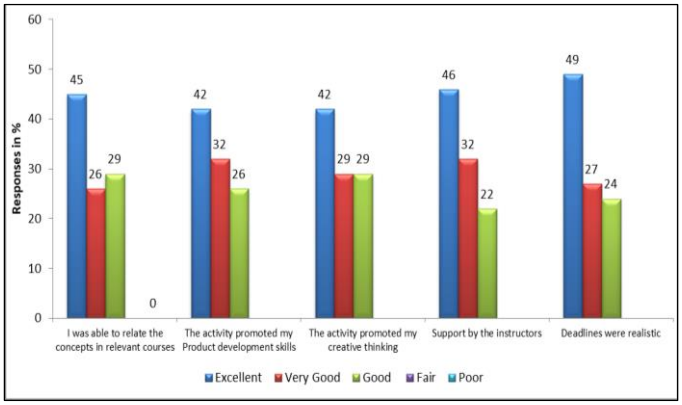


Fig 11- Learners Feedback on Integrated Learning

Discussion on RQ3:
Though there was significant improvement in the attainment of learning outcomes, there were few challenges faced during implementation. Based on the experience, the authors have come up with few mitigation strategies as reported in Table 5. The proposed solutions shall be incorporated well in advance in the future offerings.

TABLE V
ISSUES AND MITIGATION STRATEGIES

Issues	Mitigation Strategies
More time to be spent on Instructional design	PBL shall be adopted in integrated learning. Course Coordinators of System Thinking, Software Testing and Web Technologies shall be involved
Difficulty in identification of problem statements	Problem statements from Smart India Hackathon and other platforms like Kavach shall be simplified and used
Timely completion is difficult because of regular academic load.	Grades points secured in the integrated learning shall be splitted across all courses towards assignment marks
No equal contribution from all the members in a team	Specific rubrics shall be designed to assess team work and communication skills
Minimal support for debugging and addressing implementation issues.	Discussion forums shall be created. Peers and instructors shall assists in bug fixing.

VII. CONCLUSION

In this research study, the potential of integrated learning as a transformative pedagogical approach has been explored. Through interdisciplinary connections and cross-curricular projects, it fosters holistic learning experiences, nurturing critical thinking and collaboration. The study's implementation in an Information Technology curriculum demonstrated improved learning outcomes and engagement. Challenges in integration were addressed with strategic instructional designs. Integrated learning emerges as a promising solution to bridge educational gaps, align with industry demands, and enhance students' problem-solving skills. This research encourages further exploration, highlighting the importance of this approach in preparing students for multifaceted real-world challenges, aligning education with practical application. The present work shall be extended to assess the impact on creativity, communication, collaboration with exclusive rubrics. The applications developed by the learners have to be tested and reviewed by subject experts before release. The integrated project shall be made available as an open source for academic and training purposes. The impact on learning outcomes of the other related courses are also to be analyzed in detail.

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