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EDITORIAL AND ADVISORY BOARD MEMBERS

EDITORIAL

It is with great pleasure that we relaunch the Journal of Technical and Vocational Education, a flagship publication of NITTTR Chennai, then TTTI after a hiatus of 16 years. This milestone marks our renewed commitment to fostering scholarly discourse, innovation, and excellence in technical and vocational education as we have been rechristened as an Institution Deemed to be University in the Diamond Jubilee Year of 2024.

This journal aims to provide a platform for educators, researchers, policymakers, and industry experts to share their insights, experiences, and research findings on various aspects of technical and vocational education. We envision this journal to catalyze meaningful discussions, collaborations, and innovations that can help shape the future of technical and vocational education in India and beyond. In this inaugural electronic issue of our Journal, we feature a curated selection of articles that showcase the diversity and richness of research and practice in technical and vocational education. We are grateful to our authors, reviewers, and editorial team for their tireless efforts in bringing this issue to fruition.

This edition of the Journal of Technical and Vocational Education presents a diverse collection of research papers that delve into cutting-edge technologies, pedagogical approaches and societal challenges. From the integration of Augmented Reality in tourism to the ethical considerations of organ donation in the Internet of Medical Things (IoMT), these articles offer valuable insights for educators, researchers, and practitioners alike. Key themes and highlights are as follows.

Technological Advancements

"Implementation of an Augmented Reality-based Tour Guide Application in Cloud" by B. Sriman, O.Pandithurai and S.H. Annie Silviya explores the potential of AR technology to enhance the tourism experience. "Flow Analysis of Transverse Injection in A Typical Strut-Based SCRAMJET Combustor" by G. Sridhar, E. Balasubramanian and B.T.N.Sridhar delves into the complexities of aerospace engineering, focusing on the critical analysis of combustion in a SCRAMJET engine. "ML-Based Object Recognition and Object Picking Robot using ROS" by G. A. Rathy and P. Sivasankar showcases the integration of machine learning and robotics for advanced automation tasks. "Position and Velocity Analysis of Open and Closed Loop System Using Various Controllers in Underwater ROV-ORCA for Stabilized Navigation" by M. Vimal Raj, Sakthivel Murugan Santhanam, Muthumeenakshi Kailasam, B. Sandhya and G. Sree Harine investigates the intricacies of underwater robotics and navigation systems.

Pedagogical Innovations and Teacher Development

"The Importance of Ongoing Professional Development for Teachers: Enhancing Pedagogical Practices and Student Outcomes" by Sundaresan Ranganathan and M.Vetrivel emphasizes the crucial role of professional development in improving teaching practices and student learning. "Mathematics Teachers Perceptions in Action Research: Functionality in Flipped Classroom Approach" by I.S.K. Eriyagama and M. Lubna Ali investigates the effectiveness of the flipped classroom approach in mathematics education.

Social and Ethical Considerations

"Blockchain-Based Security for Organ Donation Health Records in IoMT" by C.Gethara Gowri, M.Amanullah and J.Lakshmikanth addresses the critical issue of data security and privacy in the context of organ donation within the IoMT. "The Impact of Language Diversity on Technical Education in the Andaman and Nicobar Islands: Challenges and Strategies in the NEP 2020 Context" by K.N. Shoba and T. Diana Joslin examines the challenges and potential solutions for addressing linguistic diversity in technical education within the framework of the National Education Policy 2020 in the Andaman and Nicobar Islands. "A Social Philosophical Study on Gender and Vocational Training of Persons with Disability" by Chamila Siriwardene and A.H. Indika Sanjeewa explores the crucial intersection of gender, disability and vocational training from a social and philosophical perspective.

Energy and Sustainability

"Power Quality Enhancement in Microgrid for Grid Connected Electric Vehicle Charging Infrastructure: A Critical Review" by N.Sivanantham, P.Thamizhazhagan and P. Pugazhendiran examines the crucial role of power quality enhancement in supporting the growing demand for electric vehicle charging infrastructure within microgrid systems.

This edition of the Journal of Technical and Vocational Education offers a valuable resource for researchers, educators, and policymakers seeking to understand and address the critical challenges and opportunities in technology, education, and society. We look forward to receiving your contributions, feedback, and suggestions and to working together to create a vibrant community of scholars and practitioners.

Thank you

Editor-in-Chief
Journal of Technical and Vocational Education

Contents

Implementation of an Augmented Reality-based Tour Guide Application in Cloud

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Abstract: Augmented reality applications are gaining popularity in recent times. Also, due to the pandemic, many industries have digital services and so augmented reality can be used to enhance the digital user experience of clients and customers across industries. One of the many industries in which augmented reality can be applied is the tourism industry. In this study, a way to completely digitize the touring experience is proposed. The application which has been developed will allow users to view 3D models of tourist spots, listen to historical facts about the tourist spots and view information about the spots and stored in cloud. The application was demonstrated to a wide variety of audiences and feedback was received from them. The application uses surface tracking and image tracking. Several tools such as Unity 3D Game Engine, MagicaVoxel, EasyAR Software Development Kit, Mixamo, Adobe Premiere Pro, Figma, C# programming language and Aseprite were used to create this application.

Keywords: *Unity 3D Game Engine, Augmented Reality, Tourism, Tour Guides, Tourist Spots*

I. INTRODUCTION

Augmented reality has made its way into many mobile applications. Some mobile applications are solely based on AR whereas some applications have certain features that use AR and others that don't. So, creating an application solely based on AR can prove to be immensely positive in terms of growth of the application. Moreover, AR technology can be used in many industries and one such industry is the tourism industry [1]. And so, we propose an application that will provide information about tourist spots once the image of the tourist spot is scanned through the application [2]. The application will also allow users to look at the 3D models of the tourist spots, resize the tourist spots and move the tourist spots around their physical space. Furthermore, users can listen to tour guides that explain about the significance of each tourist spot [3]. We created this application for European tourist spots and thus we named the application – Eutouria. The application provides the above-mentioned services for fictional tourist spots, famous tourist spots and damaged tourist spots [4]. This is helpful because people cannot actually visit fictional tourist spots because they do not exist in the real world. Also, people cannot actually visit damaged tourist spots because even they do not exist in the current world as they have been destroyed in the past during wars or natural calamities. Also, famous tourist spots are located in exotic regions which are expensive to visit. So, this application will bring the tourist spots to the people instead of people going to the tourist spots. We used the C# scripting language to make this app. We used MagicaVoxel to create the 3D models of the tourist spots and tour guides. Also, Aseprite was used to make 2D graphics of the tourist spots. Mixamo was used to animate the tour guides.

The information given by the tour guides was recorded by actual humans using a recording application available on android phones. These recordings were then edited using Adobe

Premiere Pro to enhance the sound quality. The integrated development environment used was the Unity 3D Game Engine. We used EasyAR SDK to implement surface tracking and image tracking [5]. The tour guide feature and tourist spots feature use surface tracking. The spots info feature uses image tracking. Figma was used to create the UI designs for the app [6]. So, in this app, people are able to engage in 3 different modes: listening to tour guides, viewing tourist spots and gathering information about such spots [7]. Image tracking application is done where an image of a tourist spot is scanned through the application and then information about the tourist spot is augmented on top of the image. These images are known as image targets and image tracking is also known as marker-based AR or target tracking. Surface tracking is done in which the user first selects the feature they want to use – tour guide or tourist spot, then they have to choose the type of tourist spot - fictional tourist spot, famous tourist spot or damaged tourist spot and then they have to choose the specific tourist spot that they want to view or know about and finally, if they selected the tour guide feature, a tour guide appears on the surface visible through the camera of the mobile phone used by the user and the tour guide starts talking about the tourist spot chosen by the user, note that by tour guide we mean a virtual 3D model of a tour guide. Alternatively, if the user selected the tourist spot feature, the tourist spot appears on the surface visible through the camera of the mobile phone of the user. The user can move the tourist spot or tour guide around their surface and also resize the tour guides and tourist spots. By demonstrating this app to a group of engineering students, we found that AR can indeed improve the touring experience [8]. This app is unique because most other AR tour guide apps require the user to be in the tourist spot physically in order to get the AR experience whereas in this app, users can get the AR experience without physically being in the tourist spot [9]. Additionally, the main concentration is not only to provide AR features but to also to make the 3D models of tour guides and tourist spots to look relatively pleasing to the eyes in order to improve user experience and user satisfaction [10].

II. RELATED WORK

The key research studies related to augmented reality based tour guides, highlight the following points. The first study focused on an audio augmented reality tour guide which can be used in museums [11]. Audio will describe about the artifact as soon as a group of people walk up to a particular monument. The audio will stop as soon as the people walk away from the exhibit. Transmitters, receivers, and microcontrollers were used to implement this idea. In another study a virtual AR tour guide for heritage sites was proposed [12]. A prototype version was made and tested in a popular heritage site in Korea. Several tourists were allowed to use the AR tour guide and they answered a series of questions relating to the performance, usefulness, and device compatibility of the software. The tour guide software enabled realistic 3D virtual characters to be superimposed on the heritage site. Further, another study was about a tour guide which would augment information about the tourist spots if the user scanned the images of the tourist spots which are available in an offline tour booklet [13].

Similarly, an AR tour guide was made using HTML/CSS, JavaScript, PHP, and SQL [14]. The tour guide proposed demonstrated that the authors had created a prototype of an application that would augment information about events, their venue and availability of tickets for the event. A tour guide application was created specifically for Malaysia in order to increase the profits made by the Malaysian tourism industry [15]. The application made recommendations to users based on the budget and objectives of the tourists. The application made use of C#, AI, and AR technologies. Another study had a prototype version of an application which was made using C#, Vuforia SDK and Wikitude SDK. In this application, image tracking was used [16]. So, information about the tourist spot was augmented on the image of the tourist spot. Also, a 3D model of a cube having the image of the tourist spot was augmented on the image of the tourist spot.

A study proposed an AR application which allows the user to scan the environment and then the application renders an older image (say an image from the 1900s) of the tourist spot which is visible in the environment which is being scanned by the user. Unity 3D Game Engine and Vuforia Software development kit were used to create this application [17]. Another study focused on intelligent tour guide android applications and how they can enhance user experience [18]. The study also explained about the implementation stages of the intelligent tour guide mobile app in detail. The next study proposed a geolocation system powered by AR [19]. Finally, the last study reviewed was about a system which can be applied in entertainment and education industries and the system used an offline tour booklet along with AR at a reduced computational cost [20].

III. IMPLEMENTATION

The programming language used to develop this application is C#. We used C# mainly to allow navigation from one scene to another and to allow navigation to different screens within a scene. We also used C# to enable and update the animations and audio of the tour guides. The IDE which was used to create this application is Unity. In Unity, we used several assets such as: scripts, scenes, materials, plugins, audios, graphics, streaming assets, fonts, 3D models, etc. to implement the app. Scripts were used to enable functionalities such as navigation, animation etc. The scripts were written in C# as mentioned above. Audios used were the audios which people can listen to when they choose the tour guide feature. The streaming assets are basically the images which the user will be scanning in order to get the info about the tourist spots. Graphics used were mainly images which we needed to make the UI of the software. We converted all these images into sprites which can be used in the UI. 3D models which we used were the 3D models of the tour guides and 3D models of the tourist spots. The fonts which we used were Notable, Montserrat, etc. The plugins which we used were EasyAR plugins and Android plugins. We used materials to give colours to the models which would display information about the spots while the spots info feature is being used. To develop the UI of the mobile app, we used several game objects available in Unity such as canvas, panels, images, text mesh pro, text, buttons, etc. We used Ctrl+D to reuse screens as and when required. Other game objects used were SceneManager, Directional Light, Main Camera and Event System. We created one separate scene which had most of the UI elements of the application. We created individual scenes for each of the tourist spots and tour guides. The spots info feature was covered in the initial scene which had all the UI elements. For the tour guides feature and tourist spots feature, surface tracking was used and for the scenes which involved surface tracking, additional game objects such as: EasyARSurfaceTracker, WorldRoot and TouchRoot were used. For image tracking, the extra game objects used were: ImageTracker, WorldRoot, RenderCamera and VideoCameraDevice. In order to implement surface tracking and image tracking in our application, we needed advanced computer vision algorithms through EasyAR. So, in order to use EasyAR, we first created an account on the EasyAR website and then we created a new sense license key by giving details such as the name of the application, the platform on which it is going to be deployed etc. Then we got the license key which we then used in Unity in order to access the services provided by EasyAR in our app, we also had to setup EasyAR in Unity. The next step was designing the 3D models. For creating the 3D models of the tourist spots, we first created 2D models using Aseprite because these models needed an extra amount of detailing which was possible with the help of Aseprite. In Aseprite, we can change the sprite size, canvas size, brush size, etc. and choose different colours from the colour palette, erase by clicking on E on the keyboard or choosing the eraser option on the screen, go to brush mode by either clicking on B on the keyboard or by choosing the brush from the screen, also draw lines by clicking on L on the keyboard, marquee by clicking on M, copy and paste by first using the marquee tool to select the area to copy and then clicking on Ctrl+C followed by Ctrl+V, and finally placing the pasted portion in the specific area of the workspace as required. After creating 2D graphics of the tourist spots, these 2D graphics were inserted into MagicaVoxel to convert

them into 3D. Note that we used this procedure only for some of the tourist spots, for most of the tourist spots, we directly made the 3D models in MagicaVoxel. In MagicaVoxel, we can click on Alt and click on the colour to select, this enables us to choose colours from the 3D models. We can also attach, erase and paint by choosing those on the screen. In MagicaVoxel, we can select all the different 3D models on the screen by clicking on All, we can increase the size of the 3D model by using 2X, we can decrease the size of the 3D model by using ½, marquee, move the 3D model backward, forward, left, right, top or bottom, also change the height, width etc. of the workspace, change the view, such as perspective view, orthogonal view etc. apply different effects such as emit, diffuse etc. take pictures of the 3D model. We can change the background, sky, intensity, ground etc. of the backdrop of the 3D model before clicking an image of it or duplicate an entire file. The files which we make in MagicaVoxel have an extension of .vox but we can export the voxel models in other formats as well such as obj. Voxel models are trending in the NFT world, gaming market and many such industries, thus we decided to make all the tourist spots and tour guides using voxel art.

Fig. 1 *Fictional Spot Info*

Fig. 2 *Fictional Tourist Spot*

Fig. 3 *Male Tour Guide*

For making the 3D models of the tourist spots, we referred to several images, portraits, paintings, 3D models etc. of the tourist spots. For making the 3D models of the tour guides, we first created a base human model with a face, body, hands and legs. Then we used this base model to create all the tour guides. We added clothes, facial features, hair and accessories to make different models from the base model. We made three types of 3D models, they are: normal male 3D models, normal female 3D models and famous fictional 3D models. We used the male and female 3D models for the various famous tourist spots and damaged tourist spots. We used the 3D models of famous fictional characters to speak about the fictional place that they were associated to. For example, Willy Wonka was the tour guide for the Willy Wonka's Chocolate factory in our app. We initially created the rough UI designs with paper and pen. Then we converted those designs into more professional looking app designs using Figma. These designs had colours, fonts, images, effects, text etc. which we actually used in the application. Figma also helped us to collaborate and work on the same file at the same time which was incredibly useful.

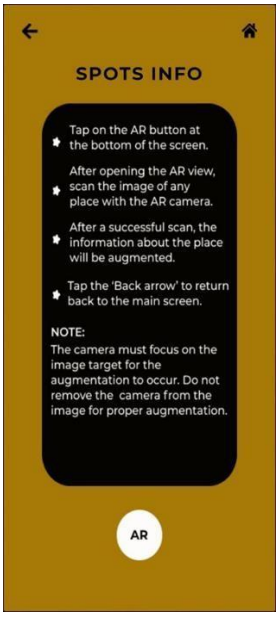

Fig. 4 *Main Screen* **Fig. 5** *Tour guide page* **Fig. 6** *Tourist spot page* **Fig. 7** *Spots info page*

We used Adobe Premiere Pro to edit the audios of the tour guides. To do this, we first uploaded the audio in the Adobe Premiere Pro software in mp3 format, then we increased the decibels of the audio as and when required. Lastly, we used Mixamo for animations. Here we have to first upload the 3D model which we want to animate. Next, we have to mark specific parts of the 3D model such as the chin, groin, knees, elbows and wrists. Then the website performs auto-rigging after which we can choose several animations. For our tour guides, we chose three different animations for each character: a standing animation, talking animation and a waving animation.

Fig. 8 *Famous spot page* **Fig. 9** *Fictional spot page* **Fig. 10** *Damaged spot page* **Fig. 11** *About page*

IV. RESULTS

The application was shown to a group of engineering students from various branches of engineering and the concept of the application was explained in detail. At the end of the demonstration, a feedback form in which various questions about the application were asked was distributed among the students. We asked a total of seven questions. For the first five questions, there were four options from which the user can choose their response, the four options were: Excellent, Good, Satisfactory and Can be improved. Table 1 shows the first five questions which were asked in the form and the different responses that we received:

Table 1. Questions asked and feedback received

Question Number	Question	Excellent	Good	Satisfactory	Can be improved
1	How was the user interface?	61.9%	38.1%	0%	0%
2	How was the tourist spot feature?	66.7%	33.3%	0%	0%
3	How was the spots info feature?	52.4%	47.6%	0%	0%
4	What do you think about the tour guide feature?	52.4%	47.6%	0%	0%
5	How was the user experience?	47.6%	52.4%	0%	0%

For the next question, there were three options from which the user can choose their answer. The three options were: Tourist Spot feature, Spots Info feature and Tour Guide feature. For the last question, we gave users two options to choose from, those two options were: Yes and No. The questions were asked to know about things like which feature was most liked by the users, do the users believe that augmented reality can replace tourism completely, how the users found the individual features, and whether the users like the user experience and user interface etc. of the application. These questions allowed us to understand more about user expectations and mindset. We also created pie charts based on the responses received so that we can know the results visually without going through a lot of data. The sixth question which we asked in the form was: Which feature did you like the most? For this question, there were three options, namely: Tourist Spot feature, Spots Info feature and Tour Guide feature. 57.1% of the students chose the Tourist Spot feature as their response, 33.3% of the students chose the Spots Info feature whereas 9.5% of the students responded by selecting the Tour Guide feature. The last question was: Do you think Augmented reality can replace the real-life touring experience? For this question, there were two options: Yes and No. 52.4% of the people responded with a No and 47.6% people responded with a Yes.

V. DISCUSSION OF RESULTS

For the last question, which was if augmented reality can replace the tourism experience, majority of the people said no, the difference between the number of people who said yes and no was relatively small though. Yet, a slightly higher number of people seemed to think that AR cannot

replace tourism, this might be because through this application people cannot actually experience travelling in a train, plane, ship or boat, they cannot actually experience the weather – snow, sun or rain of the tourist spot, they cannot actually taste the local food available in the tourist spot, they cannot listen to the local languages spoken in the area, etc. Also, during the demonstration we had hinted at these facts which are true to a great extent and must have influenced the responses of the users.

For the second last question, in which users had to choose their favourite feature of the application, majority of the people selected the tourist spots feature and this is because this is the main feature of the application – to actually look at the tourist spots. The second highest response was the spots info feature whereas the least chosen response was the tour guide feature. The reason for the tour guide feature to be the least liked feature might have been that during the demonstration of the application, we did not show the tour guide feature to the audience since the feature was not fully ready and so we only explained about the concept of the feature. Since users did not actually experience this feature, they could not perhaps imagine it and thus could not vouch for it.

For the fifth question, in which users had to rate the user experience of the application, majority of the people selected 'good' whereas the rest of the people selected 'excellent' which naturally suggests that the user experience was as per the expectations of an average user. For the rest of the questions in which users had to rate the user interface and individual features of the application, majority of the people selected 'excellent' whereas the rest of the participants selected 'good' which implies that the features and the UI were positively received by the participants.

VI. CONCLUSION

In this study, we have explained in detail about the idea and implementation of our augmented reality based tour guide application – Eutouria. The application shows 3D models of tourist spots and 3D models of tour guides which explain about the tourist spots. Also, users can move around the tourist spots and tour guides and resize them. The application also augments information about each tourist spot. In future, we plan to implement this application in virtual reality headsets as well, so that users can go inside the tourist spots instead of just looking at them from the outside. This application will be helpful for people who want to visit tourist spots without physically going to the tourist spots. This application will also help people to visit places which have been destroyed by natural calamities and man-made disasters. Furthermore, the application enables people to visit fictional tourist spots which do not exist in the real world. Moreover, the application can prove to be immensely useful for older people because they might not be physically fit to take long vacations to distant lands as the weather, food, etc. of the unknown region might harm their health. Further, this app can prove to be beneficial for people who cannot afford expensive trips abroad or people who do not have the time to take a vacation. Also, due to the pandemic, many countries have closed their borders to tourists and have many travel restrictions, so in such scenarios, this application can aid people who want to travel to different places. The demerit of this application is that even though the tourist spot comes to the user's place of choice, the user cannot get the experience of being in the tourist spot. The advantages of this application are that it is simple to use, it saves time and provides accurate information and good user experience along with a seamless user interface.

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The Importance of Ongoing Professional Development for Teachers: Enhancing Pedagogical Practices and Student Outcomes

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Abstract: The ongoing professional development of a teacher is a continuous learning process. Teachers are the backbone of imparting quality education to students and effective professional development is a critical component in improving the quality of education and enhancing student learning outcomes. Drawing upon a thorough examination of the relevant literature, this research study investigates the key elements and characteristics of successful professional development programs designed to support and empower teachers in their pedagogical practices and professional growth. This research study suggests innovative teaching methodologies that can be implemented in the modern education system to minimize interaction gaps between students and teachers while conveniently delivering structured syllabus to achieve optimal results. By implementing these teaching methods, teachers can manage their time effectively without experiencing peer pressure. This theoretical study draws upon three theories such as Self-Directed Learning, Situated Learning and Adult Learning Theory. This study highlights the teacher's individual-level approaches to professional development, emphasizing the transformative potential of providing teachers with avenues for active engagement, collaborative learning and critical reflection.

Keywords: *Conceptual Framework, Teacher Professional Development, Pedagogical Practices, Student Outcomes, Individual-Level Approaches*

I. INTRODUCTION

The critical role of ongoing professional development in elevating the quality of instruction and improving student learning outcomes has gained widespread recognition among educators, researchers and policymakers across the education sector. The need for this 21st-century educational system might be structured upon the skill demand from the current industry practices and trends. Industries are seeking skilled workforce for their work culture which rapidly creates peer pressure on the students and teachers to maintain their quality of education and make students survive more comfortably in the outside world after their graduation. To effectively foster student skill development, teachers should adapt modern learning methods to develop their student's skills and prepare them well to fulfil the industry needs with their students' acquired knowledge. Therefore, teachers must inculcate modern adaptive teaching-learning methods into the curriculum for their student's welfare and their teaching career advancement.

The Overview of Self-Directed Learning (SDL)

The self-directed learning pedagogical method focuses on the effective action of planning, executing and evaluating the learning experience by the individual learners with their interests.

The main objective of the SDL is developing student's ability in critical thinking, computational thinking, design thinking and problem-solving skill sets that fall under *"ways of thinking"*. SDL method introduces digital and technically advanced tools to keep the learners more connected in their learning phase comes under *"tools of working"*. SDL Method of teaching encourages each learner to expand their learning practices beyond the traditional classroom method and prepare themselves to learn their curriculum concepts independently which falls under *"ways of working"*. A research study conducted by Karats et al. [1] identified that SDL skills are directly associated with 21st-century skills and positively correlated with statistical evidence. The underlying theory of SDL is developed from the active learning theory. According to Michael Price's [2] explanation, *"Active learning is any method that engages students in the learning process"* which furthermore explains the importance of the active learning process among students and encourages and motivates them to identify new ways with curiosity and passion towards reading in the Self-directed learning method.

Situated Learning Theory Concept – An Overview

The previous paradigm of teaching and learning views has been much influenced by the whole new concept of analyzing the teacher's learning outcomes and their behaviour developed by *Lave and Wenger (1991)* [3]. Based on their research, a three-level model for learning is implemented to analyze the inhibition of teachers' behaviours in the classroom and capture their actions using brain research to learn how this model combines the ideas of learning through real-life scenarios with traditional learning theory. Their study broadened the implication of brand-new concepts in teaching and turned impressive interest among teachers, educators and researchers. The best example of the situated learning theory is adapting an e-learning method of teaching practices in today's education for students' self-paced learning and advanced skill development outcomes. The situated learning theory fully supports innovative modern pedagogical practices and student learning outcomes by adapting the e-learning teaching approach.

Adult Learning Theory

According to *Malcolm Knowles (1988)* [4], adult learning varies in different ways, starting from childhood learning practices. He also proposed a term called *"andragogy"* to express the different phases in learning to enhance pedagogy. The principles of andragogy are applied in children's learning for their continuous learning for the life term. Knowles' views and learning models have undergone intense research and the method suggested that adults learn differently from children. The key research difference between adult and children learning is motivated by different aspects of learning. Also, the theory described by Knowles is grouped under six aspects. They are

1. The learners need to know why they want this
2. The learners are responsible for their self-decisions
3. The value and role of the individual learner's experience
4. The learner's readiness for learning
5. The learner's self-motivation
6. The learner's perspective on dealing with the real-time scenarios

To achieve the above student learning outcomes, teachers should adapt themselves to technologically advanced innovative teaching-learning methods such as

- E-learning concept of learning (comprehensive digital learning method for student self-paced teaching)
- Domain-specific method of teaching (specialized teaching method related to the domain-specific industry need)
- Customized learning method (adaptive teaching method for different learning styles to focus on individual student's strengths and weaknesses)
- Cognitive Learning Approach (align teaching method with industry expectation to encourage entrepreneurial skill development among students and encourage project-based learning)

II. LITERATURE REVIEW

Continuous research has demonstrated that teachers' professional development is crucial for improving teaching skills and keeping them abreast of new technological advancements and educational trends, ultimately creating a better learning environment for students, as highlighted by Darling-Hammond et al. (2017) [5]. Teachers play a key role in maintaining high educational standards and encouraging students' continuous educational achievements and skill development. Therefore, it is essential to support their teaching and provide ample opportunities for students' career growth, as noted by Kiran et al. (2022) [6]. Darling-Hammond et al. (2017) cite numerous studies describing various teaching methods and practices, and the researchers emphasize the importance of adapting innovative teaching methods in contemporary education to develop students' critical thinking, problem-solving, computational thinking, design thinking, and communication skills. Addressing the need for new teaching method adaptation requires providing teachers with adequate support. Educational institutions should train teachers on effectively implementing new teaching methods, familiarize them with available innovative methods, and instruct them on using advanced learning tools to cultivate student skills and achieve positive outcomes. This can be accomplished through faculty enrichment programs and Faculty Development Programs (FDPs), along with the creation of professional learning communities (PLCs) specifically designed for teachers' growth and career advancement.

Some studies have shown that providing training to teachers positively impacts teaching performance. However, other research indicates that traditional professional development programs often fail to produce significant long-term changes in teachers' instructional practices and student learning. Consequently, many educational leaders and experts suggest focusing on personalized professional development for teachers, similar to how students are supported, to address each teacher's individual needs and teaching preferences. One effective method for personalized professional development is encouraging collaborative activities among teachers, such as observing each other's teaching styles, team teaching, and participating in professional development communities both within and outside the school. These collaborative activities facilitate peer learning and encourage the application of new teaching strategies in the classroom. A barrier to teachers' professional development is the lack of time for self-learning. To address this, educational institutions can integrate technology-driven professional development, such as e-learning platforms and virtual workshops, providing teachers with flexible learning opportunities that allow them to access resources at their convenience, as suggested by Dede (2006) [7].

Research by Kang and Hsu (2020) [8] has shown that online professional development programs can effectively engage teachers in group discussions, collaborative tasks, and real-time learning of digital tool applications through this interactive approach. Studies highlighting the role of a cognitive learning approach suggest that it increases the likelihood of implementing innovative teaching methods, helping teachers understand and adapt digital tools more easily. Timperley (2011) [9] emphasizes the importance of teachers reflecting on their teaching methods and how their students are developing their skills.

Research Goal: This core study examines how continuous professional development (PD) in learning and improvement on teaching methodologies impact both educators and students. It focuses on how professional development-specific approaches influence pedagogical practices, student engagement and learning satisfaction. The ultimate goal is to provide a theoretical and practical foundation for implementing sustainable professional development strategies across educational institutions.

Objectives of the Study:

- To examine modern teaching practices in educational institutions.
- To measure changes in student engagement in pre and post-intervention on modern teaching method into the curriculum.
- To explore the role of PLCs in supporting effective implementation of professional development strategies.

III. METHODOLOGY

The study focuses on a group of 50 participants (25 teachers and 25 students) from institutions in Tamil Nadu. Stratified random sampling was used to include participants with different educational levels, teaching experience and subject areas. This method helped to create a balanced and meaningful group for the study. The data was collected from three main sources such as surveys, feedback forms and classroom observation. Over a six-week intervention, a structured 5-point Likert Scale questionnaire was prepared for both the teachers and students to measure teaching methods and student engagement. Weekly observations were conducted to monitor teaching practices and student interaction levels. The observation was conducted focusing on the application of e-learning tools, domain-specific teaching and customized learning strategies.

Questionnaire for Students: The student questionnaire was designed to assess their engagement with modern teaching strategies and the impact of digital tools on their learning experience. Both the questionnaires were based on a 5-point Likert scale for detailed feedback collection.
1. How often do your teachers use digital tools or e-learning methods during the class?
(a) Never (b) Rarely (c) Sometimes (d) Often (e) Always
2. How engaging do you find yourself when your subject teacher uses new digital or online learning strategies?
(a) Not engaging (b) Slightly engaging (c) Neutral (d) Engaging (e) Very engaging
3. Do you feel your teacher has improved in explaining subject-specific or domain-specific concepts over the past semester?

(a) Strongly Disagree (b) Disagree (c) Neutral (d) Agree (e) Strongly Agree
4. Does your teacher offer personalized help or modify lessons to better fit your learning needs?
(a) Never (b) Rarely (c) Sometimes (d) Often (e) Always
5. How well do you understand your teaching material while studying?
(a) Not at all (b) Slightly (c) Moderately (d) Very well (e) Extremely well

Questionnaire for Teachers: The teacher questionnaire was designed to evaluate the effectiveness of the Faculty Development Programs (FDPs) and how teachers applied post-training modern teaching strategies in their classrooms.
1. How frequently do you use e-learning methods and other modern teaching methods in your teaching after participating in FDPs?
(a) Never (b) Rarely (c) Sometimes (d) Often (e) Always
2. Has the domain-specific training provided through the FDP helped you to improve your teaching in your subject handling?
(a) Strongly Disagree (b) Disagree (c) Neutral (d) Agree (e) Strongly Agree
3. Do you feel the personalized professional development opportunities have helped you to address the specific teaching challenges?
(a) Not at all (b) Slightly (c) Neutral (d) Considerably (e) Greatly
4. How often do you apply innovative teaching methodologies in your lesson planning after attending the FDP?
(a) Never (b) Rarely (c) Sometimes (d) Often (e) Always
5. How do your Professional Learning Communities (PLC's) help in improving your teaching strategies and technological advancements?
(a) Not helpful (b) Slightly helpful (c) Neutral (d) Helpful (e) Very helpful

Framework for Ongoing Professional Development (PD): The framework identifies key variables influencing the outcomes of professional development initiatives categorized into independent variables (PD approaches), mediating variables (Professional Learning Communities - PLCs) and dependent variables (teaching and learning outcomes).

(a) Independent Variables (PD Approach):

The key components of professional development are categorized into four methods, each addressing specific aspects of teaching and learning outcomes.
E-Learning Concept of Learning: Training provided in educational institutions through digital platforms tools such as learning management systems, virtual classrooms and online assessments to enhance the teaching-learning process to improve teacher's digital literacy freedom and facilitate them to access the self-paced digital learning environment. Self-Directed Learning Theory, emphasizes the learner's autonomy and the actual usage of digital resources for personalized knowledge acquisition.
Domain-Specific Method of Teaching: Professional development (PD) that focuses on encouraging subject/domain-specific knowledge and skill development among students (e.g., Engineering, Arts, Sports etc.) to enhance teacher expertise in their respective subjects for promoting in-depth understanding and effective curriculum delivery. *Situated Learning Theory*, assumes that learning is most effective when it occurs within relevant real-world applications.
Customized Learning Method: Developing adaptive learning strategies to address students'

learning needs to adapt new teaching practices to analyze diverse students' strengths, weaknesses and learning styles to strengthen student engagement and teacher's continuous learning. *Adult Learning Theory or Andragogy,* highlights the importance of personalized and experience-driven learning practices.

Cognitive Learning Approach: Professional Development focusing on reflective and critical thinking techniques for in-depth understanding and retention of knowledge to enhance the retention and application of knowledge that promotes cognitive development among student and teacher. Si*tuated Learning Theory* emphasizes the role of context and interaction in the cognitive learning approach.

(b) Mediating Variables - Professional Learning Communities (PLCs)

PLCs act as a bridge between professional development (PD) approaches and their measurable outcomes by nurturing collaboration, peer learning and ongoing professional growth. PLCs are the communities where teachers engage in shared best practices, discussions and feedback exchange to enhance the practical implementation of Professional Development by creating a supportive environment for teachers' continuous learning.

The mechanisms involved are:

1. Regular peer reviews and mentoring sessions.
2. Collaborative lesson planning and co-teaching opportunities.
3. Sharing best practices through institutional platforms.

(c) Dependent Variables – Research Outcomes

These are the outcomes of the professional development program conducted for teachers to measure their teaching and students' learning practices.

Enhanced Pedagogical Practices: The adaptation of modern teaching strategies and the effective use of technology and tools in the classroom measured by classroom observations on tool usage, lesson delivery, and student interaction levels. This leads to increased teacher effectiveness and adaptability.

Improved Student Outcomes: A higher level of students' active participation in the classroom and their academic performance measured by analyzing Student pre and post-intervention feedback, grades and assessment data leading to student learning satisfaction and more engagement.

Conceptual Framework: The framework integrates the independent, mediating and dependent variables to relate how professional development impacts teaching and learning outcomes.

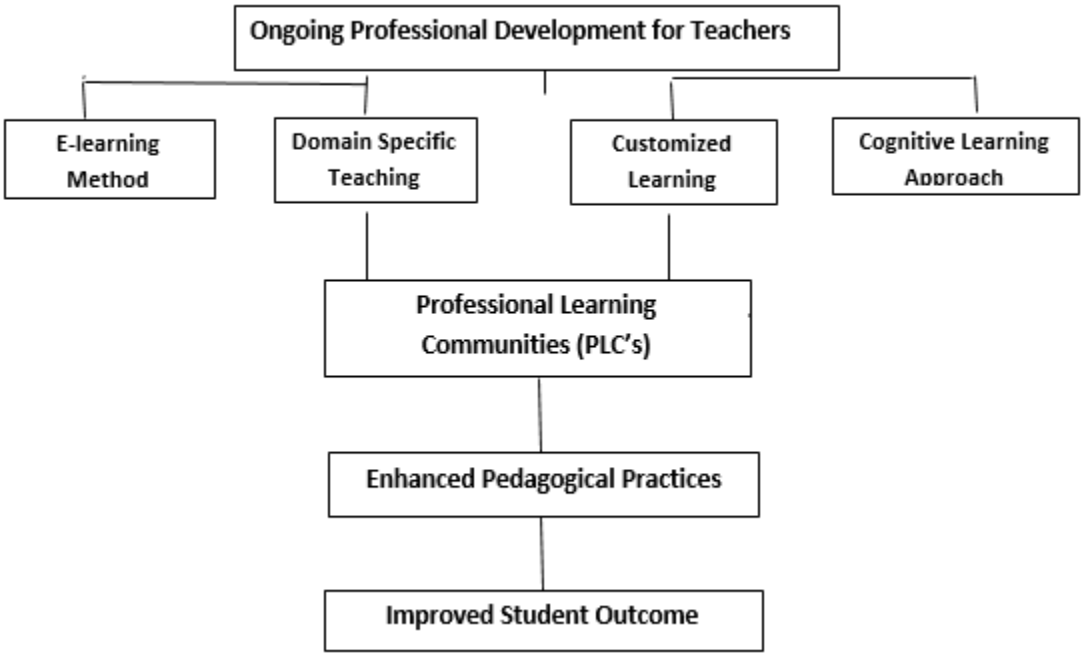

Fig. 1: The pictorial representation of the conceptual framework

Context of Ongoing Professional Development

Ongoing professional development plays a transformative role in adapting and implementing modernized teaching practices to meet current educational demands. E-learning, a key approach, positively impacts teachers by enhancing their technological skills and enabling the effective use of digital tools in the classroom. This integration leads to improved pedagogical practices and creates a dynamic teaching environment. Another essential aspect is domain-specific expert teaching, which fosters more effective subject-specific teaching methods, enhancing both teacher and student engagement with the curriculum and improving academic results. In classrooms with diverse student needs and learning styles, customized pedagogical approaches are crucial. These methods encourage teachers to adapt their teaching styles to address individual students' unique challenges, leading to greater student engagement and more impactful instruction. The cognitive learning approach focuses on developing critical thinking and problem-solving skills, helping students retain knowledge long-term. This method improves the quality of education for both students and teachers through a continuous learning process. In conclusion, professional learning communities (PLCs) bridge the gap between professional development strategies and reflective teaching outcomes by organizing teacher collaboration, peer feedback, and the sharing of best practices within the institution. Regularly conducted PLCs encourage teacher communities to identify gaps in their teaching methods, improve best learning practices, and foster positive student engagement to meet the demanding needs of a modern education system.

IV. DATA ANALYSIS AND INTERPRETATION

The collected survey data were analysed using descriptive statistical methods, including

calculating the mean, frequency, and percentage, to evaluate the effectiveness of the teaching tools used in the classroom and measure their impact. Classroom observations were conducted, and the results were reviewed to gain a clear understanding of the intervention intervals. The gathered data were processed using statistical formulas, and calculations were performed manually to determine the statistical results.

Descriptive Statistics:

Mean: The average response obtained from surveys and assessments was calculated using the formula Mean (x)= $\sum x / n$

Where, x – is individual data points and n - total number of data points

Percentage Change: The change in student engagement and test results percentage for pre- and post-intervention was calculated using Percentage Change = (Post - Pre) x 100/ Pre

Where, Post - Post-intervention value, Pre - Pre-intervention value

Paired t-Test: To measure the effectiveness of new teaching method implementation by comparing pre and post-intervention scores. The t-value was calculated using

$t = d$ and $S_d\sqrt{n}$

Where, d = Mean of the differences in paired observations, S_d = Standard Deviation of the differences and n = number of pairs

Cohen's d (Effect Size): To determine the significant change between pre and post-intervention outcomes, the effect size was calculated using:

d= Mean of Group1 – Mean of Group2 / Pooled Standard Deviation

Where, Mean of Group 1 = The average score measured after post-training, Mean of Group 2: The average score measured before pre-training and Pooled Standard Deviation: The combined two group variability was calculated using,

$$\text{Pooled SD} = \sqrt{(SD_1^2 + SD_2^2)\ 2}$$

Correlation Coefficient (Pearson's r): To examine the strength and direction of the relationship between teacher engagement in professional development activities and changes in student learning outcomes, the Pearson's correlation coefficient was calculated using:

$$r = (\Sigma\ (x - \bar{x})(y - \bar{y}) \backslash \sqrt{\Sigma\ (x - \bar{x})^2\ \Sigma\ (y - \bar{y})^2}$$

Where,

x and y are the variables, x and y are the means of the x and y variables.

PD Approach	Pre FDP	Post FDP	% of Student Learning Outcome
Usage of E-Learning Methods	2.3	4.1	78%
Student Engagement (survey data)	3.2	4.5	41%
Domain-Specific PD (test results)	60%	75%	25%
Customized learning approach	3.5	4.3	23%
Cognitive Learning Approach	2.8	4.2	50%

VI. FINDINGS

Impact of E-Learning Pedagogical Practices: The integration of E-learning practices into classroom significantly improved teaching efficiency and student participation. Teachers reported a 78% increase in their knowledge and the ability to use the digital tools in their classroom after participating in the professional development program. The involvement of students is 41% higher engagement in their lessons and active listening after the digital tool implementation into their curriculum practices. The teachers noted that digital tools integration yield more interaction and flexible lesson delivery which aligned well with student's learning preferences.

Effectiveness of Domain-Specific Teaching: Teachers specializing in their respective domain-specific subjects (eg. Mech, ECE, EEE) demonstrated a 25% improvement in the delivery of subject content after attending the FDP. This improvement was better matched with current industry standards because of the change in their teaching method. On the other hand, 15% increase in student class test results was observed indicating enhanced understanding and attention to complex concepts. Teachers identified that domain-specific training helped them to connect their curriculum with real-world applications.

The Role of Customized Learning Approach in Academics: This Approach Proved to be a highly effective strategy for addressing diverse classroom challenges faced by educators. 23% of teachers reported that tailoring their teaching methods to individual student learning styles improved the classroom environment. Focusing on student's strengths and weaknesses yields a more inclusive and engaging student environment. This approach not only helped students to grasp complex concepts but also helped teachers to refine their teaching techniques. Teachers also noted that this approach created a more focused and productive learning space.

Influence of Cognitive Learning Approach: This approach involving learning strategies such as critical thinking exercises, reflective teaching practices and problem-solving exercises had a transformative impact on both teachers and students. Teachers who integrated cognitive learning strategies realized a 50% improvement in student analytical skills and met their industry demands beyond academic performance. Teachers noted that this approach encouraged students to actively participate in the learning processes and apply their knowledge to practical scenarios.

VII. DISCUSSION

The overall findings of the research highlight the significant role of ongoing professional development in improving the pedagogical practices of teaching methods and enhancing student outcomes. This study demonstrates how differently teachers can implement e-learning, domain-specific teaching, customized learning and Cognitive Learning approaches to significantly impact the overall teaching methods and students' learning experiences.

Impact of E-Learning Teaching Method:

The increased usage of digital tools and learning platforms among teachers following their participation in Faculty Development Programs (FDPs) and Professional Development Programs (PLCs) highlights the growing potential of technology in modern education. Teachers reported an increase in their ability to adapt and integrate e-learning tools into the classroom which identifies the increasing importance of digital literacy in today's educational environment. This change reflects the urgent need for educators to adapt to the digital era and is necessary to equip students for a technology-driven world. Through this study, students also reported a higher level of engagement in lessons where digital tools were actively used. The integration of e-learning

methods in their classroom gives space for students to connect more deeply with the curriculum. These study results showcase the relevant principles of Self-Directed Learning Theory, which emphasizes that students benefit from using digital platforms as valuable tools for self-paced learning and staying connected in the digital age. Teachers who are skilled in using these tools can effectively improve their student's learning styles and create a dynamic classroom environment.

Effectiveness of Domain-Specific Teaching:

The domain-specific training sessions offered through the FDP programs showed significant benefits, particularly in subject-based teaching methods. Teachers specializing in STEM (Science, Technology, Engineering and Mathematics) subjects showed improvement in delivering their subject content while students' test result scores improved in these core subjects. This finding supports the principles of Situated Learning Theory**,** which suggests that learning is more effective when it occurs within a specific context or subject domain. These studies highlight that focusing on domain-specific teaching helps teachers develop in-depth, long-term knowledge promoting continuous professional growth and improvised learning experiences for students. It also enhances students' learning experience by making the content more relevant. The study also highlighted the importance of specialized professional development programs for different subjects to meet the student's specific needs.

Role of Customized Learning Approach:

A personalized professional development case study proved to be one of the most effective strategies to help teachers address their unique teaching challenges in the classroom. The Personalized Learning and Differentiated Instruction approach helped teachers to customize the curriculum to meet their individual needs and goals. By implementing this approach, teachers can improve the quality of teaching methods and create a better learning atmosphere for their students. This customized learning approach will encourage the teacher's community to take ownership of their professional development.

The Influence of the Cognitive Learning Approach:

Teachers who incorporate a knowledge-based teaching approach into classroom discussions have seen significant changes in their student's understanding of concepts and their active participation in the classroom. This finding supports the cognitive load theory. This emphasizes the importance of cognitive learning approaches in helping students retain knowledge and understand complex concepts. Effectiveness of cognitive learning strategies in improving teaching practices and student learning outcomes. It emphasizes the need to regularly practice professional development programs and faculty development programs to focus on improving intellectual learning techniques, the study suggests that conducting regular training will encourage the teaching community to create a more thoughtful and reflective classroom environment. This adaptation will also encourage the student community to effectively develop and use digital skills to learn at their own pace.

The Role of PLCs and FDPs among Teachers Community:

The role of Professional Learning Communities (PLCs) and Faculty Development Training Programs (FDPs) plays a key role in the modern educational system to effectively transfer the skills, resources and knowledge from professional development programs to classroom practices. Teachers who participated in Professional Learning Communities and Faculty Development Training Programs observed higher levels of collaboration among faculty, valuable peer teaching suggestions and opportunities for continuous learning. Developing communities like this inside a campus will serve as knowledge-sharing platforms for sharing individual best practices, addressing real-time challenges and support required from the educational institution which amplifies the benefits of professional development programs. This study highlights the importance of collaborative learning environments where teachers can learn and grow professionally from one another, share resources and continuously develop their teaching strategies. The success of Professional Learning Communities and Faculty Development Training Programs in this study suggests the need for ongoing peer collaboration considered to be a key component of professional development initiatives. These collaborative efforts not only help teachers grow professionally but also improve the overall teaching and learning experience.

VIII. CONCLUSION

This research confirms that ongoing professional development is essential for helping teachers improve their modern teaching methods and student success. The findings show that professional development programs, especially those focused on implementing e-learning, domain-specific teaching, customized learning, and cognitive learning approaches, have a strong positive impact on both teaching effectiveness and student engagement with the curriculum.

E-learning methods help teachers integrate technology and digital tools into the classroom, making lesson planning for each semester more interactive and results-oriented. They also help students become more comfortable with digital tools and advance their technical and industry-ready skills.

Domain-specific training ensures that teachers gain the in-depth knowledge needed to teach complex concepts, simplifying even the most challenging topics for clearer and more efficient instruction. This approach helps teachers achieve high levels of student academic performance while increasing classroom efficiency, which in turn enhances the institution's reputation.

A customizable teaching approach provides personalized instruction tailored to the unique needs of each student. This approach helps teachers implement more relevant and effective teaching strategies for improved classroom engagement and learning outcomes.

The cognitive teaching approach encourages teachers to refine their own teaching methods and focus on areas where individual students need more attention in their classroom learning. This approach helps teachers monitor their students' learning levels and guide them toward better academic performance.

Teachers play an important role as a bridge between students, industry, and educational institutions. By connecting these three aspects, teachers can help students gain the practical skills

and knowledge needed for employment. This also helps educational institutions develop course curricula and ensure their relevance to industry requirements and standards. Teacher communication with industry experts helps the institution organize regular student training and placement preparation. Regular industrial visits for teachers help the institution structure its curriculum to align with industry standards. This role and guidance from teachers facilitates a smooth transition from education to employment for students while maintaining industry relationships and the institution's reputation for placement success. Through professional learning communities (PLCs) and regular faculty development programs (FDPs), teachers can continually develop their knowledge and adopt innovative teaching methods that ultimately benefit the student learning environment. PLCs provide a structured space for teachers to collaborate regularly and act as a platform to share experiences and learn from each other. Participating in PLCs allows teachers to discuss their real challenges and find solutions by implementing new ideas and testing different teaching approaches. This collaborative learning helps teachers discover new strategies, such as more effective technology integration and the use of student-centered teaching and learning techniques. Long-term collaboration through PLCs supports teachers in improving their teaching strategies and becoming more effective in the classroom. FDPs, on the other hand, provide professional training opportunities where teachers can learn from experts and gain insights into the latest trends related to e-learning platforms, domain-specific teaching, customized learning, and cognitive learning approaches. These programs support teachers in adapting practical tools and knowledge needed to implement an innovative teaching culture that meets evolving educational standards. When teachers regularly engage in PLCs and FDPs, they not only improve their teaching methods but also enhance student engagement and achievement. This ongoing professional development ensures that teachers can adapt to the changing needs of students and educational environments, fostering better learning outcomes. This study suggests that schools and educational institutions should adopt a combined approach to professional development by introducing the four methods outlined above and promoting teacher collaboration through regular PLCs and FDPs. By doing this, teachers can continually improve their teaching methods to achieve the best learning outcomes for all students.

IX. RECOMMENDATIONS

Invest in Digital Learning Infrastructure: Schools and educational institutions must invest in digital learning infrastructure to empower teachers with the technology necessary to improve their teaching skills. Educational institutions should provide infrastructure to access e-learning platforms, interactive learning software, and digital tools, helping teachers create more dynamic and engaging classrooms. Facilitating access to digital learning tools helps teachers address the diverse needs of individual students. For example, with e-learning platforms, teachers can provide tailored resources and assessments to differentiate instruction based on individual learning styles. Using technology in the classroom helps students develop essential digital literacy skills, crucial in 21st-century education.

Offer Subject-Specific Professional Development for Teachers: Subject-specific professional development training, including workshops, seminars, and skill-building sessions, should be designed for teachers in various subject areas. These programs help teachers address unique challenges and meet the specific needs of their students. For instance, science teachers would benefit from workshops on conducting classroom experiments or integrating STEM (science, technology, engineering, and mathematics) projects into their lessons. Similarly, language teachers

may need training to improve students' writing and communication skills by presenting lessons clearly and engagingly. Subject-specific training not only boosts teachers' confidence but also helps simplify complex concepts for better student understanding. Teachers supported by educational institutions are more likely to inspire a passion for learning among their students and demonstrate the effective application of their subjects in practice.

Promote Customized Professional Development Within Institutions: Every teacher faces unique challenges and has specific areas for personal growth. Therefore, it is necessary to promote individualized professional development programs within institutions for the benefit of the teaching community. Tailored professional development helps teachers focus on their individual needs. Whether it involves learning new technology, improving classroom management skills, or refining student engagement strategies, institutions should offer flexible professional development options that meet teachers' unique needs. This can be achieved by providing various opportunities, such as online courses, one-on-one faculty training, faculty exchange programs, and workshops tailored to specific areas where teachers want to develop skills. Institutions should also promote self-assessment and goal-setting to empower teachers to take ownership of their professional growth. Tailored professional development not only benefits teachers but also leads to better outcomes for students. When teachers receive training that directly addresses their challenges, they can introduce new strategies and use them effectively in the classroom. For example, teachers struggling with classroom management can receive targeted training, leading to immediate improvements in student behaviour and a better overall learning environment.

Implement Self-Evaluation for Continuous Career Development: Teachers who participate in self-assessments gain a deeper understanding of how their teaching affects student outcomes and can adjust their teaching methods accordingly. Reflective teaching involves reviewing lesson plans, student participation, and regular evaluation results to identify what works well and what needs improvement. Teachers can evaluate their teaching strategies by keeping a diary and recording progress for self-analysis. Participating in peer observation or self-assessment activities also helps teachers become more aware of their weaknesses, enabling them to make informed decisions to improve their teaching. A continuous self-assessment process helps teachers stay updated, adaptable, and responsive to the changing needs of their students, ensuring they remain effective in the classroom and achieve good results.

Encourage Collaboration through PLCs and FDPs: Professional learning communities (PLCs) provide a forum for teachers to discuss teaching strategies and reflect on classroom experiences with peers. These collaborative discussions help teachers discover innovative teaching methods and develop new ideas to improve student engagement and success. Teachers can also observe each other's teaching methods and provide constructive feedback. To promote a culture of shared learning and responsibility, regular Faculty Development Programs (FDPs) should be conducted at the institutional level to keep teachers informed about the latest trends and innovations in education. FDPs provide structured opportunities for teachers to learn new skills, explore advanced teaching techniques, and stay abreast of changes in the curriculum or educational policy. By implementing FDPs, institutions ensure that teachers remain engaged, confident, and prepared to meet the evolving demands of their profession. Teachers who participate in these programs are also motivated to use new strategies in the classroom, leading to continued professional growth. This growth directly benefits students by creating more innovative, engaging, and effective teaching methods. This study suggests that educational institutions should prioritize developing a structured FDP schedule to promote continued training and development throughout the academic year, considering teachers' well-being and professional excellence.

Encourage Industry-Aligned Teaching for Faculty: A key issue facing many educational institutions is the gap between academic learning and current industry needs. Educational institutions and faculty often lack exposure to current industry practices and technologies, resulting in outdated curricula that fail to equip students with the skills demanded by the workforce. Institutions should not restrict faculty from integrating relevant industry practices into their teaching to bridge this gap. Institutions should create opportunities and a supportive learning environment for their faculty, regardless of salary concerns, pressure to rush through the syllabus, or penalties for working hours. Institutions should support and encourage faculty to engage with industries by arranging regular industry visits, faculty internships, and sabbaticals to gain a deeper understanding of industry advancements, practices, and technological innovations. This industry exposure will help faculty enhance their curricula and implement industry-relevant teaching methods to nurture their students in all aspects of the industry. Such initiatives will help institutions improve students' employability, career success, and overall quality of education by adopting industry-relevant curricula, thereby benefiting both students and faculty through continuous development.

This study recommends that institutions focus on collaborative initiatives such as professional learning communities (PLCs) and faculty development programs (FDPs), which are important components of continuing professional development. These programs encourage collaborative peer learning, sharing best practices, and continued growth among teachers. In addition, training programs should be tailored to meet the unique needs and challenges of different disciplines to ensure effective and long-term improvements in teaching and learning for the benefit of the teacher and student community at large.

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Flow Analysis of Transverse Injection in a Typical Strut-Based Scramjet Combustor

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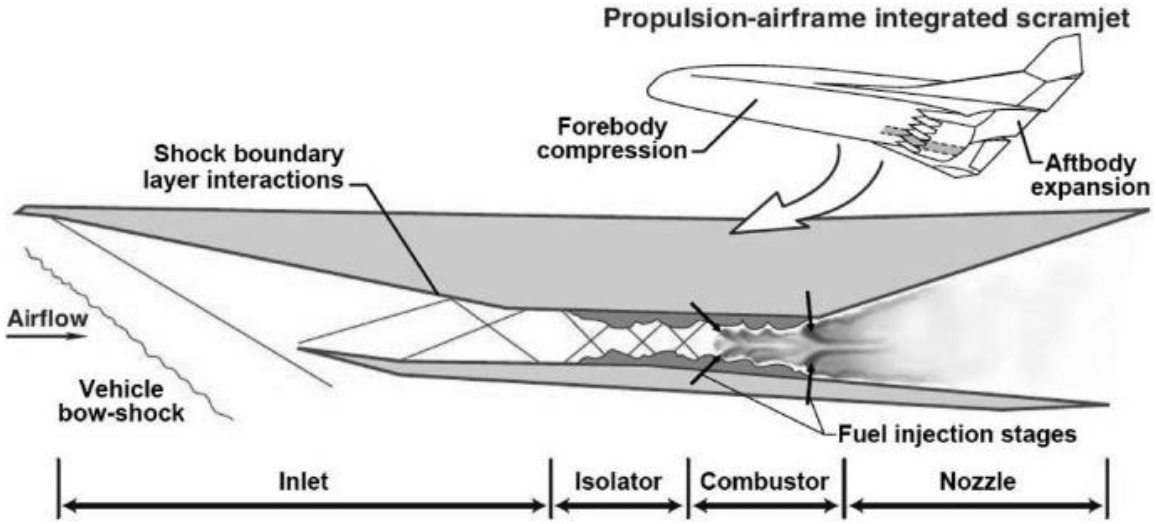
***Abstract*:** In scramjet engines, combustion occurs at supersonic speeds, posing challenges to flame stabilization and fuel mixing since the flame can easily be extinguished before reaching the nozzle. Adding struts in the combustor can help slow down the main flow slightly, which aids fuel-air mixing and stabilising the flame. Transverse injection was preferred due to its mixing efficiency. In the present study, an experimental flow visualization analysis of non-reacting flow in the Scramjet combustor was conducted using air as the transverse injection medium. Visualization of transverse cold flow inside the scramjet combustor was performed with a half-swept, V-grooved strut, where the injection was tested in two positions: one in front of and one behind the strut. The position of the injector was at 30% of the strut length and was analyzed at strut angles of 0° and 20°. The secondary transverse injection was maintained at 12 bar while comparing the flow field between the plane and the V-grooved strut. The impact of secondary injection while placing the V-grooved strut was also observed under different injection pressures of 12 bar and 11 bar by maintaining the combustor inlet total pressure of 10 bar. Using a high-speed jet facility and a scramjet combustor with an exit Mach number of 2.55, the study employed air for secondary injection to simulate the effects of hydrogen in cold flow conditions. The flow visualization was done by using the Schlieren technique, while pressure measurement points marked recirculation zones and shock locations. The experimental observations showed that the grooved strut improved mixing efficiency compared to the flat strut, as indicated by a larger vorticity region seen behind the strut. The shock patterns under varied injection pressure were the same for the grooved strut configuration. The mixing of secondary fluid with the main flow of air enhanced the combustion efficiency and it was visually proven by flow visualization.

***Keywords**: Scramjet Combustor, V-Grooved Strut, Transverse Injection, Cold Flow Analysis, Flow Visualization*

I. INTRODUCTION

Struts are solid structures positioned at the injection point in combustors to improve mixing. They generate vortices in the flow and enhance the entrainment of fuel and air, leading to more efficient mixing. The numerical investigation [1] was done to study the mixing and flow field characteristics of a Straight Strut (SS) and a Tapered Strut (TS), both with a constant ramp angle and height, at free-stream Mach 2. The hydrogen and ethylene were injected transversely from the rear of the strut. The Schlieren images highlight the shock-expansion wave interaction, shock/shear layer interaction, and shock/shock interaction. In the gas flow field inside a strut-based liquid-kerosene-fueled scramjet combustor [2], the thermochemical analysis of various parameters was conducted

by comparing cross-sectional views at different longitudinal locations and the axial distribution of area-averaged properties. From the comparison of computed thrust and combustion efficiency across different cases, the study found that higher combustion efficiency does not necessarily result in higher thrust. The drag caused by the fuel injection struts plays a significant role in determining the overall performance of the scramjet combustor. Another study [3] examines the impact of fuel injection schemes on the performance of a model scramjet combustor. It concludes that injecting fuel upstream of the ramp improves fuel spread. The flow over the cavity is significantly influenced



by the ramps and fuel injection between the ramps enhances fuel distribution within the combustor.

Fig. 1 The Scramjet Engine

Another study [3] examines the impact of fuel injection schemes on the performance of a model scramjet combustor. It concludes that injecting fuel upstream of the ramp improves fuel spread. The flow over the cavity is significantly influenced by the ramps and fuel injection between the ramps enhances the fuel spread within the combustor. A detailed investigation of flame characteristics [4] of scramjet combustor with a staged strut and wall ramp-based injection scheme was conducted. It focussed on the interface region between supersonic and dual-mode combustion and seems to exist in stable states at that type of combustion. They varied the equivalence ratios of both the first and second injection stages which was inferred. They have mentioned techniques for handling high temperature, long duration Schlieren system which was noted. The three-dimensional Reynolds Averaged Navier-Stokes (RANS) equations, coupled with the two-equation SST K-omega turbulence model, were employed for numerical simulation to study the mixing characteristics of transverse injection flow fields [5], combined with a micro-ramp and port hole to enhance mixing. Comparisons were made for various port hole locations with different aspect ratios. Among the tested cases, the aspect ratio of 64:1 was found to be the most efficient for injection compared to the others.

The mixing characteristics based on the traditional transverse injection technique were investigated using three-dimensional Reynolds Averaged Navier-Stokes (RANS) equations, coupled with a two-equation K-Omega shear stress transport (SST) turbulence model [6]. A symmetric cone-shaped ramp was mounted, and it was observed that stronger streamwise vorticity, generated by various mixing enhancement strategies, was the primary factor in improving mixing. However, the

study revealed that the mixing length and pressure loss at transverse velocities exhibit opposite trends as the intensity of the stream velocity varies.

The study investigated the effects of a micro-ramp on a transverse jet in supersonic crossflow using Large Eddy Simulation (LES) at Mach 2.7, employing the recycling-rescaling method to replicate the turbulent boundary layer [7]. The researchers tested under different cases for front and back jet flow, and plate jet configurations and compared their mixing efficiencies at various length-to-diameter (x/d) ratios. The results showed that the back jet was more efficient than the other two configurations for all x/d ratios. They concluded that the jet positioned behind the micro-ramp achieved significantly greater penetration. Additionally, when comparing the probability distribution of the mass fraction in the jet plume, it was observed that the main jet in the back jet easily reached the plume's centre. The influence of vortex generators in a solid scramjet was studied through direct-connect fire tests at a Mach number of 5.5 at an altitude of 23 km [8]. Hydrocarbon fuel was used in the form of a fuel-rich solid propellant. The results were compared to a benchmark configuration without vortex generators, revealing that the configurations with vortex generators significantly enhanced fuel-air mixing and stabilized combustion. The combustion efficiency [9] reached 0.60 with vortex generators, compared to only 0.11 in the benchmark case. Additionally, the ignition time delay was significantly reduced in the presence of vortex generators compared to the benchmark configuration. This study examines the impact of transverse flow using a notch-type strut, which features a V-shaped notch inclined at a specific angle from the middle to the end. This design generates oblique shocks [10] on either side of the strut, thereby enhancing the degree of mixing of fuel and air. This study [11] also made a numerical analysis on the same conditions and calculated the amount of vorticity generated at the aft surface of the strut. This study had a great impact on pursuing the current study. The pressure location in the combustor walls can be predicted by knowing the shock-impinging location in the combustor walls. This leads to Shock-boundary layer interaction [12-13]. To enhance mixing characteristics, more than one ramp or strut can be placed in the combustor simultaneously, leading to high total pressure loss [14-17].

Also, the thermoacoustic characteristics [18] impact the material structure which rises due to shock impingement. As more shocks are created, the more the acoustic characteristics dominate and the more the drag. In other cases, the fuel could be ejected directly from the strut by placing the injection hole between the cavity [19]. Numerical mixing studies were also done in this field using commercial CFD software to determine the degree of mixing [20].

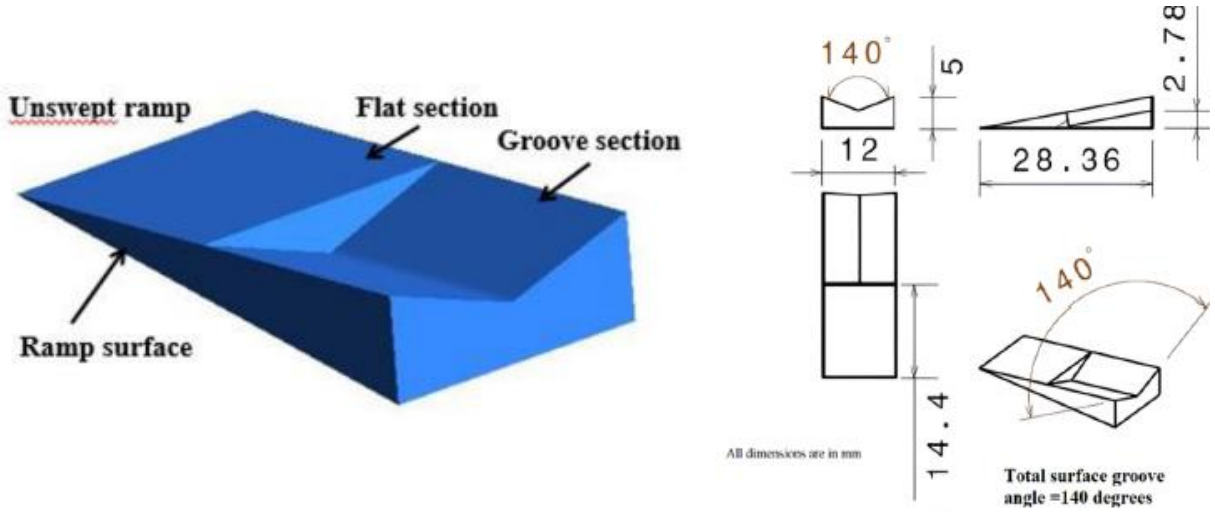


Fig. 2 Notch shaped strut and its dimensions

II. METHODOLOGY

The scramjet combustor uses high-temperature materials such as Heat-resistant alloys and ceramic matrix composites to withstand high temperatures. For making cold flow studies, SS304 material was used because it withstands high temperatures up to 1450°C and high pressures. Hence, the combustor was fabricated with SS304 alloy. The SS304 material of the required dimensions is trimmed in the shape of a cuboidal block. Then the block was given to wire cutting for fabricating the combustor model according to the dimensions of the jet facility. The fabricated combustor was drilled and bored at the required location for secondary injection. A mini settling chamber was made inside the combustor material by drilling tapped hole at the required depth and closing by using sealed screws leaving a gap inside for holding pressure. Then the ports are fixed at the holes to record total pressure. The inclinations of grooves are kept at 0˚ and 20˚ respectively as specified in [11].

The fabricated base plate model of the combustor was fixed with the existing combustor model using bolts and screws. The side walls of the combustor are made up of imported cast acrylic with a low refractive index for effective visualization of Schlieren images. The acrylic had a thickness of 8mm to withstand high transient pressure. The injector of diameter 1mm and length 50mm was made up of SS304 and the setup was fixed on the base plate of the combustor. The model was subsequently linked to an open jet facility operating at a pressure of 12 bar. An effective advisory light source (Sodium-vapour lamps) was set for the Schlieren setup. The resultant image of Schlieren was focused with a high-speed camera for generating effective photographs. The compressor was charged until its working pressure was reached by noting down pressure gauge readings.

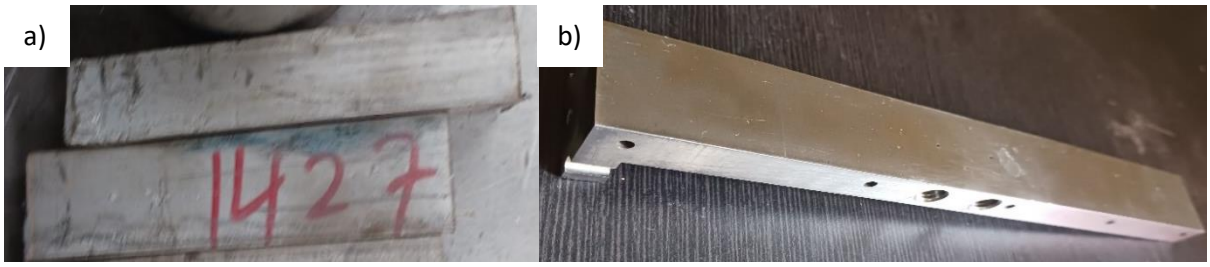


Figure **4** a) SS304 blocks b) SS Base plate of combustor after fabrication

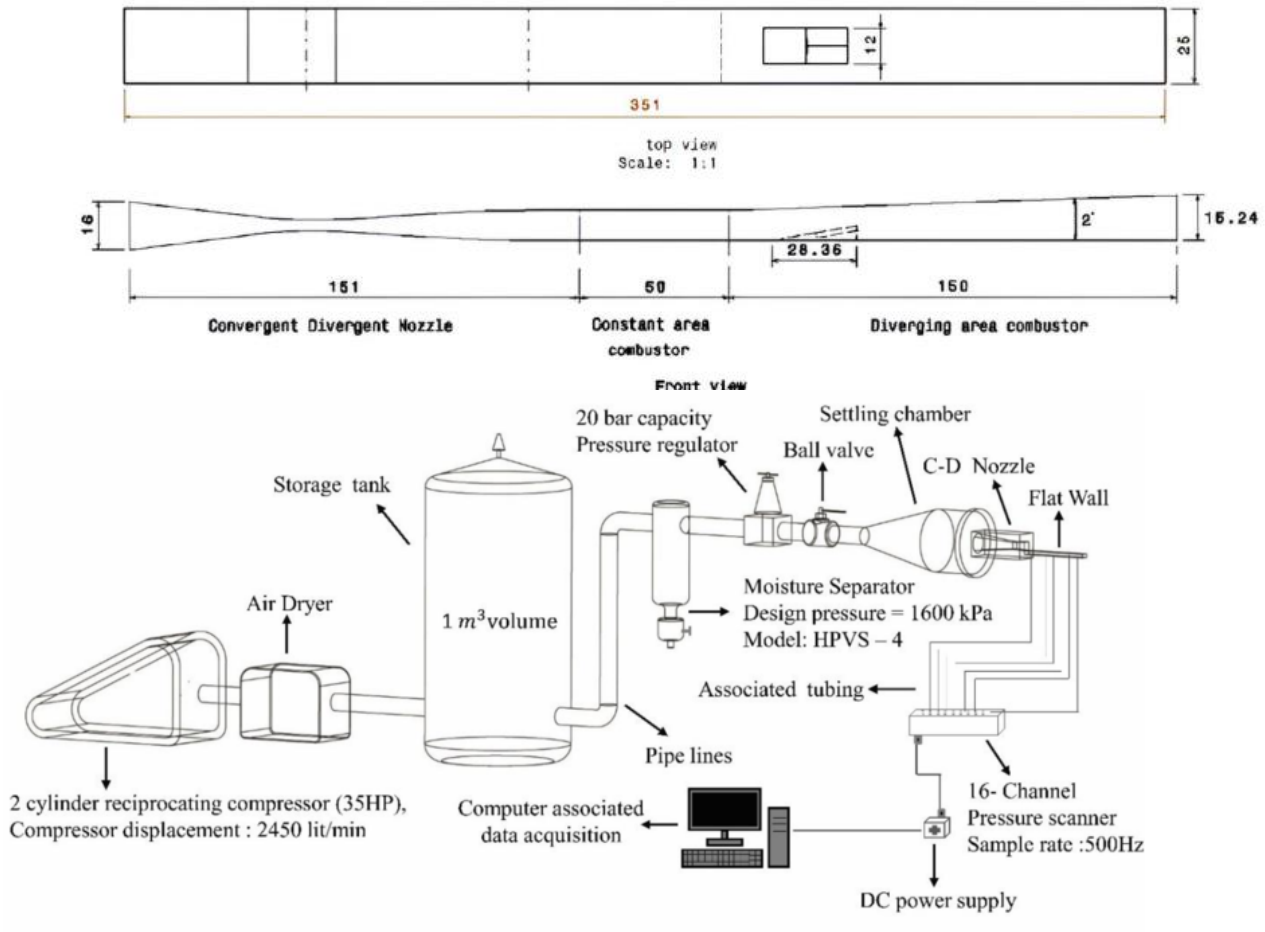


Figure 6. Schematic representation of Combustor

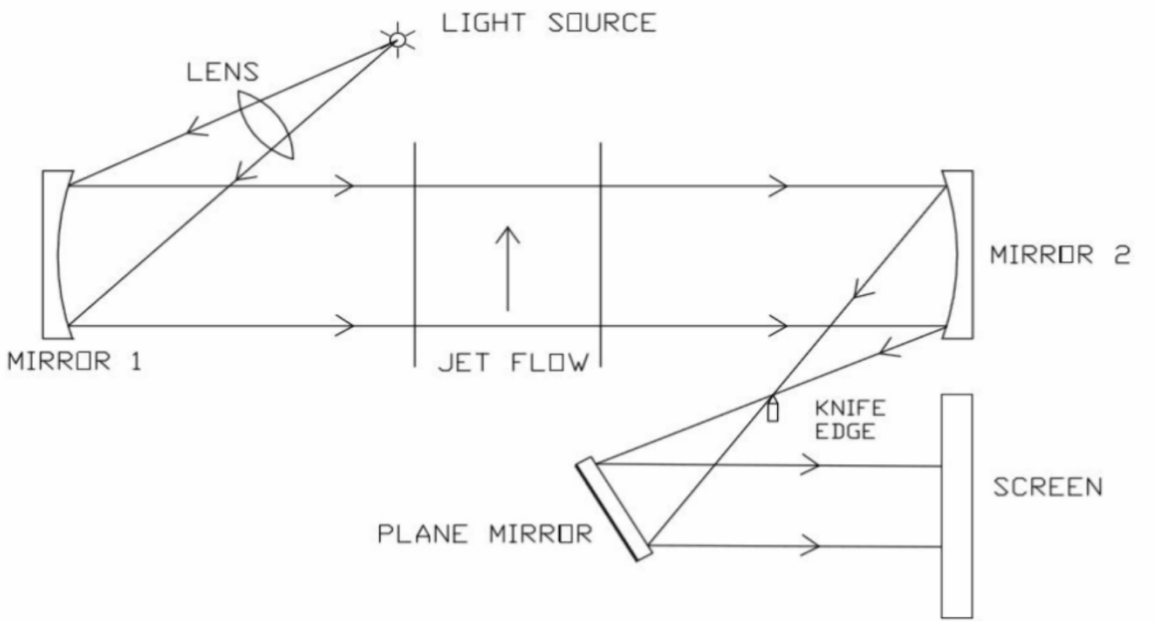


Fig. 7. Schematic representation of Schlieren system

The Illustration in Fig.7 was the schematic of the Schlieren system, which comprises two concave mirrors arranged in a Z-formation. A 200W halogen lamp serves as the light source, and each concave mirror has a focal length of 1100 mm, with a surface accuracy of λ/6. The other details were discussed briefly in [21]. The boundary conditions of this experiment are represented in the Table 1.

Type of boundary	**Boundary condition**	**Value**
Combustor Inlet	Total pressure	10 bar
Injector inlet in the presence of plane ramp	Total pressure	12 bar
Injector inlet in the presence of V-grooved strut	Total pressure	12 bar or 11 bar
Combustor inlet	Temperature	303 K
Combustor exit	Mach number	2.55
Injector inlet	Velocity	Sonic conditions

Table 1: Boundary Conditions

III. RESULTS AND DISCUSSION

The experiments were divided into two cases. In Case 1, the injector was positioned ahead of the ramp, while in Case 2, the injection occurred behind the ramp. The boundary conditions were selected according to the combustor exit Mach number. The flow field was examined by analyzing the Schlieren images for injection occurring at 30% of the ramp length ahead of the ramp, with a 20° strut, combustor inlet total pressure of 10 bar, and injection pressure of 12 bar is applied. Since the primary injection pressure is 10 bar, the secondary injection pressure must be greater than 10 bar to overcome the potential obstruction from the primary flow. The flow-field experiments were conducted for plane-ramp and grooved ramp at 12 bar injection pressure and the flow-field is

compared using flow visualization.

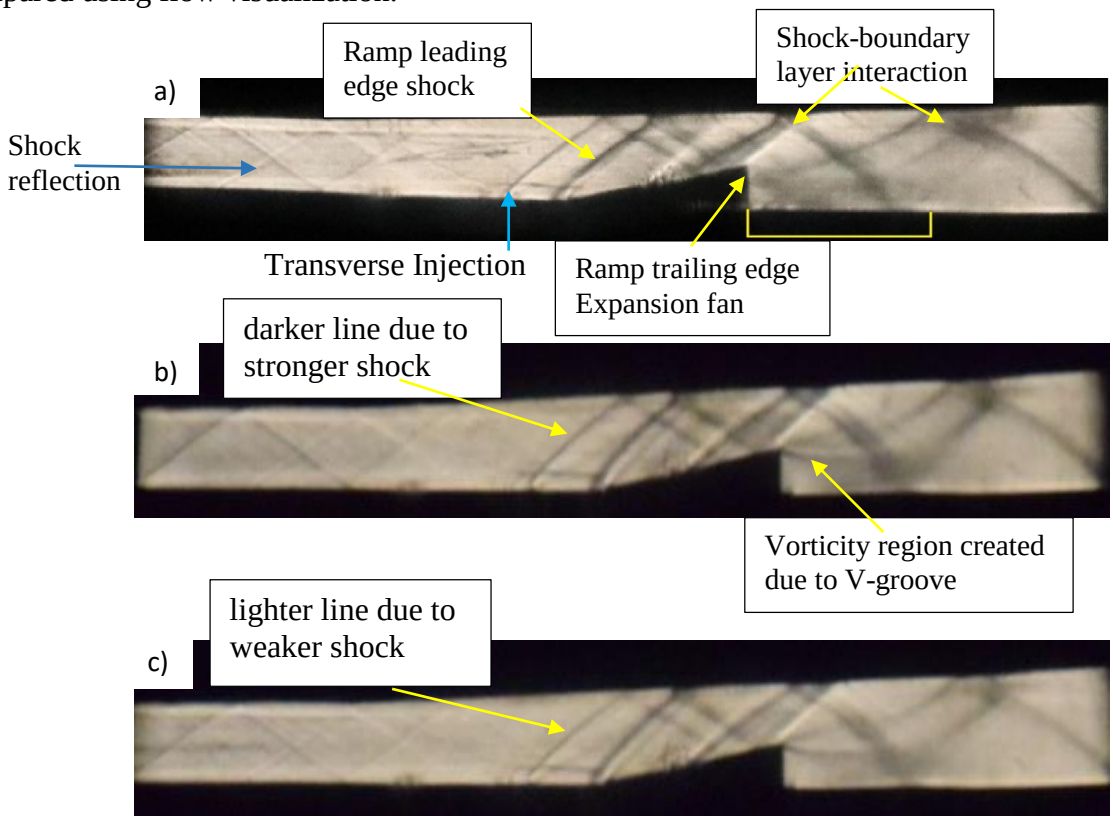


Fig. 8: Schlieren images of different flow-field in strut based combustor with injectior positioned at 30% of strut length ahead the strut a) Plane ramp with 12 bar injection pressure b) 20° grooved ramp with 12 bar injection pressure c) 20° grooved ramp with 11 bar injection pressure

The plane ramp configuration shown in Fig. 8 a) in which the injector was placed ahead of the strut. It can be observed that a normal shock was created at the place of injection. Due to shock reflection, the secondary flow gets turned to the recirculation region at the aft surface of the combustor. The dark area behind the strut shows the high-density region where the secondary fluid mixing region occurs. At the same time, there were many shock-boundary layer interactions at divergent sections of the combustor which may cause significant pressure loss and lead to flow separation.

The Schlieren representation of case 1 as depicted in Fig. 8 signifies that, the injection takes place ahead of the ramp. The position of the injector was at 30% of the strut length ahead or upstream of the strut. The total pressure of the combustor inlet was maintained at 10 bar. From Figure 8 it can be observed that there was no difference between the shock patterns at 12 bar Fig.(8b) and 11 bar Fig.(8c) injection. From [11] it was evident that the vortex strength was predominant within one ramp length behind the ramp. Hence, the transverse injection was done at 30% of the strut length. This shows that at higher pressures, the range of pressure of secondary injection does not significantly affect the shock patterns generated around the ramp. The shock patterns in Figure 8

can be seen curved behind the 20° grooved strut but the pattern was straight behind the plane ramp. This was due to the three-dimensional effect on the flow pattern projected in the two-dimensional Schlieren image.

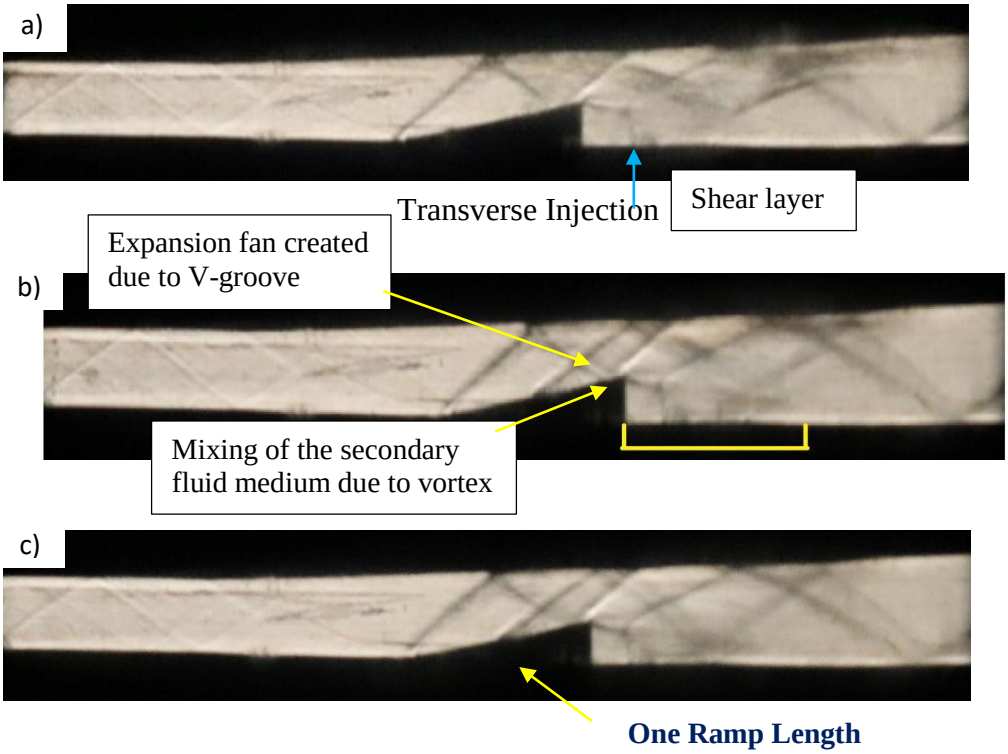


Fig. 9: Schlieren images of different flow-field in strut-based combustor with injector positioned at 30% of strut length behind the strut a) Plane ramp with 12 bar injection pressure b) 20° grooved ramp with 12 bar injection pressure c) 20° grooved ramp with 11 bar injection pressure

Similarly Figure 9 a) provides the Schlieren representation of case 2 in plane ramp configuration where the injection occurs behind the ramp. The position of the injector was at 30% of the ramp length behind the ramp. The shear layer of the plane ramp could be seen while the secondary medium encounters it. Due to its encounter, the mixing happens within the vortex region. The recirculation region could be seen clearly after the ramp till the injection. If the injector were positioned farther behind the strut, the shear layer might become relatively weaker, leading to reduced mixing. In this case, there was no difference between the shock patterns at 12-bar and 11-bar injection but the intensity changes. It indicates that, during high-pressure values, the variation in secondary injection pressure has minimal impact on the shock patterns formed around the ramp. The shock patterns observed in Fig. 10 a) and 10 b) can be seen curved behind the 20° grooved strut but the pattern was straight behind the plane ramp. **In the case of a plane ramp, there is no dimensional variation in the transverse direction. However, for the 20° notched ramp, the dimensional variation introduces a 3D relieving effect. Hence, the curved pattern of the shock was predominant due to 3D effects.**

IV. CONCLUSION

The experimental studies investigated the impact of secondary fluid injected in the transverse direction in a typical strut-based scramjet combustor. The present study used a plane strut and a typical V-grooved strut under different injection pressures. The experiments are divided into Case 1 for injection ahead of the strut and Case 2 for injection behind the strut. From the observations, it was predicted that, compared to the plane strut, the V-grooved strut generated more vorticity in the Z-direction under identical injection pressure. The V-groove created a three-dimensional vortex behind the strut leading to enhanced fluid mixing when injection occurred ahead of the strut. Under varying injection pressures, the shock patterns remain constant, with only the mass flow rate was changing. Thus, case 1 with a V-grooved strut at 11 bar injection could enhance combustion. However, In case 2, reverse flow was observed in the secondary fluid. In the plane ramp configuration, fluid was carried away from the recirculation zone which diminished the mixing phenomenon. In the V-grooved strut configuration, the fluid remains within the vortex region existing up to one strut length beyond the strut which enhanced the mixing. Therefore, case 2 for the V-grooved ramp could be advantageous for effective mixing, as it took place within the circulation zone, unlike case 1 and it was considered for enhancing the combustion efficiency. In future, the shock impact points will be determined which may be useful in recording wall pressure. Also, CFD simulation will be conducted to validate the experimental studies under different turbulent models and to quantify the degree of mixing.

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Blockchain-Based Security for Organ Donation Health Records in IoMT

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Abstract: Organ donation is a crucial aspect of healthcare, offering life-saving opportunities to those in need. However, flaws in the existing system have contributed to the rise of organ trafficking. The recent development of the Internet of Medical Things (IoMT) presents a transformative solution by leveraging a variety of bio-sensors, both invasive and non-invasive, to collect health-monitoring data. For IoMT applications, ensuring secure sensitive health records between connected devices and remote servers is essential to enable efficient analysis and decision-making across distributed networks. Our research explores how quantum blockchain technology can bolster the security of health records associated with organ donation and transplantation in IoMT systems. We propose an innovative platform aimed at enabling secure and transparent organ matching among healthcare providers, donors, and recipients, with an emphasis on preventing organ trafficking. This platform can also be adapted for other critical applications, such as plasma donation and medical distribution, which are particularly important in light of the ongoing pandemic. To accomplish this, we introduce the Quantum Key Distribution Blockchain Scheduling (QKBDS) approach, which combines blockchain technology for scheduling local sensor data and health records with quantum blockchain for remote scheduling through key distribution. Simulation result indicates that QKDBS surpasses current blockchain and quantum methods in efficiently managing IoMT applications, including organ donation and health record security, across distributed network nodes

Keywords: *Organ Donation, Blockchain, Interoperability, Internet of Medical Things (Iomt), QKD, Hyperledger Fabric, Decentralized, QB-IMD*

I. INTRODUCTION

Organ donation is a life-saving act that enables individuals to offer the gift of life to others, However, the process is accompanied by concerns such as the risk of transmitting infectious diseases, and allergens, and the possibility of organ rejections. To guarantee the safety and transparency of organ donation, rigorous regulations, and storage of organs. Organ transplantation refers to the complex surgical process of removing an organ from a donor and implanting it into a recipient. Furthermore, allocation systems are designed to prioritize fairness and equity, ensuring the organs are distributed to those in greatest need. Utilizing blockchain technology for secure

organ donation represents an innovative approach to tackling the global challenge of organ shortages. The decentralizing and transparent nature of blockchain facilitates the safe and efficient exchange of information among donors, hospitals, and transplantation teams. It safeguards the integrity of the organ donation process, minimizes the risk of fraud, and offers donors greater control over their contributions. The secure and transparent system has the potential to increase the availability of organs, saving countless lives and enhancing the overall organ transplantation process. However, a significant challenge remains in addressing the stark imbalance between the growing organ demand and the limited supply.

A new platform for organ transplant aims to minimize organ trafficking. Currently, two types of models oversee the management of organ donation, transportation, and transplantation processes. Centralized Models and Blockchain-based Decentralized Models are two primary approaches governing organ donation, transportation, and transplantation processes. The main challenge with centralized models is compromised data security due to third-party involvement. Additionally, a lack of transparency in the processes for stakeholders exacerbates issues such as illicit organ allocation and unethical modifications to organ waitlists, leading to a decline in trust in the system [1-3]. Furthermore, these models do not enable patients to monitor the organs allocated to them during transportation from the donor. This limitation stems from the reliance of centralized systems on third-party data management, which hinders patients' ability to track the condition of organs throughout their journey. Moreover, centralized models are vulnerable to single points of failure [4-5]. As a result, research is increasingly moving away from centralized, data immutability, enhanced security and integrity, greater process transparency, reliability, and the creation of a more trustworthy environment. This transition also seeks to remove the need for third-party data management. However, the cost-effectiveness of the current decentralized model for managing organ donation, transportation, and transplantation remains a significant concern. Additionally, similar to existing centralized models, these decentralized models do not provide stakeholders with light intensity inside the container, as well as the container's orientation and vibration. This lack of transparency substantially increases the risk of organ contamination during transport highlighting a crucial shortcoming in ensuring the safety of organ delivery [6-7].

Implementing a cost-effective, decentralized, secure, and reliable system for managing organ donation, transportation and transplantation is essential for building trust among both donors and patients. Such a system should ensure transparency throughout the entire process from organ donation and efficient donor-patient matching to the transportation of the organ from donor to recipient and its subsequent transplantation. It must guarantee that organ allocation is based on a fair "first come, first served" principle, without bias, and that the established organ waitlist remains unalterable. Additionally, the system should provide patients with complete transparency and allow them to monitor the condition of the allocated organ throughout its journey, ensuring its viability despite potential fluctuations in temperature and humidity. Furthermore, the framework should include safeguards for the organ container to prevent risks such as accidental opening, tilting, or falling during transport.

Internet of Things

Internet of Things (IoT) is an intelligent computing technology that wirelessly connects various physical devices [8]. A complete IoT architecture includes the perception layer, network layer, and

application layer. The perception layer consists of wireless sensors that capture and preprocess information. The network layer transmits and aggregates data between different devices, while the application layer enables customized utilization of terminal device data. IoT is pervasive computing [9], and its emergency has driven rapid growth in the medical and healthcare industries. It is estimated that by 2025, AI-driven Internet of Medical Things (IoMT) technology will generate a value of 1.17 billion dollars in the medical market [10]. The emergence of IoT has significantly advanced the healthcare industry [11], particularly in addressing cardiovascular disease, which is one of major threats to human health. ECG [12] is a standard way to monitor heart activity, and its data is with temporal continuity. As an important biological signal of the human body, ECG is used for identification [13]. Arrhythmia Detection System is an IoMT-based system that stores vast amounts of heartbeat data. With high sensitivity and importance for personal privacy. To address security and sharing needs, blockchain technology provides a feasible solution for the secure storage of medical data through the concept of decentralization [14]. Combining blockchain technology with IoMT better meets the requirements for secure and efficient sharing of data.

II. BLOCKCHAIN TECHNOLOGY

Blockchain is an innovative technology that provides ownership verification, transparency, enhanced security, and privacy. By employing hash functions and public-key cryptography, it addresses data privacy, security, and integrity challenges. The technology's potential growth could significantly impact these areas. In 2008, Satoshi Nakamoto introduced the Bitcoin white paper [18], which outline Bitcoin's core purpose: facilitating transactions without the need for a trusted third party(TTP). Unlike traditional financial truncations that rely on institutions such as banks—which can access users' financial data and involve lengthy processes and additional fees—Bitcoin enables secure, verified transactions between parties directly, without intermediary involvement.

Research on blockchain and cryptocurrency has been intensely focused in both industry and academia for:

Distributed storage: Blockchain transparently records data and transmits it to third parties upon receipt. A key feature of decentralized information processing is that records are stored with the data owner.
Consent: The Consensus Algorithm governs the admission, storage, and distribution of network information. Data is updated when all network participants reach a consensus on a decision.
Immutability: Modifying records is challenging. Alterations or updates to data within a single block in the chain are not permitted.
Increased Capability: Blockchain minimizes the need for intermediaries, streamlines network data authorization, and effectively safeguards patient privacy across various fundamental healthcare applications.

Subsequent transactions create new blocks, which are validated by network nodes know as miners and then added to the chain, increasing both its size and length. The hash of the preceding block acts as a tamper-evident measure. Any changes to the block alter the hash, disrupting the entire cryptographic chain and making any tempering easily detectable across the network. The standard configuration of a block in the blockchain is illustrated in Fig.1.

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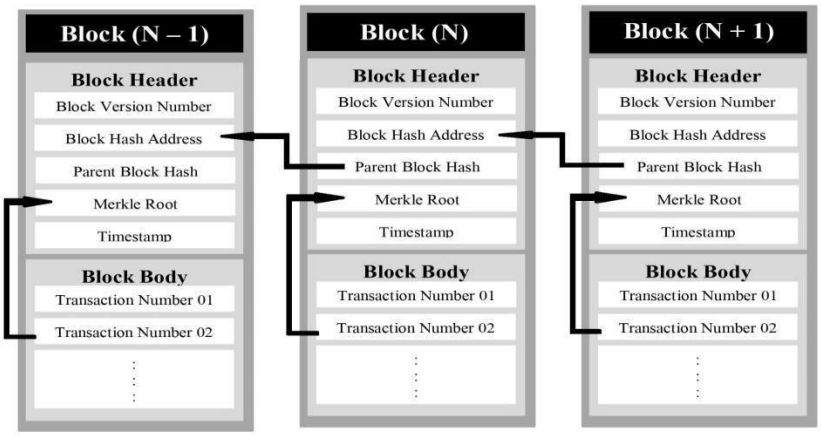

Fig. 1 Standard configuration of a block in the blockchain

Quantum Computing

Quantum computing is an emerging technology that has recently gained significant attention. Its advancements are profoundly impacting current cryptosystems and offering new perspectives on complex challenges. For instance, Shor's algorithm can efficiently solve problems related to finding hidden subgroups within infinite abelian groups, while Grover's algorithm provides a quadratic speedup for searching unordered collections [19]. This field is highly competitive and holds considerable potential for future development. From a post-quantum perspective, it is crucial to assess the security of current blockchain methods against quantum threats [20]. Quantum computers and their algorithm [21] pose a significant risk to existing public-key cryptography schemes. Predictions suggest that quantum computers could become feasible by 2026 and achieve a 59% probability of practicality by 2031 [22]. Since most blockchain systems depend heavily on public-key digital signatures and value transfers, they are particularly vulnerable to quantum attacks. Fedorov et al.[23] argue that without integrating quantum technologies, current blockchain systems may become obsolete. Although some interim solutions employ post-quantum cryptography, they are not entirely secure. Thus, it is essential to consider the impact of quantum computing on organ donation management.

Challenges in Implementing Quantum Encryption and Blockchain Integration

Implementing this model presents several challenges. First, quantum encryption necessitates substantial investment in quantum computing infrastructure and expertise. Second, integrating quantum encryption with blockchain technology requires a thorough evaluation of its potential effects on the performance and scalability of the blockchain network [24]. Lastly, the model must include robust authentication and access control mechanisms to ensure that only authorized individuals can access donor and transplant records.

Ensuring the confidentiality of critical medical data is an additional concern with quantum-safe organ donor and transplant file exchange, alongside the previously mentioned challenges [25]. While quantum cryptography can protect files from unauthorized access, it may not be sufficient

to defend against cyberattacks that seek to infer sensitive information from patterns within encrypted files. Researchers are exploring ways to enhance quantum-safe patient record exchanges by integrating privacy techniques such as diverse datasets and secure multi-party computation to address these issues [26].

Despite these challenges, the quantum-safe exchange of donor and transplant records holds the potential to transform healthcare by enabling secure and efficient data interchange [27]. Distributed ledger technology and quantum cryptography could provide an unprecedented level of security and confidentiality, while also advancing clinical outcomes and scientific research.

Innovations and contributions of the QB-IMD Quantum Blockchain system

Research on the quantum blockchain is still in its initial stage. Therefore, this article designs a quantum blockchain-based system Quantum Blockchain for Internet of Medical Data (QB-IMD) for medical data processing, which is a complete idea and has good security, confidentiality, and feasibility. The innovations and contributions are listed in the following.

A Comprehensive QB-IMD scheme for organ donation and transplant processing is presented, which not only verifies new blocks but also enables blind computation for both medical and organ donation data. The system employs homomorphic encryption to achieve the required data processing results while preserving medical privacy.

A quantum blockchain data structure and an innovative algorithm called QEMR are proposed. The QEMR algorithm, integrated into the QB-IMD system, is utilized within the quantum blockchain to validate the authenticity of new diagnostic data and manage organ donation and transplant records. By leveraging quantum signatures and quantum identity authentication this algorithm mitigates the security risks associated with digital signatures and enhances the blockchain's resilience against quantum attacks.

Quantum Key Distribution (QKD)

QKD is a method used to share encryption keys securely between two parties. It leverages the principles of quantum mechanics to ensure that any eavesdropping or interception of the key will be detected. The most common protocol used in QKD is the BB84 protocol. Key features of QKD include:
Quantum Superposition: QKD uses the properties of quantum bits (qubits), which can exist in multiple states simultaneously.
Quantum Entanglement: Two particles can be entangled so that the state of one instantly influences the state of the other, regardless of distance.
Security: Any attempt to eavesdrop on the quantum channel will alter the quantum states and can be detected.

III. Blockchain Scheduling

Blockchain scheduling refers to managing and optimizing tasks or processes within a blockchain network. It involves creating a decentralized system that enables efficient and secure management

of tasks, communication, and resource allocation. This approach helps to mitigate the risks associated with centralized scheduling, such as single-point failures and data tempering. Blockchain scheduling ensures transparency, immutability, and trustworthiness, making promising solutions for industries that require secure and efficient task execution such as supply chain management, logistics, and cloud computing. Key elements include:

Decentralization: Blockchain scheduling operates on a decentralized network, eliminating the need for a central authority or intermediary. This makes it more resilient to single points of failure and reduces the risk of manipulation.
Transparency: All scheduled events, transactions, or tasks are recorded on a shared, immutable ledger visible to all participants. This transparency ensures that every participant has a clear, consistent view of the schedule.
Immutability and Security: Once a schedule or appointment is recorded on the blockchain, it cannot be altered or deleted without consensus. This feature enhances the integrity and security of the schedule, preventing tampering or unauthorized changes.
Smart Contracts: Blockchain scheduling often involves smart contracts—self-executing code with predefined conditions. For example, a smart contract could automatically trigger a task when certain conditions are met, such as time or resource availability.
Automation and Efficiency: By integrating smart contracts, tasks can be automated, reducing the need for manual intervention. This automation can streamline processes like appointment booking, supply chain logistics, or resource allocation.
Consensus Mechanisms: Protocols like Proof of Work (PoW) or Proof of Stake (PoS) are used to agree on the state of the blockchain and schedule transactions.
Transaction Ordering: Ensuring transactions are processed in the correct sequence to maintain consistency and avoid conflicts.

Combining QKD and Blockchain Scheduling

The integration of QKD with blockchain technology could enhance the security and efficiency of blockchain networks.
Enhanced Security: QKD could be used to securely distribute cryptographic keys used in blockchain networks, making it extremely difficult for unauthorized parties to access or tamper with blockchain data.
Secure Transactions: By integrating QKD with blockchain scheduling, transaction verification and scheduling could benefit from the added security of quantum cryptography, protecting against future quantum-based attacks.
Quantum-Resistant Algorithms: As quantum computers could potentially break current cryptographic methods, QKD could be part of a transition to quantum-resistant algorithms and protocols in blockchain systems.
Efficient Scheduling: Blockchain scheduling could be optimized using quantum algorithms for faster consensus or transaction processing, although this is still a theoretical area under research.

V. Proposed System QB-IMD

The system proposed is divided into three layers: 1) application layer; 2) sensing layer; and 3) cloud layer. Among them, the application layer stores the medical information obtained by the devices. The medical data is called electronic medical record (EMP) After QB-IMD, legitimated

EMR blocks are added to the chain, and EMR data can be processed blindly. The Structure diagram of our QB-IMD is in Fig, 2, The functions of each layer are described in detail below.

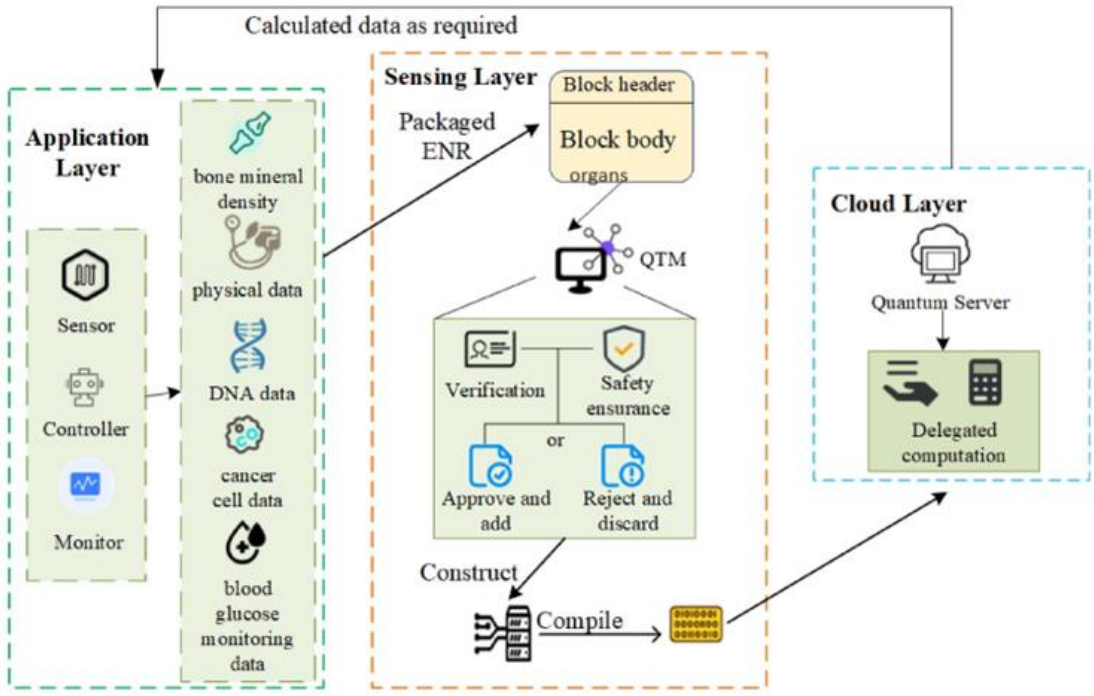

Fig. 2. Quantum blockchain-based medical data processing architecture diagram.

A. Application Layer

The application layer primarily gathers, integrates, and packages data from physical devices. As depicted in Fig. 2, the data collected from devices like sensors, controllers, and monitors are referred to as EMRs. This data includes but is not limited to, bone density, heart rate, DNA information, Cancer cell analysis, blood glucose levels, and organ details. Since this information is often considered sensitive patient data, maintaining its privacy in crucial. The package EMR data is then transmitted to the sensing layer.

B. Sensing Layer and Distributed QEMR Algorithm

The sensing layer is primarily responsible for block packaging and block additions, which is where the blockchain technology operated. The proposed distributed QEMR algorithm is also implemented within this layer, focusing on EMR block authentication. By integrating quantum signature and quantum communication technologies, the blocks are secured against attacks from malicious eavesdroppers, ensuring that each added block is trustworthy.

New EMR blocks generated by the application layer are transmitted to the sensing layer, where they are automatically packaged into a block. Over time, a continuous chain of blocks forms within the sensing layer. The designed quantum block structure is shown in Fig. 2. The block header includes the block address, Previous block address, timestamp, quantum signature, and quantum key, The block body contains the EMR information sent by the application layer,

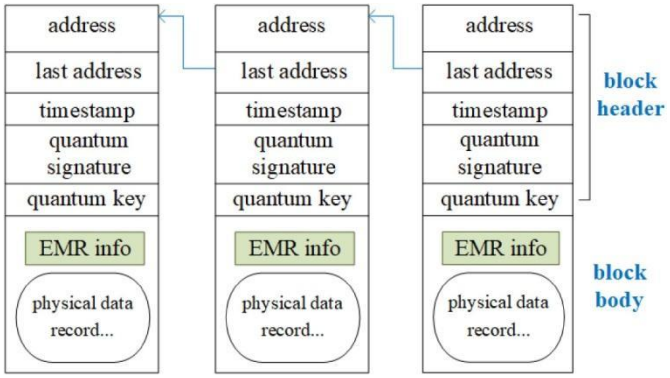

Fig. 3. New quantum blockchain structure

Table 1: Data Structure of Blockchain

Data structure	Description
Address	The specific address of the block, a string of hexadecimal has values generated by SHA256.
Last address	The address of the previous block.
Timestamp	The time when the block joined this blockchain.
Quantum signature	Signature shared by nodes
Quantum key	Key shared by nodes
EMR info	The EMR information send by the application layer

A blockchain encapsulates medical records over a specific period. The data structure of our blockchain is illustrated in Table I.

In the sensing layer, a distributed quantum EMR protocol (QEMR) is implemented to filter and validate legitimate blocks. The entire QEMR algorithm is divided into six stages, as depicted in Fig. 4. These stages are as follows:

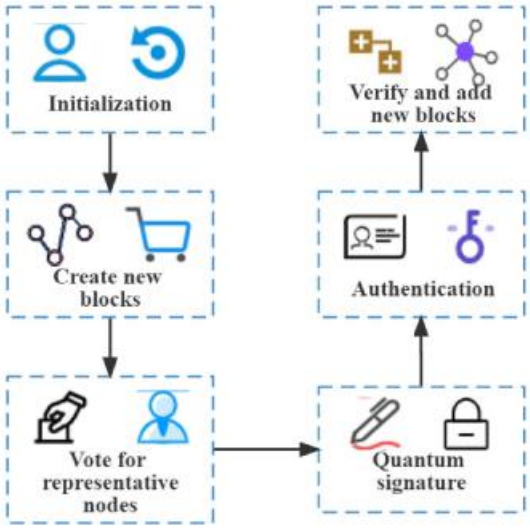

Fig. 4. Six stages of QEMR

1. **Initialization:** Within the sensing layer, EMR blocks are linked to create a distributed quantum blockchain. Each node is capable of preparing, storing, and measuring quantum states as well as exchanging quantum states and classical information with other nodes. The key strings within the quantum networks are distributed in an unconditionally secure manner by using the BB84 protocol [23].
2. **Create New Blocks:** When a new EMR is generated, the system automatically creates a new block. The block is initially assigned an address but remains unlinked to the blockchain until it undergoes authentication. It is assumed that the existing N blocks (where N is a large number) are trustworthy and have been added to the chain following the QEMR protocol. When a device from the application layer provides a block of data, a new block is generated and then authenticated by the representative node selected in the subsequent step. Only verified and legitimate blocks are allowed to join the chain.
3. **Vote for Representative Nodes:** The representative nodes is composed of main node and several backup nodes. The Bods counting method [24], [25], [26] is used to vote for these representative nodes. Nodes selected through the Borda counting method are those with relatively low error rates and strong support.
4. **Quantum Signature:** A total of M backup nodes are configured. The main node is responsible for evaluating the legality of pre-joined blocks and holds the rights to record and broadcast information. Suppose Alice is one of the backup nodes. Bob is the main node, and Charlie is a new node seeking to join the blockchain,

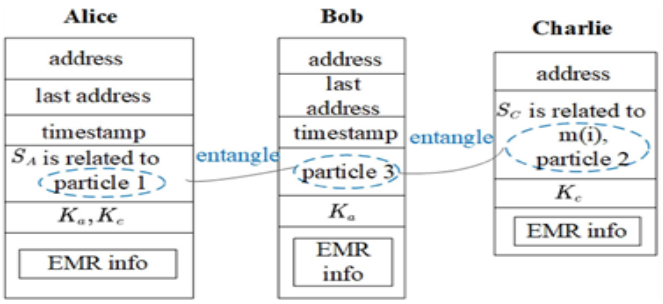

Fig. **5**. Alice, Bob, and Charlie's blocks

Alice prepares n qubits {|0⟩,|1⟩}\{|0\rangle, |1\rangle\}{|0⟩,|1⟩} corresponding to the classical message bit mmm. These qubits are represented as as |m⟩={m1,m2,…,mn}|m\rangle = \{m_1, m_2, \dots, m_n\}|m⟩={m1,m2,…,mn}, where each qubit mim_imi is defined as mi=xi|0⟩+yi|1⟩m_i = x_i|0\rangle + y_i|1\ranglemi=xi|0⟩+yi|1⟩, with |xi|=0|x_i| = 0|xi|=0 and |yi|=1|y_i| = 1|yi|=1 or |xi|=1|x_i| = 1|xi|=1 and |yi|=0|y_i| = 0|yi|=0. One of the backup nodes, Alice, shares a quantum key KaK_aKa with the main node, Bob and a quantum key KcK_cKc with the new node, Charlie. The keys are established using the BB84 protocol [23].

5. Authentication: In this phase, Bob has to verify Alice and Charlie's signatures. After receiving S_A and particle 3 from Alice and Charlie, Bob decrypts S_A with K_a to obtain TA and (a_i, b_i). Also, Bob decrypts S_c with Kc to obtain R_C

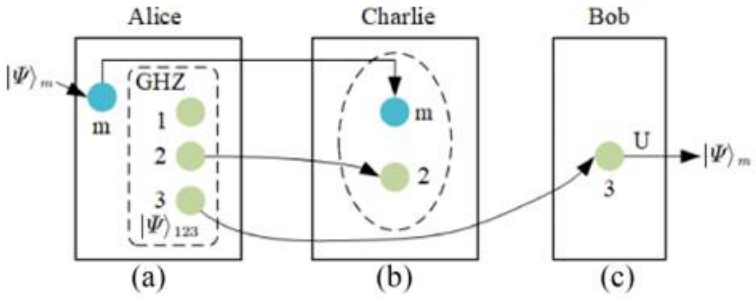

Fig. 6. Schematic diagram of particle flow in QMER.

Bob compares (xi, yi)(x_i, y_i)(xi,yi) and (xi, yi)(x_i, y_i)(xi, yi) to determine if they match. If they are equal, he can conclude that SAS_ASA and SCS_CSC are legitimate signatures. This also indicates that both the backup node and the block seeking to be added to the chain are honest and valid. In the end, the main node Bob counts the number of backup nodes that have completed authentication. A backup node that either fails to authenticate within the allotted time or experiences an interruption in its information will be deemed a faulty node off, if $M \geq 3f+1$, the main node Bob will classify the new block as legitimate. A schematic of the particle flow for signature and authentication is illustrated in Fig 6.

6. Verify and Add New Blocks: Finally, the correctness of the new block is verified by 1) ensuring the block size and the length of each field are within the specified limits; 2) confirming the accuracy of the timestamp, and 3) validating all EMR messages in the block to ensure their legitimacy. Once these checks are complete, the main node adds the block to the chain and assigns it an address, which is a string of hexadecimal hash values. The address of the new EMR is linked to the address of the previous block, ordered chronologically by timestamp.

C. Cloud Layer

The cloud layer is primarily responsible for processing EMR data without revealing any privacy. The QTM in the sensing layer compiles this information into classical bits 0 and 1 first, This system uses homomorphic encryption to process the information, which is also a delegated computing method. If the application layer wants to send encrypted messages to the QTM and the cloud layer. Fig 7 and Fig 8 show a set of universal quantum circuits for delegated computing. Specifically, X= | 0) (1| +|1)(0|.Z = |0)(0| - | 11|,H|a → -1) ^{a}|1)(1/2)(|0 +(),S|a → $(e_{i\pi}/2)_a$|a, CNOT| a|b= |a)|a +b),T |a → $(e^{i\pi/4})^a$|a).a,b € {0,1}.

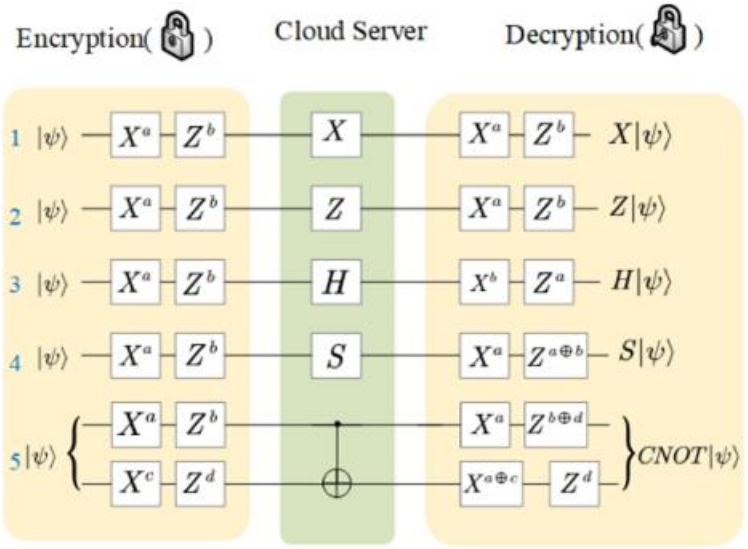

Fig.7. Universal quantum circuits {X,Z,H,S,CNOT} for delegated computing

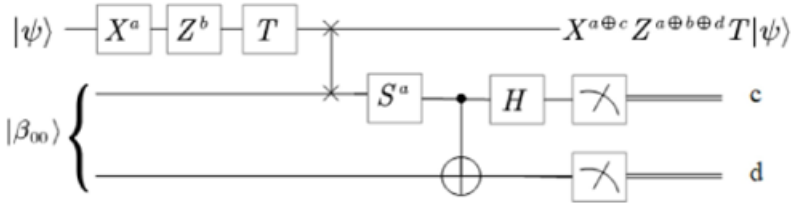

Fig. 8. Universal quantum circuit for delegated computing

There are three key entities involved in information processing: 1) the application layer, which represents the client; 2) the quantum terminal, which serves as an intermediary; and 3) the cloud layer, which performs blind information processing. The client-side information remains confidential and is not exposed to the cloud layer, while the desired processing results are still obtained. Specifically, the circuit in Fig. 9 requires the client and server to pre-share a pair of Bell states. The client encrypts the data and uploads it to the quantum server (QS). The QS applies a T-Gate to the data, and the resulting quantum state is then exchanged for its own Bell state using a swap gate, which is sent back to the client. The client performs a Bell measurement, and the results of measurements ccc and ddd are used to update the key. The server then sends the state of the first quantum bit to the client, who decrypts it to obtain.it T | ψ. The flowchart of the cloud layer for data privacy processing is shown in Fig 9.

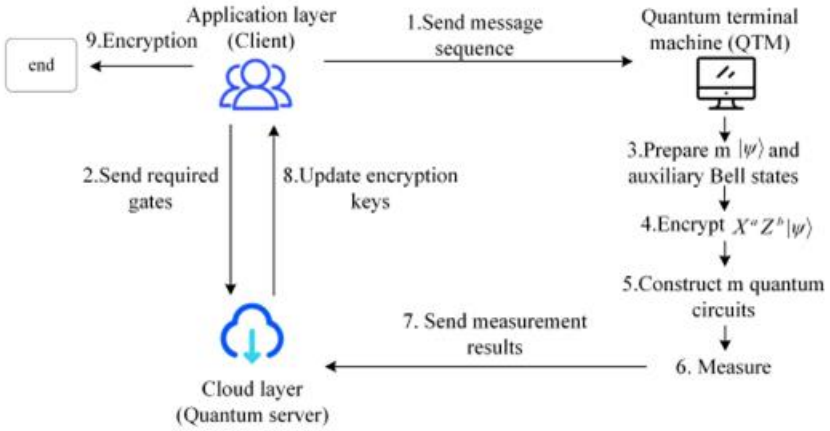

Fig. 9. Flowchart of the cloud layer for data privacy processing.

The process of delegated computing is presented as follows.

Step 1: In response to a request from the application layer, the QTM selects a block or a batch of blocks to produce a sequence of message bits. It encodes the numerical values in the medical data as digits 0 and 1.

Step 2: one of the six circuits shown in Fig 7 and 8 is selected at random to encrypt the X, Z, H, S, CNOT, and T circuits. The X, Z, H, S, and T circuits require only two classical bits each, while the CNOT circuit needs four classical bits.

Step 3: QTM prepares multiple states | ψ and sends them to the application layer. The application layer encrypts $X^aZ^b|\psi$,a,b ∈ {0,1}. If a CNOT gate is used, The encryption is $X^aZ^b \bigotimes X^cZ^d$. If a T-gate is used, let the application layer entangle with the cloud server via the bell states.

Step 4: The application layer informs the cloud QS which circuits to use. The QS then executes the specified gates and returns the resulting output bit sequence.

Step 5: The application layer decrypts the message using the methods outlined in Figs. 7 and 8 to obtain the desired processed data.

V. PERFORMANCE ANALYSIS

The proposed QB-IMD blockchain scheme is compared with other blockchain schemes.

A. Security Analysis of the QEMR Protocol

Intercept-Resend Attack: In this scenario, an eavesdropper named Eve attempts to intercept sensitive EMR records within the quantum channel. Her goal is to capture and then resend a falsified EMR record to another block, ultimately disrupting the QEMR protocol's integrity. However, during the security verification phase, Eve faces a critical obstacle: she cannot accurately determine whether each quantum particle is encoded in a linear or diagonal basis. This lack of knowledge results in a 50% error rate for each of Eve's the likelihood of detecting Eve's interference is high, effectively enabling early detection of any intercept-resend attack attempts on the QEMR protocol is (1/2) + (1/2) x (1/2) = (3/4). Assume that there are NMM rounds quantum state transmissions and NCM rounds security checks in the blockchain over time, $N_{MM} + N_{CM} = N$. Let $c = N_{CM}/N$. for N=1,2,3… , the probability that Eve will be detected is (3/4)c(1-(3/4)c)+(3/4)c(1-(3/4)c)2,… After N rounds of quantum messaging, the probability of Eve being detected is

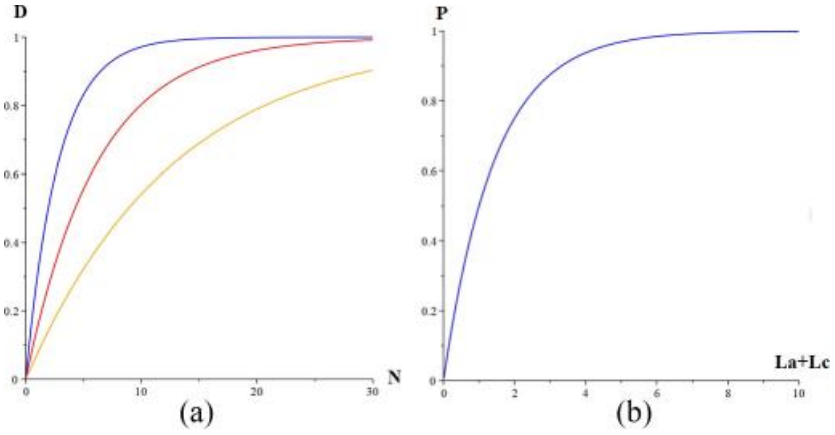

Fig. 10 Probability of EVE being detected under intercept-resend attacks

Eve's forged signature is detected. Yellow line: c=0.1; red line: c=0,2; and blue line: c=0.4. Assuming c=0.1,0.2 and 0.4, the relationship between D and N is shown in Fig 9(a). When $N \rightarrow \infty$ $D \rightarrow 1$.

2) Entangle Measure Attack: Consider that Eve attempts to carry out an entangle-measure (EM) attack to intercept the key and insert a fraudulent medical record, aiming for unauthorized duplication (Double spending). However, this approach is rendered ineffective. In the Quantum Signature phase (step 2.4), for instance, Alice retains particle 1 and send particle 2 to Charlie. To

gather information on the target qubit, Eve would try to entangle the transmitted particle with an auxiliary particle she holds, using specific unitary operations. The unitary operation in question is designed to $U|0|E=a|0|E_0+b \mid 1| E_1$, $U \mid 1|E = C|| E_2+d|1|E_3$. |E is the auxiliary particle of Eve and $|a|^2 =|b|^2 =|C|^2 +|d|^2=1$. | E0 is orthogonal to $|E_1$, $|E_2$ is orthogonal to E_3

IV. CONCLUSION

To ensure a reliable, secure, and confidential environment for IoMT, introduces a novel quantum blockchain-based medical data processing system called QB-IMD. Within the QB-IMD framework, the sensing layer employs a distributed QEMR algorithm designed to authenticate the legitimacy of ENR data transmitted from the application layer. A Subst of representative nodes is selected using the Borda counting method to optimise the use of quantum and classical resources. Quantum signature and quantum communication technologies are utilized to safeguard the blockchain's security. In the cloud layer, the required data is encrypted and processed using quantum delegated computation schemes that remain to be tested. The concept is highly innovative and the analysis is thorough. However, the classical blockchain is susceptible to attacks from quantum computing. Their innovation is evident in the design of the QTM and the application of blockchain technology. While the solution is comprehensive, the article does not include details of the blockchain structure itself. The quantum blockchain IoMT model proposed by Qu et al.is highly feasible and introduces a new quantum blockchain structure. However, it does not address the processing system. Through decryption, the application layer can obtain the necessary computational results while keeping the EMR data confidential. Mathematical proofs, theoretical analysis, and experimental simulations demonstrate that the QEMR is resistant to attacks such as intercept-resend and signature forgery. Additionally, delegated computing in the cloud layer is proven to be secure and feasible.

Currently, due to experimental limitations, our work is primarily focused on the theoretical aspects of quantum blockchain. Given the rapid advancements in optical quantum computing technology, we are preparing to design and implement a quantum blockchain algorithm or technology utilizing optical quantum computing, aiming to enhance the feasibility and practicality of quantum blockchain technology in the future.

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The Impact of Language Diversity on Technical Education in the Andaman and Nicobar Islands: Challenges and Strategies in the NEP 2020 Context

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Abstract: Technical education in the Andaman Islands faces challenges due to a diverse student population with varying language proficiencies. The primary hurdles stem from the varying language proficiencies of students, particularly in English, which is often the medium of instruction for technical subjects. Forty-two teachers of Dr. B R Ambedkar Institute of Technology, Port Blair (the only engineering institution in the islands) teaching diploma-level and undergraduate degree programs belonging to various engineering disciplines, participated in this study. Qualitative data was collected in the form of interview responses through semi-structured open-ended questions and a detailed analysis was conducted. Additionally, a focus group discussion with 10 teachers focussing on the challenges and opportunities of this multilingual pedagogic context was also done. The research examines how language diversity impacts teaching practices, the challenges faced by teachers, current strategies used to adapt, and the perceived benefits and drawbacks of multilingual classrooms. It aims to identify effective strategies to create inclusive learning environments and inform policy and practice in technical education, aligning with the National Education Policy 2020's emphasis on multilingualism.

Keywords*: Multilingualism, Technical Education, Language Diversity, Inclusive Learning Environments, National Education Policy 2020*

I. INTRODUCTION

The Andaman and Nicobar Islands, one of the Union Territories of India separated from the mainland is a unique archipelago with a rich linguistic and cultural tapestry, presents a distinctive challenge in technical education: a diverse student population with varying language proficiencies. Many tribal and indigenous communities in the Andaman and Nicobar Islands have yet to participate in higher education, particularly technical education. A significant portion of students, especially those from the inter-island regions (North and Middle Andaman and Nicobar), are first-generation college students, often with English as their third language. Even within relatively homogeneous classrooms in Port Blair, diverse learning styles (auditory, visual, and tactile) and multilingualism can complicate the learning process. This linguistic diversity, while enriching, can create significant communication barriers between teachers and students, hindering effective instruction and learning, considering the fact that the English language is used as the medium of instruction. This research delves into this under-explored area within technical education, focusing on the specific context of the Andaman Islands. By examining the experiences of faculty at Dr. B.R. Ambedkar Institute of Technology, Port Blair, the study aims to uncover the multifaceted challenges and opportunities arising from multilingual classrooms in technical education.

Research on the impact of language diversity on technical education is limited, particularly in regions like the Andaman Islands. Previous studies have primarily focused on the challenges faced by multilingual students in general education settings (Baker, 2011; Cummins, 1999) [1,2]. However, the specific needs of technical education, which requires specialized language and technical skills, remain largely unexplored. While NEP 2020 doesn't explicitly discuss multilingualism in technical education, it does emphasize multilingualism as a key principle throughout the education system. "The policy strongly recommends the use of the mother tongue/home language as the medium of instruction in the early years of schooling, so that foundational literacy and numeracy skills are developed strongly." This principle emphasizes the importance of building a strong foundation in the mother tongue, as it facilitates better understanding and retention of concepts. With relevance to technical education, it can be understood that while technical subjects might require specialized language, using the mother tongue can help students grasp fundamental concepts more effectively. It can also bridge the gap between theoretical knowledge and practical applications, especially in fields like engineering and technology.

It also states that “the policy emphasizes the importance of multilingualism, and recommends that students should learn at least two languages in addition to their mother tongue/home language." Learning multiple languages has been shown to enhance cognitive abilities, including problem-solving, critical thinking, and creativity. These skills are crucial for success in technical fields. At a global level, exposure to multiple languages can broaden students' perspectives and prepare them for a globalized world. This is especially important in technical fields, where international collaboration and cultural understanding are increasingly vital. The policy also highlights that "Every effort will be made to ensure that all languages, including Indian languages, classical languages, and foreign languages, are taught with the highest quality." [3]The policy's emphasis on quality language education is essential for technical education. Students need to develop proficiency in technical English to access global research, publications, and industry standards. Furthermore, in regions with diverse linguistic groups, promoting indigenous languages can help preserve cultural heritage and foster a sense of identity among students. This can also contribute to the development of technical terminology in these languages.

These principles can be applied to technical education by ensuring that technical concepts are taught in a language that students understand well, whether it is their mother tongue or a language they are proficient in. Additionally, technical institutions can incorporate multilingual resources and teaching materials to cater to the diverse linguistic needs of their students. Thus, NEP 2020 presents both challenges and opportunities for teachers of technical subjects. On one hand, the emphasis on multilingualism and the use of mother tongue/home language can make it challenging to maintain a consistent level of technical language proficiency among students. Teachers may need to adapt their teaching methods to accommodate diverse language abilities and cultural backgrounds. On the other hand, NEP 2020's focus on experiential learning, critical thinking, and problem-solving skills aligns well with the goals of technical education. Teachers can leverage these principles to create engaging and interactive learning experiences that foster creativity and innovation. Additionally, the policy's emphasis on teacher training and professional development can help equip teachers with the necessary skills to effectively implement the new curriculum and teaching methodologies.

II.THEORETICAL IMPLICATIONS OF THE STUDY

The increasing globalization of higher education has brought about a significant rise in multilingual classrooms, particularly in technical institutions. While English has emerged as the lingua franca of science and technology, the diverse linguistic backgrounds of students, especially in the Indian context, presents unique challenges and opportunities in technical education. This research explores the interplay between multilingualism, English as a Medium of Instruction (EMI), and technical education. By drawing on theories such as sociocultural theory, cognitive theory, communicative language teaching, and content-based instruction, this study investigates the impact of these factors on student learning, teacher practices, and institutional policies.

The sociocultural theory emphasizes the role of social and cultural factors in language learning. It highlights the importance of creating a supportive and inclusive learning environment where students can develop their language skills through authentic, real-world contexts. By analysing how cultural and linguistic diversity in the classroom can be leveraged to enhance language learning the study explores how teachers can create culturally responsive learning experiences that cater to the diverse needs of students. Concepts related to schema theory, information processing, and metacognition which are associated with the Cognitive theory of learning delve into the mental processes involved in language learning, such as attention, memory, and problem-solving. It emphasizes the importance of active learning and strategic thinking. By investigating how students process and comprehend technical information presented in English, this study explores strategies to enhance students' cognitive abilities and improve their language learning outcomes.

Communicative Language Teaching (CLT) highlights communicative competence, authentic language use and task-based learning which emphasizes the importance of developing communicative competence, which involves the ability to use language effectively in real-world contexts. It focuses on using authentic materials and tasks to create meaningful learning experiences. teachers as facilitators who guide students' learning journeys. The role of teachers in such contexts involves creating a safe and inclusive space where students feel comfortable using their home language to ask questions and participate in discussions. Teachers can also use scaffolding techniques to support students' understanding of complex technical concepts, regardless of their language proficiency level. Based on these theoretical constructs, the present study aims to understand the challenges faced by teachers in multilingual contexts, the effectiveness of English Medium Instruction in technical education, and the strategies that can be employed to create inclusive and effective learning environments.

III. REVIEW OF LITERATURE

Khubchandani (1978) [4] has explored how the linguistic heterogeneity in India has paved the way for the nation to become one of the linguistic laboratories of multilingual experience in the world. Biswas (2013) [5] identifies migration for economic development as a key reason for the multilingual situation in the Andaman and Nicobar Islands. His study also investigates how the social, economic, political and other situational factors of this place have been of special interest to sociologists, social psychologists, economic and political scientists. The migratory aspects have direct implications for educators too who are responsible for the growth and development of the society in discussion.

Mandal (2023) in his study on 'English Education in Andaman and Nicobar Islands' has presented the evolutionary nature of English as a medium of instruction in the islands from the pre-independence era. His brief study presents the multilingual dimensions of the educational scenario. Das (2024) in his study titled 'An Analysis of Establishment and Development of Schools and higher Educational institutions in the Andaman and Nicobar Islands' has also presented an evolutionary history of the educational scenario in the islands discussing the opportunities and challenges faced by the stakeholders.

Wijayanti (2024) in the study 'Linguistic Diversity in Education: Strategies for Inclusive Learning Environments' investigates the intricate dynamics of linguistic diversity in junior high school education, with the aim of illuminating the experiences of students from diverse linguistic origins. The study emphasizes the importance of recognizing and appreciating the diverse linguistic environments within educational settings. While Bahasa Indonesia is the primary language used by 18 out of 30 students, other languages such as Lampungnese and Javanese are also present.

These studies offer different perspectives on language diversity in education. They highlight the challenges faced, explore various strategies for overcoming them, and emphasize the importance of creating inclusive learning environments that value multilingualism. By exploring a range of research on this topic, you can gain a more comprehensive understanding of the complexities surrounding language diversity in educational settings.

IV. RESEARCH DESIGN

The present study seeks to contribute to the growing body of knowledge on multilingual education by investigating the following key questions:

- How does language diversity impact teaching practices in technical education?
- What specific challenges do teachers face due to language differences in their classrooms?
- What strategies do teachers employ to adapt to the diverse language abilities of their students?
- What are the perceived benefits and drawbacks of multilingual classrooms for both teachers and students?
- What support systems and resources would be beneficial for teachers to overcome language barriers?

By addressing these questions, this research aims to identify effective strategies for creating inclusive learning environments that cater to the diverse linguistic needs of students in technical education. The findings of this study can inform the development of pedagogical approaches, curriculum design, and teacher training programs to enhance the learning experiences of multilingual students in technical institutions. Furthermore, this research aligns with the goals of the National Education Policy (NEP) 2020, which emphasizes the importance of multilingualism in education. By understanding the challenges and opportunities of multilingualism in technical education, this study can contribute to the implementation of NEP 2020's vision in a practical and effective manner. This research employs a qualitative research design to explore the impact of language diversity on technical education in the Andaman Islands. By combining semi-structured interviews and focus group discussions, the approach assisted in gathering rich and in-depth data

from a diverse range of participants. The study involves 42 faculty members from Dr. B.R. Ambedkar Institute of Technology, Port Blair, who teach diploma-level and undergraduate engineering programs. These participants were selected based on their experience and expertise in teaching diverse student populations.

Semi-structured interviews were conducted with individual faculty members to explore their experiences, challenges, and strategies related to teaching in a multilingual context. Interview responses were collected through a virtual tool for open ended questions. Individual responses were also collected from teachers through one to one conversations. The responses to such semi-structured interviews were transcribed and Focus group discussions were organized with a smaller group of 10 faculty members to facilitate open dialogue and generate rich discussions on shared experiences and perspectives. The demographic information of the sample of the research study is presented below.

Out of the 42 faculty members, 29 were male and 13 were female. The teachers' mother-tongue varied widely including Hindi, Punjabi, Bengali, Marathi, Telugu, Tamil, Urdu, Nicobarese and other languages. Similarly, the students in their classrooms spoke at least two or more languages sometimes, the language that was majorly spoken by the students was sometimes unknown to the teacher vice versa. In this linguistically heterogeneous context, the teachers, though bilingual or trilingual, found it challenging to cater to the learning needs of all students especially in the context of technical subjects. Though the medium of instruction was English, based on the varying language proficiency, the teachers modified their choice of the instruction language considering the range of languages being spoken in the class.

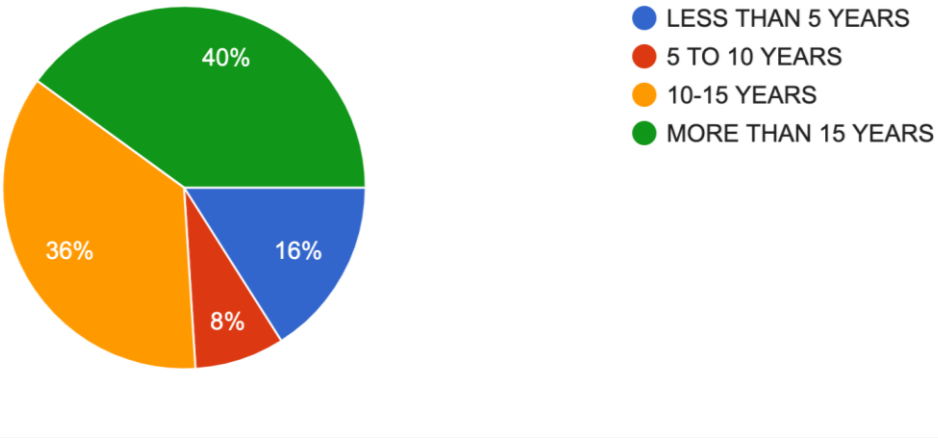

Fig. 1. Distribution of Teaching Experience

A significant portion of the faculty, 40%, has over 15 years of teaching experience. This indicates a strong presence of seasoned educators. The next largest group, comprising 36% of the teachers, has between 10 and 15 years of experience. A smaller proportion of teachers, 16%, has between 5 and 10 years of experience. Only 6% of the teachers have less than 5 years of experience,

suggesting a relatively stable faculty with a limited number of recent hires. Overall, the data suggests a faculty with a strong blend of experienced and moderately experienced teachers, indicating a balance between institutional knowledge and fresh perspectives.

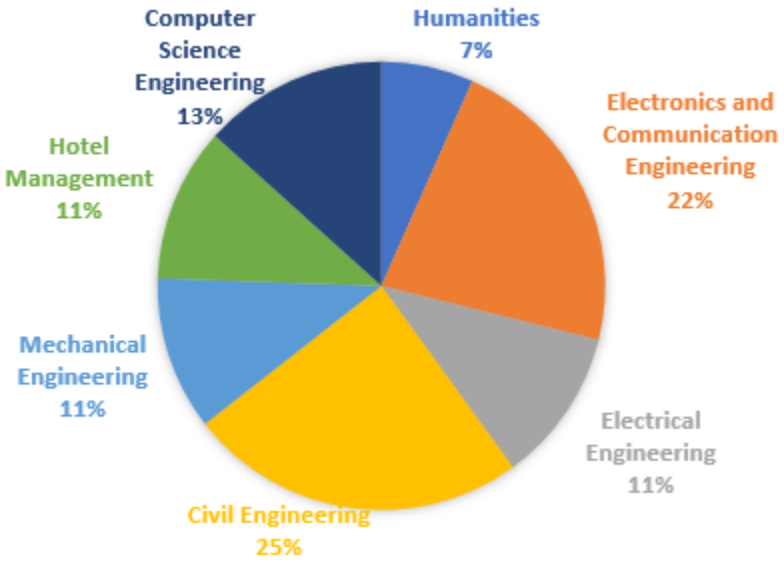

Fig. 2. Distribution of Domain Specialisation

The teacher population is primarily concentrated in engineering disciplines, with the majority of teachers (24%) belonging to the Electronics and Communication Engineering department. Civil Engineering follows closely with 24% of the faculty. Mechanical Engineering and Hotel Management each account for 11% of the faculty, while Electrical Engineering constitutes 10%. Computer Science Engineering has 13% of the faculty, and Humanities has the smallest representation with only 7%.

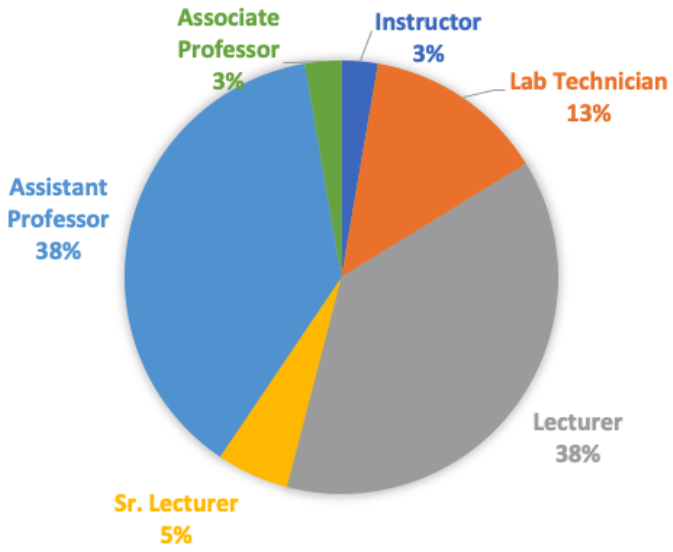

Fig. 3. Distribution of Designation

Lecturers constitute the largest group, making up 44% of the total faculty. Assistant Professor: The next largest group is Assistant Professors, accounting for 44% of the faculty. Lab Technicians: Lab Technicians make up 16% of the total faculty. Other Designations: The remaining designations, namely Instructor, Sr. Lecturer, and Associate Professor, each represent a small percentage of the faculty, with 3%, 6%, and 3%, respectively.

VI. ANALYSIS AND INTERPRETATION

This section presents an analysis, interpretation, and codification of teacher responses for the interviews conducted on challenges of language differences. The collected data was analysed using thematic analysis identifying key themes and patterns within the interview transcripts and focus group discussions. The analysis will focus on understanding the impact of language diversity on teaching practices, the challenges faced by teachers, the strategies employed to adapt to diverse language abilities, and the perceived benefits and drawbacks of multilingual classrooms.

A. How language diversity affects their teaching practices

Based on the data from the interview responses, language diversity impacts teaching practices and experiences in engineering classrooms in Andaman in several ways. The challenges included communication barriers due to which students struggle to understand lectures, textbooks, and assignments due to limited English proficiency can make it difficult for teachers to effectively communicate concepts. Moreover, students who are shy to speak in class due to language limitations can hinder classroom discussions and reduce opportunities for formative assessment. One teacher mentioned "Students struggling to understand lectures due to limited English proficiency..."This highlights the communication barrier issue. Another teacher added "Students who are shy to speak in class due to language limitations..." This emphasizes the potential for reduced participation. In order to tackle this challenge, teachers adapted the following strategies. Some teachers reported using a mix of Hindi and English to explain concepts, while others

mentioned catering to students from Bengali backgrounds. They also emphasised the importance of clear explanations, potentially using simpler language and varied teaching methods like presentations, demonstrations, and digital tools. Additionally, they believed in creating a supportive environment where students feel comfortable using their preferred language initially, then gradually building confidence to participate in English, was mentioned by one teacher. "Some teachers reported using a mix of Hindi and English to explain concepts..." This showcases a strategy for addressing communication barriers. "Teachers emphasize the importance of clear explanations, potentially using simpler language..." This highlights a general teaching adaptation for diverse language proficiency. Having students from diverse backgrounds can bring in multiple perspectives and enrich classroom discussions. Overall, the impact of language diversity appears to be mixed. While it creates challenges, teachers adopt various strategies to address them. The excerpt also highlights the potential benefits of multilingual classrooms.

B. The specific challenges they face due to language differences.

Comprehension of Instructions and Explanations: The response "students fail to give answer when I ask questions...students writing skills are very poor" and "At times students hesitate to ask questions...Teachers may face difficulties in communication and ensuring all students understand the material equally," offers some insights into the challenges teachers face due to language differences. This suggests students struggle to answer questions and have limited writing skills. This may indicate difficulties understanding technical terms, complex instructions, or the overall content of lectures due to language barriers. This may also imply that students lack the necessary language skills to comprehend questions or express themselves effectively in writing.

Limited Student Participation: The statement about students hesitating to ask questions indicates a potential barrier to participation as mentioned by a teacher." At times students hesitate to ask questions..." Students may feel uncomfortable speaking due to language limitations, leading to reduced engagement in discussions. It also suggests shyness or apprehension related to language proficiency.

Ensuring Understanding Across the Class: The statement regarding teachers potentially facing difficulties in communication and ensuring comprehension implies challenges in conveying complex technical topics in a way that caters to all students' language abilities. "Teachers may face difficulties in communication and ensuring all students understand the material equally" highlights the teachers' concern about achieving equal comprehension for all students.

Additionally, challenges may vary based on the subject's vocabulary and complexity. For example, subjects with a heavy reliance on specialized terminology might pose greater communication barriers. Based on the identified themes, we can categorize the challenges into broader groups highlighting understanding deficit, reduced participation and uneven comprehension. Students have difficulties understanding instructions, explanations, and technical vocabulary due to language barriers. Students exhibit hesitancy to ask questions and participate in discussions due to language limitations. Teachers are concerned about ensuring all students, with varying language abilities, grasp the material equally especially in technically subjects. This also necessitates a nuanced approach to teaching, as different students may prefer auditory, visual, or tactile learning styles. This linguistic and cultural diversity can lead to increased reliance on teachers and a more complex learning environment.

C. Teacher adaptation strategies for multilingual classrooms

There is some extent of observed success of the institute's skill-based and activity-based learning in addressing the challenges of multilingual classrooms. However, for producing globally competent professionals, following strategies are also adapted:

Language Simplification and Supportive Materials: Teachers said "Break down complex topics into smaller, easier-to-understand chunks..." This highlights the use of simpler language and breaking down complex concepts. Others agreed "Use of Pictures, diagrams, and models that help explain ideas without needing much of words..." This emphasizes the use of visual aids to support understanding. Both quotes showcase teachers adapting their explanations to be more accessible for students with varying language proficiency levels. By using simpler language, breaking down complex topics, and incorporating visual aids, teachers attempt to bridge the language gap and enhance comprehension.

Multilingual Strategies: "English becomes the mode of communication...Incorporating varied cultural knowledge in the class, collaborative/team learning, visual transcript" While this prioritizes English, it also suggests incorporating cultural elements and collaborative learning, which can benefit students with diverse language backgrounds. This quote showcases a combination of strategies. English is the primary mode of communication, but incorporating cultural knowledge and collaborative learning can provide additional support for students. Additionally, the mention of a "visual transcript" might imply using translated materials or visual representations alongside spoken language.

Promoting Interaction and Alternative Assessments: "Teachers adapt their methods by using differentiated instruction...using alternative assessment methods." This suggests using various methods beyond just written exams, but doesn't explicitly mention group work. The quote indirectly suggests using alternative assessments. To strengthen this category, you'll need to look for quotes in the complete data that directly reference using group work or collaborative learning strategies to promote interaction and provide alternative assessment methods beyond written exams. Teachers often utilize personality tests and learning style assessments to foster collaboration and trust, which can be challenging due to the islands' unstable weather, natural calamities, and sometimes hostile social environment. Understanding students' backgrounds and experiences is crucial for effective teaching. The current recruitment process through the UPSC (Union Public Service Commission) ensures a diverse pool of teachers, addressing the linguistic needs of the student population. Many teachers provide technical vocabulary glossaries to aid comprehension. Consistent efforts are made to incorporate culturally relevant content into the curriculum.

D. Perceived benefits and drawbacks of multilingual classrooms for teachers and students

The benefits as perceived by students could include improved understanding - "Understandability (from the students' point of view)") suggests students perceive a benefit in being able to use their home language for clarification. The teacher perception includes diverse perspectives as teachers felt "Exploring diversity and learning new languages" are the perceived benefits, cultural enrichment - "Students and teachers get knowledge about others cultures and share knowledge about their culture that creates some emotional bond and strong understanding", and improved communication "Students interact quickly with teachers". However, these are teacher perceptions. The drawbacks from the student perspective include difficulty in "grasping complex topics as complex topics might be harder to grasp initially when explained in a non-native language". As a

result, students often become overly reliant on teachers and struggle to maintain focus when traditional lecture-based methods are employed. DBRAIT Institute has been successfully addressing this issue by adopting a skill-based and activity-based approach, reducing the reliance on lengthy lectures. Active experimentation has led to higher placement rates for technical education graduates. Teachers highlight communication challenges - "Language barriers can make it difficult to communicate effectively with all students", time constraints - "Takes more time to cover lessons", and challenges with assessments "Preparing students to understand answer questions in English for the board exams". Thus, it is clear that while students perceived an enhanced understanding through home language use teachers felt that exposure to diverse perspectives, cultural enrichment, and potentially improved student interaction. On the other hand, in a multilingual classroom, students had difficulty understanding complex topics in a non-native language and teachers faced communication challenges, time constraints due to adaptation methods, and assessment difficulties related to language variations.

E. Teacher Requested Support Systems and Resources

Professional Development: Training on teaching multilingual learners - "Training on effective pedagogy for multilingual classroom" and cultural competency - "Training in Culturally Responsive Teaching" are mentioned as helpful resources.
Language Support Specialists: Teachers mention a need for specialists such as bilingual aides "Teachers believe that translated materials, language support specialists, and professional development on effective strategies would be helpful" or ESL (English as a Second Language) teachers "Teachers believe that support systems such as language specialists, bilingual aides, professional development on teaching English as a second language...would be helpful".
Instructional Materials and Technology: The teachers mention the need for translated materials - "Teachers believe that translated materials, language support specialists, and professional development on effective strategies would be helpful" and access to technology for language support "Access to language support technology". Some teachers mentioned bridge courses “Bridge courses to read, speak and write in English as it's the medium of learning" and textbooks in various languages "Textbook availability in various languages" as helpful resources.
Perspectives from the Focus Group Discussion:

In focus group discussions, teachers expressed frustration with the limited availability of technical vocabulary in regional languages, hindering students' ability to grasp complex concepts and apply them in practical settings. Teachers highlighted the lack of standardized technical terminology in regional languages, leading to confusion and inconsistency in communication and assessment. They also expressed concern about the lack of culturally relevant examples and case studies in technical textbooks, making it difficult to connect with students from diverse backgrounds. It was also clear that teachers felt overwhelmed by the additional workload associated with adapting teaching methods and materials to cater to diverse language abilities. These perspectives summarise the challenges teachers faced in multilingual contexts in technical classrooms. Contrarily, the discussion also threw light on how certain benefits emerged in such classrooms. A few teachers observed that multilingual classrooms fostered a deeper understanding of different cultures and perspectives, enriching the overall learning experience. Students from diverse linguistic backgrounds often brought unique insights and problem-solving approaches to technical challenges. Additionally, multilingual classrooms encouraged students to develop stronger

communication and interpersonal skills, essential for collaborative work in the engineering field. The table below summarises the key points from the focus group discussion held based on the thematic orientation highlighting challenges, benefits, strategies and support systems.

Table 1. Results of the Focus Group Discussion

Theme	**Teacher Perception**	**%**	**Views as quoted by teachers**
Challenges	Comprehension of Instructions and Explanations	70	"It's frustrating when students struggle to understand basic technical terms, even after repeated explanations."
	Limited Student Participation	6	"The lack of consistent technical terminology across different languages creates a significant barrier to effective communication and assessment."
	Uneven Comprehension	70	"Many students come from diverse cultural backgrounds, and it's challenging to find relevant examples that resonate with all of them."
Benefits	Diverse Perspectives	50	"Having students from diverse linguistic backgrounds brings a richness to classroom discussions that I wouldn't have otherwise experienced."
	Improved Understanding	50	"I've learned so much about different cultures and perspectives from my students, which has broadened my own understanding of the world."
	Stronger Skills	75	"Students who have to navigate different languages often develop strong communication and problem-solving skills."
Strategies	Peer Learning	65	"Peer learning has been incredibly effective. Students who are more proficient in English can help those who are still learning."
	Technology Integration	85	"I've started using online dictionaries and translation tools to assist students in understanding technical terms."
	Local Resources	40	"Incorporating local case studies and real-world examples has increased student engagement."
	Safe Environment	60	"Creating a safe and inclusive classroom environment is important. Students need to feel comfortable asking questions without fear of judgment."
Support Systems	Professional Development	80	"We need more professional development opportunities specifically focused on teaching multilingual learners."
	Feedback and Support	70	"Regular feedback and support from experienced colleagues would be extremely beneficial in navigating the challenges of teaching in a multilingual environment."

VII. DISCUSSION AND INTERPRETATION: LANGUAGE DIVERSITY IN TECHNICAL EDUCATION

This research explored the challenges and opportunities of language diversity in technical education classrooms in the Andaman. By analysing teacher responses, we gained insights into how language differences impact teaching practices and the perceived benefits and drawbacks of multilingual classrooms.

Challenges and Teacher Adaptation: The data highlights communication barriers and student hesitation to participate as key challenges. Teachers adapt by using simpler language, incorporating visual aids, and leveraging multilingual strategies like translation tools or a common language alongside English. These efforts resonate with NEP 2020's emphasis on fostering a multilingual learning environment. However, challenges remain, particularly regarding assessment methods that may not adequately cater to diverse language proficiency levels.

Perceived Benefits and Drawbacks: The perceived benefits include exposure to diverse perspectives and cultural enrichment for both teachers and students. Students also appreciate the potential for improved understanding through their home language. However, drawbacks exist. Students might struggle with complex topics initially, while teachers face communication challenges and time constraints due to additional adaptation methods. Addressing these issues requires further exploration of effective assessment methods for multilingual classrooms, aligning with NEP 2020's goal of holistic learning assessments.

Support Systems and Resources: Teachers identified a need for professional development in teaching multilingual learners and cultural competency. Additionally, access to language support personnel, translated materials, and technological tools was emphasized. These needs align with NEP 2020's vision of providing quality teacher education and promoting inclusivity. Future implications include developing training programs for teachers on effective multilingual teaching methodologies, integrating cultural competency into teacher education curriculum and investing in resources like bilingual aides, translated materials, and language learning technology for classrooms.

VIII. RECOMMENDATIONS AND FUTURE IMPLICATIONS

Addressing language diversity in technical education requires a multi-pronged approach. The slower pace of teaching required to accommodate diverse learners may lead to a reduced curriculum coverage. Additionally, academic isolation and limited access to training opportunities can hinder teacher development. Exposing students to competitive technical environments and industry experts can motivate them and bridge the gap between theory and practice.

By building teacher capacity, providing necessary resources, and potentially adapting assessment methods, we can create more inclusive learning environments that leverage the strengths of multilingual classrooms. As suggested by James and Brookfield (2004), critical incident questionnaires can be used to assess teaching styles and encourage a shift towards more visual and interactive approaches. Team teaching can foster inclusive learning environments, particularly when combining the strengths of oral and visual teachers. By training oral teachers to be more interactive and visual teachers to be more student-centered, a more effective and engaging learning

experience can be created. This aligns with NEP 2020's vision of promoting multilingualism and fostering excellence in education for all. Further research could explore specific subject-based challenges and opportunities within multilingual classrooms, along with the effectiveness of different teacher adaptation methods and support systems. This will contribute to a more comprehensive understanding of how to optimize technical education for diverse language backgrounds in India and beyond.

The focus-group discussion (FGD) with ten teachers addressing the question "How can teachers navigate this path of a multilingual environment and make learning effective?" The following observations were recorded as discussed by teachers. Based on the FGD, the following recommendations can be made. Teachers can foster a student-centered environment with opportunities for peer interaction and group work in mixed-language groups, encourage students to explain concepts in their preferred languages to enhance understanding and build confidence, integrate diverse cultural contexts and examples into technical subjects to promote cultural relevance, create safe and inclusive spaces where students feel comfortable using their home languages to ask questions and participate.

To develop strategies for effective communication, teachers can utilize simpler language and break down complex topics into smaller, manageable units, incorporate visual aids like diagrams, models, and pictures to support explanations, explore using a common language alongside English, if appropriate, for initial explanations, consider using translation tools and technologies to support student comprehension.

Additionally, they can adapt assessment methods by moving beyond traditional written exams towards a more holistic approach, including assessments that allow students to demonstrate their understanding in various ways, like presentations, practical tasks, or projects. They can also consider using formative assessments throughout the learning process to identify areas where students might need additional language support.

In a similar vein, policies can be framed for investing in teacher training focusing on developing and offering professional development programs focused on effective teaching methodologies for multilingual classrooms. Training programs can also educate teachers on methods to integrate cultural competency training into the teacher education curriculum. Teachers can be provided with resources and support by allocating resources for hiring bilingual aides or ESL teachers to provide in-class language support. Creating translated instructional materials and textbooks in various languages relevant to the curriculum and equipping classrooms with technological tools for language learning and translation support can also be helpful. Aligning Assessment Systems by exploring ways to adapt assessment methods to better accommodate diverse language proficiency levels and considering offering exams in multiple languages or developing alternative assessment formats that don't heavily rely on written English skills can be recommended. It is obvious that promoting inclusivity and equity by acknowledging the value of multilingualism in technical education and promote inclusive learning environments can be valuable. Similarly, developing policies and practices that support the integration of students from diverse language backgrounds into technical education programs is also crucial. By implementing these recommendations, both teachers and policymakers can work together to create a more inclusive and effective learning environment for all students in multilingual technical classrooms. This aligns with the goals of NEP 2020 and paves the way for a future where language diversity is seen as an asset, not a barrier, in technical education.

IX. LIMITATIONS

This research study offers valuable insights into language diversity in technical education, but there are some limitations to consider. The research only analysed a limited set of teacher interviews. A larger and more diverse sample size, including students from various backgrounds, could provide a more comprehensive picture of the challenges and opportunities. The study primarily focused on teachers' experiences. Including interviews with students would offer their perspective on communication barriers, preferred learning styles, and the effectiveness of teacher adaptation methods. The data doesn't specify the technical subjects taught. Challenges and opportunities might vary depending on the subject's complexity and vocabulary usage. Ideally, the research would consider how language diversity impacts different technical fields. While the analysis identified some teacher adaptation methods, a deeper dive into their perceived effectiveness would be valuable. Further research could explore specific strategies and solicit teacher feedback on their success. Despite these limitations, the research provides a valuable starting point for understanding the complexities of language diversity in technical education. Future research can address these limitations to build a richer and more nuanced understanding of this topic, ultimately leading to the development of more effective teaching practices and policies for multilingual classrooms.

X. CONCLUSION

This study examines the challenges and strategies needed to address the unique situation in the Andaman where students come from various linguistic backgrounds, many from tribal and indigenous communities yet to fully participate in higher technical education. This research also explored the challenges and opportunities presented by language diversity in technical education classrooms in the Andaman and Nicobar Islands. By analysing teacher responses, we gained valuable insights into how communication barriers impact teaching practices and how teachers currently adapt their methods.

The research highlights the potential benefits of multilingual classrooms, including fostering diverse perspectives and enriching cultural understanding for both teachers and students. However, it also identifies key challenges like communication difficulties, limitations in assessment methods, and the need for additional support systems.

Moving forward, addressing these challenges requires a multi-pronged approach. Teachers can benefit from professional development in teaching multilingual learners and culturally responsive teaching. Additionally, providing access to resources such as bilingual aides, translated materials, and language learning technology can empower teachers to create more inclusive learning environments. Policymakers play a crucial role in supporting this shift by investing in teacher training, allocating resources for multilingual classrooms, and exploring ways to adapt assessment systems to better accommodate diverse language proficiency levels.

This research aligns with NEP 2020's vision of promoting inclusivity and multilingualism in education. By embracing this diversity and implementing effective strategies to overcome challenges, we can empower students from all linguistic backgrounds to excel in technical education and contribute to India's future workforce.

Further research directions can include exploring the specific challenges and opportunities of language diversity in different technical subjects, investigating the effectiveness of various teacher adaptation methods in promoting student learning, conducting research involving students' perspectives on language diversity in technical education and examining the impact of language policies and assessment systems on multilingual classrooms. By continuing to explore these areas, we can build a comprehensive understanding of how to harness the power of language diversity to create thriving technical education programs for all students in India.

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Power Quality Enhancement in Microgrid for Grid Connected Electric Vehicle Charging Infrastructure – A Critical Review

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Abstract: In recent years, with the rapid adoption of EV charging stations and their integration into microgrids, maintaining a reliable and high-quality power supply has become crucial. This review examines the significance of power quality in microgrid environments with a focus on enhancing the charging infrastructure for electric vehicles (EVs) tied to the grid. The integration of electric vehicles (EVs) into microgrid-connected charging stations has brought forth challenges related to power quality, necessitating advanced techniques for enhancement. The study explores various methods, technologies, and strategies employed to address power quality issues in microgrids, specifically concerning EV charging infrastructure. Focusing on mitigating voltage fluctuations, harmonic distortions, and ensuring grid stability, this review examines various approaches. Advanced control algorithms, energy storage systems (ESS), active/passive filters, and smart grid technologies emerge as key solutions. Additionally, the abstract highlights the integration challenges of EV charging stations into microgrids and the evolving concept of vehicle-to-grid (V2G) technology. Furthermore, the review discusses challenges, future directions, and potential research avenues aimed at optimizing power quality within microgrids supporting EV charging infrastructure for a sustainable energy ecosystem.

Keywords: *Power Quality, Microgrid, Electric Vehicle Charging*

I. INTRODUCTION

Conventional automobiles are being substituted with plug-in hybrid electric vehicles (EVs) due to the release of hazardous gasses and environmental pollutants. Consequently, the usage of electric vehicles is rising. Renewable energy sources like solar power and electric vehicle chargers are essential for lowering our dependency on fossil fuels and are the natural evolution of our energy system [1]. In recent years, the growing integration of electric vehicles (EVs) into the power grid has presented new challenges and opportunities for the effective management of power quality within microgrid environments. The integration of electric vehicles (EVs) into microgrid-connected charging stations has revolutionized the transportation sector, introducing new complexities to the power grid. This paradigm shift, while promising in reducing carbon emissions and promoting sustainability, has concurrently posed challenges to the grid's power quality [2].

The surge in EV adoption has led to increased power demand, causing voltage fluctuations, harmonic distortions, and unbalanced loads within microgrids. These issues can adversely affect the grid's stability and reliability, compromising the performance of both charging stations and other connected electrical loads. Also demands robust and reliable charging infrastructure, emphasizing the need for enhancing power quality to ensure an efficient and uninterrupted energy

supply. Ensuring a stable and high-quality power supply is crucial for both the grid's reliability and the efficient operation of EVs. Consequently, the need for effective strategies to mitigate these power quality concerns becomes imperative [14].

This review delves into the critical role of power quality enhancement in microgrids, particularly concerning the charging infrastructure for grid-connected electric vehicles. The proliferation of EVs has reshaped the traditional power grid dynamics, creating a complex interplay between energy supply, distribution, and consumption. As EVs draw significant power during charging, their connection to microgrids requires sophisticated measures to mitigate potential disruptions to overall grid stability and ensure seamless operation. This review explores the multifaceted aspects of power quality within microgrids, encompassing voltage stability, frequency regulation, harmonics mitigation, and overall grid resilience. It delves into the diverse methodologies, technologies, and control strategies employed to address power quality issues, specifically tailored to accommodate the demands of EV charging infrastructure. Examining various control techniques, power electronics solutions, and intelligent energy management systems, this review aims to dissect the methods utilized to optimize power quality in microgrid settings supporting EV charging [3].

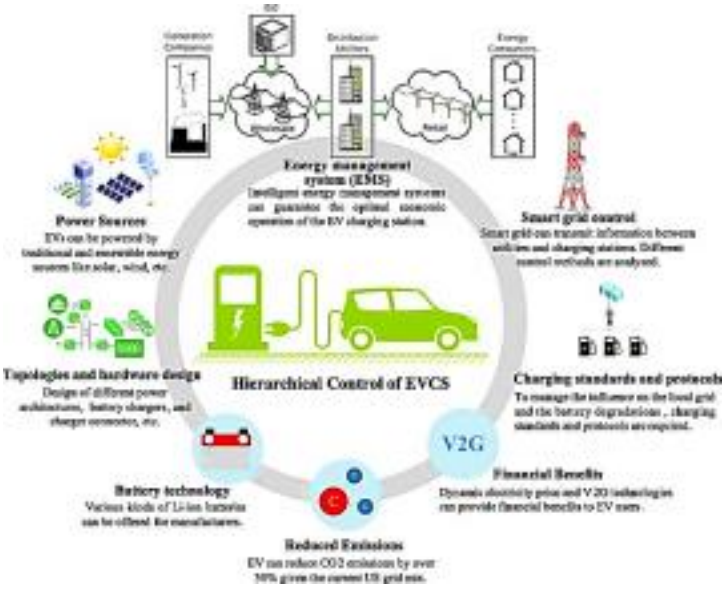

Fig. 1. Road Map of Electric Vehicle Charging Station

It aims to explore and analyse a spectrum of cutting-edge techniques designed to enhance power quality in microgrid-connected EV charging stations. Advanced control algorithms, such as model predictive control or fuzzy logic, offer precise management of power flow and grid stability. Energy storage systems (ESS), including batteries and supercapacitors, emerge as potent tools for buffering power fluctuations and optimizing grid performance. Additionally, active and passive filtering technologies play a pivotal role in eliminating harmonics and ensuring voltage stability. Furthermore, the integration of smart grid technologies offers real-time monitoring, fault detection, and adaptive control mechanisms, contributing significantly to maintaining power quality standards. However, the integration of EV charging stations into microgrids brings its own set of challenges, including bidirectional power flow management and the evolution of vehicle-to-grid (V2G) capabilities, which necessitate innovative solutions [4].

In India, various renewable energy sources are instrumental in improving power quality in microgrid connected electric vehicle (EV) charging stations. These sources contribute to a more sustainable and reliable power supply while mitigating power quality issues. Solar PV systems are widely adopted in India for power generation. They can be integrated into microgrids serving EV charging stations to provide clean energy, reduce dependency on the main grid, and stabilize power supply. Wind turbines are another prevalent renewable energy source in India. When incorporated into microgrids, wind power contributes to the energy mix, especially in areas with favourable wind conditions, reducing reliance on conventional power sources. Although less common in microgrids due to specific location requirements, hydropower can be integrated into certain regions of India, providing consistent and reliable renewable energy to stabilize microgrid operations. Biomass and biogas technologies utilizing organic waste materials can generate electricity. These sources can contribute to the energy mix and help in diversifying renewable energy sources in microgrids. Combining multiple renewable sources, such as solar-wind or solar-hydro, in hybrid systems offers increased reliability and power generation stability, minimizing the intermittency associated with individual sources [5].

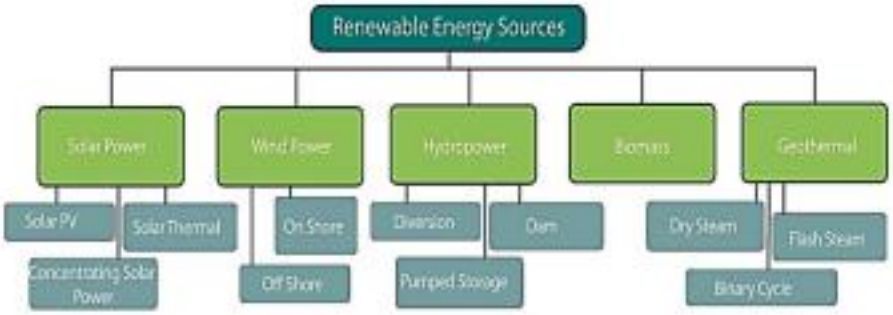

Fig. **2**. Promising Renewable Energy Sources

These renewable energy sources, when properly integrated into microgrid-connected EV charging stations, contribute to a more sustainable and resilient power supply. They help mitigate power quality issues by providing cleaner energy, reducing reliance on fossil fuels, and enhancing the stability and reliability of the microgrid, thereby supporting the growth of electric vehicle infrastructure in India [5].

This comprehensive review intends to delve into each of these power quality enhancement techniques, highlighting their functionalities, strengths, and limitations. Real-world case studies and experimental results will be presented to showcase the practical efficacy and implications of these methods in ensuring a robust and sustainable microgrid-connected EV charging infrastructure. Ultimately, this exploration aims to contribute to the advancement of power quality enhancement methodologies, enabling reliable and efficient operations in the evolving landscape of EV charging within microgrids. This study will discuss the existing challenges, emerging trends, and potential research avenues for enhancing power quality in microgrids, thereby contributing to the development of a sustainable and efficient energy ecosystem capable of supporting the expanding network of grid-connected electric vehicle charging infrastructure.

II. POWER QUALITY CHALLENGES IN MICROGRIDS:

The study emphasizes the importance of maintaining PQ in the electrical power system to provide end customers with an effective and dependable energy supply. The ideal role of the electrical grid is to provide consumers with an ideal voltage supply. The ultimate goal of the power supplier is

to produce and supply the perfect voltage and current, which are both single-frequency sine waves at nominal levels with constant amplitude and frequency. The voltage and current must also be in synchronization [6]. This includes equipment manufacturers, facility designers, standards bodies, and suppliers of generation, transmission, and distribution in addition to end users. The equipment linked to the electrical grid is one of the many elements that influence PQ. Due to the substantial use of power electronic equipment in microgrids and RES-based power systems, their PQ is especially sensitive. PQ disturbances can result from transitions, voltage dips, swells, harmonics, imbalances, and oscillations.

Voltage Fluctuations: Voltage fluctuation is "a sequence of random voltage changes with magnitudes ranging from 0.95 to 1.05 p.u." or "systematic variations of the voltage waveform envelope." The word describes variations in the voltage amplitude that can happen once, repeatedly, arbitrarily, or regularly [7]. Figure 3 illustrates an example of voltage fluctuation in an arc furnace operating. Variable loads or generation could be the source of voltage fluctuation [8]. Moreover, abrupt grid disruptions that result in notable voltage swings might be caused by short circuits, transmission line problems, or equipment failures; depending on how serious and what kind of fault these disturbances are, voltage dips or spikes may result [9]. Variations in voltage inside the microgrid may result from sudden shifts in the demand for EV charging. High loads may impact the stability and functionality of linked equipment during concurrent EV charging sessions, resulting in voltage sags or swells.

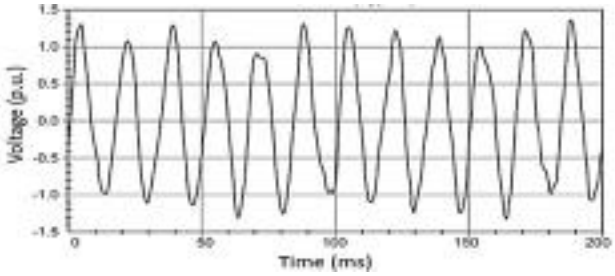

Fig. 3. Voltage fluctuation Induced by Arc Furnace

Harmonic Distortions: Harmonics are waveform distortions that occur as integer multiples of the fundamental frequency. Non-linear loads and devices bring on these distortions in normal operation, which are frequently made worse by power electronics. [8]. Regular operation of non-linear devices and loads typically results in the injection of current harmonics. DGs frequently use devices like pulse-width modulation (PWM) inverters, which are major generators of voltage harmonics because of their series connection with internal device impedances [7]. The Total Harmonic Distortion (THD) index commonly measures the severity of harmonic disturbance. The THD index is the ratio of the root-square of harmonic content to the nominal fundamental voltage (or current), expressed in percentage. This is shown in below equation, where Vh is the RMS value of the nth harmonic component of voltage (or current), and Vn is the RMS value of the nominal fundamental voltage (or current). Nonlinear loads associated with EV chargers can introduce harmonics into the grid. These harmonics, typically in the form of distorted currents or voltages, can degrade power quality, causing overheating in equipment and affecting the efficiency of power distribution.

Frequency Variations: The fundamental frequency of the power system deviates from its nominal

value, known as power frequency fluctuations. There is an innate relationship between the generator rotational speeds inside the power system and the system's frequency, which is constant and steady-state [7]. The power system frequency is set by the balance between the generation capacity and the load, and any changes to this balance could result in minute fluctuations in frequency. Large and sudden changes in EV charging demand may cause frequency deviations within the microgrid. Frequency variations outside the acceptable range can impact the synchronization of grid components and affect the performance of sensitive equipment.

Unbalanced Loads: Unequal voltage magnitudes, current magnitudes, or phase angles across various phases are the hallmarks of imbalances, often known as imbalances [7]. A three-phase residential feeder's voltage imbalance trend is displayed in Figure 4. Particularly in systems with single-phase loads, voltage imbalances are generally less noticeable than current imbalances [7].

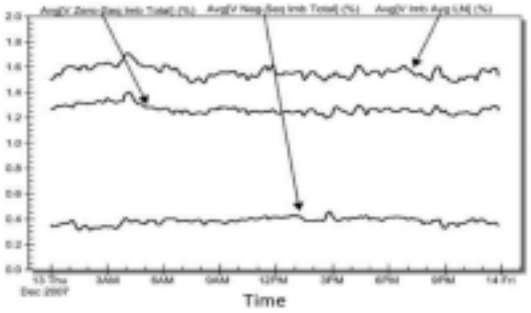

Fig. 4. Voltage Unbalance Trend for a Three-Phase Residential Feeder

Uneven distribution of charging among EVs or asymmetric load profiles can create unbalanced conditions in the microgrid. Unbalanced loads can lead to voltage imbalances and affect the overall power quality by causing uneven stress on the grid components.

$$\%VUF = \frac{\text{Negative sequence voltage component}}{\text{Positive sequence voltage component}}$$

Voltage Flicker: Power systems are susceptible to variations in voltage, and one common occurrence in low voltage (LV) and medium-voltage (MV) distribution networks is Rapid Voltage Change (RVC). Switching procedures that negatively impact equipment functioning are typically linked to RVCs [10]. Flicker, characterized as the "impression of unsteadiness of visual sensation induced by a light stimulus whose luminance or spectral distribution fluctuates with time," is the primary effect of RVC. Rapid changes in charging loads or variations in renewable energy sources can cause voltage flicker. This fluctuation in voltage perceived by the connected devices can lead to disruptions or disturbances in their operation.

Grid Instabilities: The grid may become unstable due to variations in frequency and voltage since solar energy is sporadic, and its generation is unpredictable depending on weather and time of day. The fluctuation in renewable energy sources is one of the primary reasons for grid instability in integrating renewable energy. The weather and daily cycles affect wind and solar output, unlike conventional power facilities that can be managed and changed to match demand [11]. Sudden changes in power demand or integration of intermittent renewable energy sources without proper control mechanisms can lead to grid instabilities, affecting overall power quality and system reliability.

Electromagnetic Interference (EMI): A vehicle's power converter is the main source of

electromagnetic interference (EMI). EMI is produced by harmonics and by high-speed switching devices used by power converter systems to operate at high frequencies over a broad range. Electric motors must run at high power levels, similar to the power converter, as this could release electromagnetic emissions (EME) through impedance, which varies with frequency. An electric vehicle motor generates electromagnetic noise (EM
noise) by using power inverters that operate at high speed, resulting in surge voltages at the terminals [12]. The charging process of EVs may generate electromagnetic interference that can affect nearby electronic devices and communication systems if not appropriately mitigated. By sorting out these power quality issues in microgrid-connected EV charging stations requires the implementation of advanced control strategies, appropriate filtering techniques, proper grid management systems, and smart charging protocols. Ensuring a stable and high-quality power supply to EVs while maintaining the reliability of the microgrid infrastructure is crucial for sustainable and efficient operation.

III. CHALLENGES ON VEHICLE-TO-GRID (V2G) OPERATIONS AND ISLANDED MODE

Vehicle-to-grid (V2G) charging technology is advantageous to energy providers and customers. It permits energy to move from an electric car's battery back to the power grid in a single direction. Thanks to this technology, we can get the most out of our current cars because EVs function as large-wheeled batteries supporting the grid. This is particularly crucial when the grid's energy comes from erratic renewable sources like solar and wind.

By 2030, there will be between 140 and 240 million electric cars on the road, translating to at least 140 million mobile energy storage devices with a combined storage capacity of seven trillion watt-hours. During Vehicle-to-Grid (V2G) operations and islanded mode in microgrid-connected electric vehicle (EV) charging stations, several power quality issues may arise due to the bidirectional power flow, disconnection from the main grid, and the dynamic nature of EV charging and discharging. Some of these power quality issues include:

Table 1. Voltage Fluctuation Range of various EV Charging Scenario

EV Charging Scenario Voltage Fluctuation Range	
Slow AC Charging (Level 1)	±3%
Moderate AC Charging (Level 2)	±4%
Fast DC Charging (Level 3)	±5%
Simultaneous Multiple EV Charging	±6%
EV Charging with Voltage Regulators	±2%
EV Charging with Dynamic Load Management	±3%

Voltage and Frequency Instabilities: The voltage and frequency will be the focus of the investigation. The ability of the system to sustain equilibrium following a disturbance is the definition of stability. A disturbance occurs when the V2G is operational on the case study's distribution model, at which point the voltage and frequency are assessed. The voltage of the

Jordanian electricity system must remain constant between 220 volts and 50 Hz.

Table 2. THD Value at Various Scenarios of Load

	Load	PEV state	Semester	Penetration level for PEV	Total harmonic distortion
Scenario 1	peak	Discharging	Summer	70%	THD=<5% for IEEE standard
Scenario 2	peak	Discharging	Summer	50%	THD=<5% for IEEE standard
Scenario 3	Off-peak	Charging	Summer	70%	THD=<5% for IEEE standard
Scenario 4	Off-peak	Charging	Summer	50%	THD=<5% for IEEE standard
Scenario 5	peak	Discharging	Winter	70%	THD=<5% for IEEE standard
Scenario 6	peak	Discharging	Winter	50%	THD=<5% for IEEE standard
Scenario 7	Off-peak	Charging	Winter	70%	THD=<5% for IEEE standard
Scenario 8	Off-peak	Charging	Winter	50%	THD=<5% for IEEE standard

The power quality, which also impacts equipment life, is the subject of another study. Equipment life is shortened, and maintenance requirements rise with unclean electricity. Voltage distortion is the main factor affecting power quality, and it will be assessed for each odd harmonic component before being assessed as a whole (THD) [14]. The technology of PEVs with dual orientations for generating and loading would impact frequency as the balance between load and generation determines it. A study is done on the frequency response to disturbances at the distribution model. Three feeders are defined for a switch event if they all have a fault and are disconnected at the same time. [14]. In V2G scenarios or islanded operation, sudden changes in power flow caused by EVs discharging energy back to the grid or islands can lead to voltage and frequency instabilities. These fluctuations may occur due to varying charging/discharging rates or sudden disconnections from the main grid [13].

Voltage Sags and Swells: As opposed to voltage sags (dips), voltage swells are less frequent and are typically caused by faults in the system. This causes the voltage level of the healthy phases to rise quickly. A sag (dip) is a drop in rms voltage or current at the power frequency that lasts for 0.5 cycles to 1 minute, falling between

0.1 and 0.9 pu. Swell a rise in rms voltage or current at power frequency lengths of 0.5 to 1 minute, to a value between 1.1 and 1.8 pu. [15]. In order to prevent sag or swell, Dynamic Voltage Restorers (DVRs) have been created to regulate the power supply to essential loads. DVRs do this by injecting a voltage of the necessary magnitude, phase angle, and frequency in series with the line and the load. Rapid changes in power flow during V2G operations or islanded mode can cause voltage sags or swells. When EVs switch between charging and discharging modes or when multiple EVs simultaneously feed power back to the microgrid, voltage variations can affect power quality [13].

Table 3. Voltage Sag and Swell Range of various EV Charging Scenario

EV Charging Scenario Voltage Sag	Voltage Swell	
Slow AC Charging (Level 1)	-10% to -15%	+10% to +15%
Moderate AC Charging (Level 2)	-8% to -12%	+8% to +12%
Fast DC Charging (Level 3)	-12% to -18%	+12% to +18%
Simultaneous Multiple EV Charging	-15% to -20%	+15% to +20%
EV Charging with Voltage Regulation	-5% to 8%	+5% to +8%
EV Charging with Dynamic Voltage Control	-7% to -10%	+7% to +10%

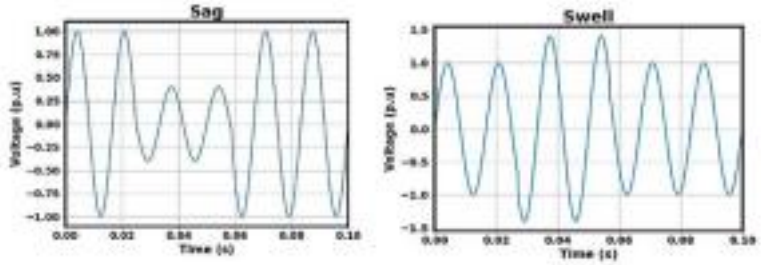

Fig. 5. Voltage Sag and Swell Waveforms

Harmonic Distortions: Generally, regulatory limits apply to distortion loads concerning overall harmonic distortion, emissions at higher frequencies, and harmonics first. A dichotomy exists whereby the acceptable voltage distortion levels for the electric network to which the load is linked are set, and each load is then assigned a specific amount of current distortion restrictions. The network characteristics and load mix assumed by this method are subject to change due to the growing amount of distorting loads that are now diffusely connected to LV distribution, such as EVs. The following examination highlights the more consolidated harmonic interval (up to the 40th harmonic) and goes over the various compatibility levels and emission limitations [17]. Bidirectional power flow from EVs introduces harmonics into the microgrid. In V2G operations, the switching converters in EV chargers and inverters can produce harmonics that degrade power quality, affecting other connected loads and equipment.

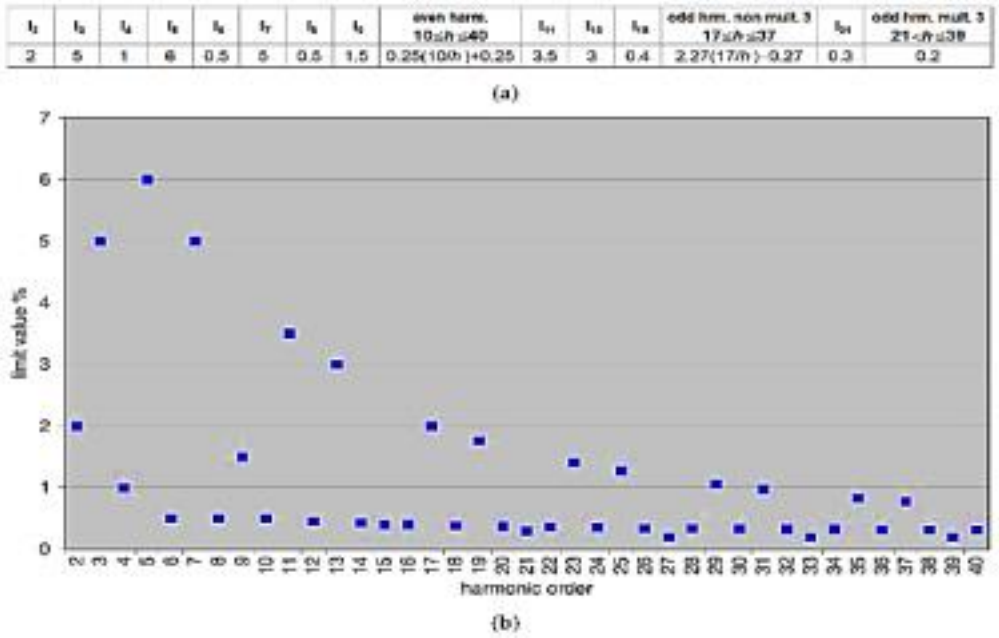

Fig. 6. Harmonic Distortion Compatibility levels for LV Distribution Grid with a Prescribed Voltage THD Level of 11%: (a) Numeric Values, (b) Graphical Form.

Table 4. THD Value at Point of Common Coupling of various EV Charging Scenario

EV Charging Scenario	THD at Point of Common Coupling (%)
Slow AC Charging (Level 1)	8-12
Moderate AC Charging (Level 2)	10-15
Fast DC Charging (Level 3)	15-20
Simultaneous Multiple EV Charging	18-25
EV Charging with Advanced Filters	5-8
EV Charging with Passive Filters	7-10

Reactive Power Imbalance: In this research, DG units in islanding microgrids are controlled using an adaptive virtual impedance technique. The virtual impedance at the fundamental positive, fundamental negative sequence and harmonic frequencies are calculated based on transient real power changes. A transient control term is added to the traditional real power-frequency droop control to trigger tiny transient power changes. Reactive power, imbalance power, and harmonic power sharing mistakes in a microgrid can be adjusted steadily through the interplay between real power changes and the virtual impedance control [18]. V2G operations might lead to an imbalance in reactive power, affecting the overall power factor of the microgrid. Uneven distribution of reactive power among different EVs and loads can lead to inefficiencies and affect power quality.

Table 5. Reactive Power Imbalance Range of various EV Charging Scenario

EV Charging Scenario Reactive Power Imbalance	
Slow AC Charging (Level 1)	±5%
Moderate AC Charging (Level 2)	±7%
Fast DC Charging (Level 3)	±10%
Simultaneous Multiple EV Charging	±12%
EV Charging with Power Factor Correction	±3%
EV Charging with Reactive Power Compensator	±4%

Islanding Challenges: In an islanding operation, parallel DG units must appropriately share the load requirement. The reactive power-voltage magnitude droop control and real power-frequency control methods have been created to enable the power-sharing requirement without requiring any communications between DG units. To achieve precise reactive, imbalanced, and harmonic power sharing, a schematic compensation approach must be developed for an islanding microgrid with many nonlinear or imbalanced loads [18]. When the microgrid operates in islanded mode due to a grid outage or intentional isolation, challenges related to frequency regulation, load balancing, and stability arise. Varying EV charging/discharging patterns in islanded mode can exacerbate these challenges.

Transient Events: The terminology transient refers to a disturbance characterized with a high magnitude but short duration, typically between 50 ns and 50ns for both voltage and current. The two main categories of transitory phenomena are oscillatory and impulsive. According to [7], "sudden, non-power frequency change in the steady-state condition of voltage, current, or both that are unidirectional in polarity – either primarily positive or negative" describes an impulsive transient. These are characterized by peak value, ascent, decay, and duration time.

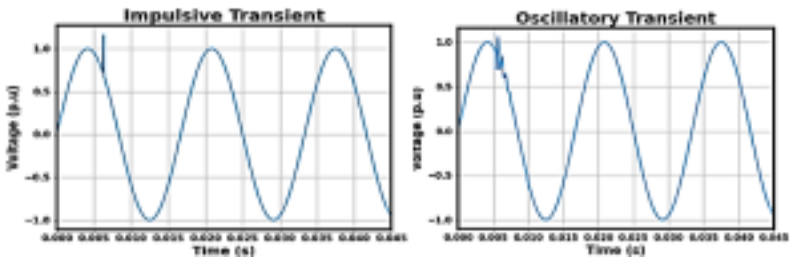

Fig. 7. Transient behaviour of the Microgrid

Most often, lightning strikes create impulsive transients, which, when they strike transmission lines, cause impulsive overvoltage [19]. Transient events, such as sudden connection/disconnection of EVs or switching operations during V2G transactions, can create transients in the microgrid, potentially causing voltage spikes or dips that impact power quality.

Table 6. Transient Phenomena on Microgrid

Category	Typical Spectral Content	Duration	Magnitude	Causes	Consequences
1. Transients					
Impulsive				Lightning strikes, Arcing due to hardware	
Nanoseconds	5 ns rise	< 50 ns			
Microseconds	1 µs rise	50 ns – 1 ms			
Milliseconds	0.1 ms rise	1 – 50 ms			
Oscillatory				Switching operations in capacitors banks or microgrids, Tap changing on transformers	Damages of electronic equipment, Malfunction of variable speed drives
Low frequency	< 5 kHz	0.3 – 50 ms	0 – 4 p.u		
Medium frequency	5 – 500 kHz	20 µs	0 – 8 p.u		
High Frequency	0.5 – 5 MHz	5 µs	0 – 4 p.u		

These power quality challenges during V2G operations and islanded mode requires sophisticated control strategies, advanced grid management systems, predictive control algorithms, and effective communication protocols. Proper coordination and control of power flow, voltage regulation, and frequency stability are essential to maintain high-quality power supply and grid reliability during these operating modes.

Table 7. Transient Duration Range of various EV Charging Scenario

EV Charging Scenario Transient Occurrence (Magnitude) Duration		
Slow AC Charging (Level 1)	+/- 5% of Nominal Voltage	<1 ms
Moderate AC Charging (Level 2)	+/- 8% of Nominal Voltage	<2 ms
Fast DC Charging (Level 3)	+/- 10% of Nominal Voltage	<3 ms
Simultaneous Multiple EV Charging	+/- 12% of Nominal Voltage	<5 ms
EV Charging with Surge Protection	+/- 4% of Nominal Voltage	<1 ms
EV Charging with Transient Filters	+/- 6% of Nominal Voltage	<2 ms

4. EXISTING POWER QUALITY IMPROVEMENT TECHNIQUES:

Power quality enhancement techniques for microgrid-connected electric vehicle (EV) charging stations encompass a range of strategies aimed at mitigating power fluctuations, harmonic distortions, and ensuring stable, high-quality power delivery.

1. Advanced Control Algorithms: Implementation of sophisticated control algorithms like Model Predictive Control (MPC), Fuzzy Logic Control, or Adaptive Control enables precise

management of power flow within microgrids. These algorithms optimize energy distribution, voltage regulation, and frequency control, contributing to enhanced power quality. MPC algorithms predict system behaviour and make control decisions by solving optimization problems over a finite future horizon. In microgrid-connected EV charging stations, MPC can optimize power flow, manage energy distribution, and maintain desired voltage and frequency levels while considering dynamic changes in demand and supply [20]. Fuzzy Logic Control (FLC) employs linguistic variables and rule-based reasoning to regulate power quality parameters. Fuzzy logic controllers, adaptable to varying conditions, aid in maintaining stable voltage and frequency levels by adjusting control actions based on input data from sensors and grid conditions. Adaptive Control algorithms continuously adjust control parameters based on real-time system feedback. Adaptive control techniques enhance power quality by adapting to changing conditions, load variations, and system disturbances in microgrid-connected EV charging stations [21]. PID controllers adjust the control effort based on proportional, integral, and derivative terms. PID control can be applied to regulate voltage, current, or frequency in microgrids to ensure optimal power quality. Droop Control which is Commonly used in microgrids, adjusts the output of distributed energy resources (DERs) based on frequency deviation [27]. This method aids in maintaining grid stability and balanced power flow within microgrid-connected EV charging stations. Hierarchical Control strategies involve multi-level control hierarchies where different controllers manage various aspects of the system. They optimize power flow, voltage regulation, and frequency control by coordinating the actions of different components within the microgrid. Each algorithm has its strengths and applications. Implementing a combination of these algorithms tailored to specific power quality requirements is crucial in ensuring stable and reliable power supply to microgrid-connected EV charging stations. Their effectiveness lies in their adaptability to varying grid conditions, load changes, and real-time operational needs. These algorithms primarily focus on managing power flow, regulating voltage, and ensuring grid stability.

Table 8. Advanced Control Strategies

Controller	Advantage	Limitation	References
MPC	Delivers robust performance for nonlinear systems. Ability to operate at low switching frequency shows enhanced response to unreliability. Capability to control current with less harmonics.	Not adaptable to variation in system parameters. Inefficient load sharing. Mathematical calculations are difficult to compute.	[20]
Adaptive control	Simple implementation. Transient response is faster.	Adaption process is slow.	[21]
SMC	Robust performance during transient conditions and fluctuations. Minimum harmonics.	Complexity in design. Prone to chattering issues due to switching frequency.	[22]

KF	Accurate under frequency variations.	Difficulty in co-variance selection.	[23]
H infinity control	Minimum harmonics and enhanced performance. Robust control action and Tracking error is minimum. It can be implemented for both linear and unbalanced non-linear systems.	System response and dynamics are slower. It needs the aid of complicated systems and mathematical equations for understanding.	[24]
BSC	This control is used for stochastic non-linear systems.	With the increase of system order this control is more complex.	[25]
IC	High computational speed. High convergence rate.	Neural network complexity is proportional with harmonic component.	[26]

2. Energy Storage Systems (ESS): Energy storage system utilization is a key component of microgrids in conjunction with RESs. To support microgrids, individual loads put in microgrids or the utility grid, energy storage systems (ESS) are typically used to store excess electricity supplied by renewable energy sources (RESs) [28]. Energy storage devices are only sometimes implemented in the microgrids of review papers concerning supplementary power sources. Integrating ESS such as batteries, supercapacitors, or flywheels helps in buffering power fluctuations and providing ancillary services. ESS can balance loads, offer peak shaving, and aid in voltage stability, improving power quality in microgrids connected to EV charging stations [28]. ESS are categorized according to how energy is used in a certain way. Energy storage systems (ESS) fall into the following categories: mechanical, electrochemical, chemical, electrical, thermal, and hybrid. Additionally, these systems can be further categorized based on the materials and formation method [29].

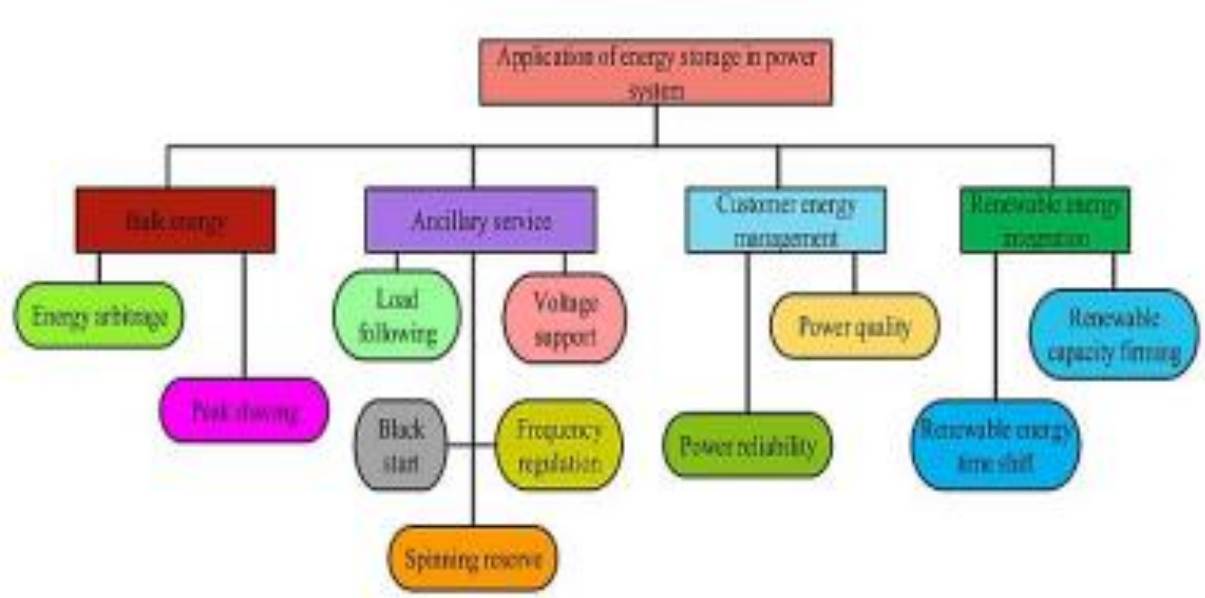

Fig. 9. Application Overview of Energy Storage System

Fig. 8. Distribution of different energy storage systems

3. Active and Passive Filters: Employing active filters (like active power filters or active harmonic filters) and passive filters (such as LC filters) assists in eliminating harmonic distortions and mitigating voltage fluctuations. These filters ensure a cleaner power supply to the charging stations and the grid, enhancing overall power quality. Passive filters are composed of passive components like resistors, capacitors, and inductors [30]. They are designed to mitigate specific harmonic frequencies and can be categorized as:

1. **Low Pass Filters:** These filters allow frequencies below a certain cutoff frequency to pass through while attenuating frequencies above that threshold. They are commonly used to filter out high-frequency harmonics in power systems.
2. **High Pass Filters:** Opposite to low pass filters, high pass filters allow higher frequencies to pass while attenuating lower frequencies. They can be used in certain applications to target specific harmonic distortions.
3. **Band Pass Filters:** These filters permit a specific band of frequencies to pass while blocking others. They are utilized to target and mitigate a narrow range of harmonic frequencies.

Passive filters are relatively simple in design, cost-effective, and suitable for addressing certain specific harmonic issues within a limited frequency range. However, their effectiveness might

vary based on load variations and system changes.

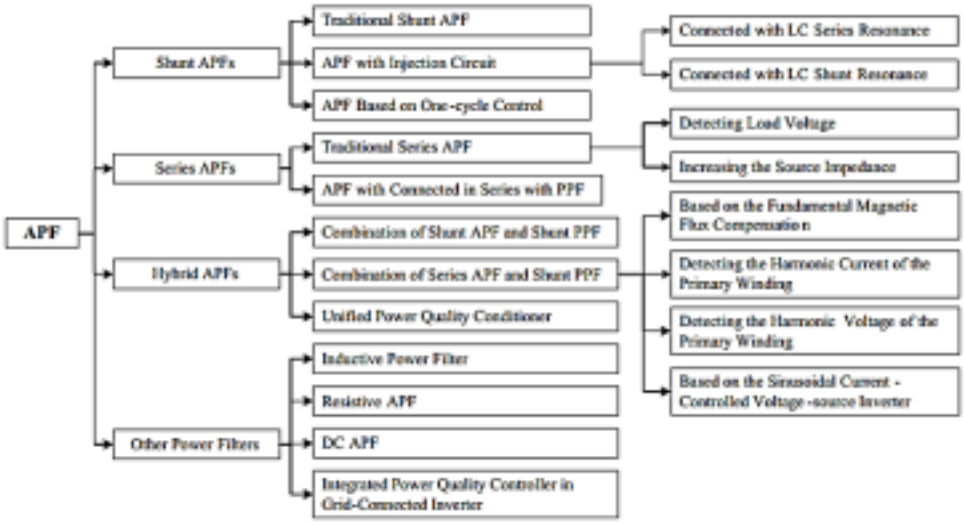

Fig. 10. Classification of Active Power Filter [37]

Active filters use power electronic devices and control systems to actively detect and compensate for harmonic distortions and other power quality issues. They offer more flexibility and adaptability compared to passive filters and can address a broader range of problems [50]. Voltage Source Converters (VSCs) filters are capable of injecting harmonic currents of opposite phase to cancel out undesired harmonics, effectively compensating for harmonic distortions. VSC-based active filters can be dynamically controlled to handle changing load conditions. Current Source Converters (CSCs) filters work by controlling the current injected into the system to counteract harmonic currents or other disturbances. They are often used to provide reactive power compensation and harmonics mitigation. Active filters offer higher efficiency, faster response times, and adaptability to varying load conditions. They are well-suited for complex power systems with non-linear loads and dynamic operating conditions. However, they are typically more expensive and require more sophisticated control mechanisms compared to passive filters. Both active and passive filters play essential roles in power quality improvement [31]. The choice between them depends on factors such as the nature of the power quality issue, system requirements, cost considerations, and the desired level of flexibility and control. Often, a combination of both types may be employed to achieve comprehensive power quality enhancement in a given power system.

Table 9. Types and Control Attributes of DFACTS Devices [31]

DFACTS Controller	Control Attributes	Type of Connection
DSSC (Distributed Static Series Compensator	Effective impedance of the transmission lines, Reactive power flow and voltage injection.	Series

DVR (Dynamic Voltage Restorer)	Voltage sag, Voltage swell, Harmonics, Notch, and Distortion by Non-linear load Currents.	Series
DSVC (Distributed Static VAR Compensator)	Voltage Stability and control, muffling of oscillations and Compensation of VAR's.	Shunt
DSTATCOM (Distributed Static Compensator)	Transitory and dynamic stability, Fault current, Active and reactive power flow and muffling of oscillation.	Shunt
UPQC (Unified power quality conditioner)	Voltage sag, swell, harmonics, reactive power flow and voltage flickers.	Shunt-Series
DTCSC (Distributed Thyristor Controlled Series Compensations)	Current control, transitory and dynamic voltage, fault current and muffling of oscillations.	Shunt-Series
IPFC (Interline Power Flow Controller)	Active and Reactive power Supply, Voltage imbalance and fault current.	Series-Series

IV. Bidirectional Power Flow Management and V2G: Both active and passive administration are considered when operating a V2G network, whether centralized or decentralized. To manage bi-directional power flow between UG and EV, an aggregator operator (AO) is responsible for gathering data from the linked EVs across the network and sending out the necessary control signals. The AO schedules every linked EV based on load demand and generation, and energy loading and unloading are optimized according to the vehicles' battery capacity and charging/discharging schedule [32]. To address challenges related to bidirectional power flow in EV charging stations, Vehicle-to-Grid (V2G) technology allows EVs to not only draw power but also feed excess energy back to the grid. This bidirectional capability requires sophisticated control mechanisms to manage power flow effectively without compromising grid stability. Bidirectional power flow management allows for power to be sent back to the grid from distributed energy resources (DERs) or energy storage systems when there's excess generation [33]. This helps in stabilizing the grid by balancing supply and demand, especially during peak load times. With the increasing adoption of renewable energy sources like solar and wind, bidirectional power flow management facilitates the smooth integration of these intermittent resources into the grid. It allows excess renewable energy to be stored or redirected back to the grid when needed, reducing issues related to variability and intermittency [34]. By enabling power to flow bidirectional, the system can manage and balance loads more effectively. This includes shifting energy consumption to off-peak times, reducing strain during high-demand periods, and optimizing the utilization of available resources [35].

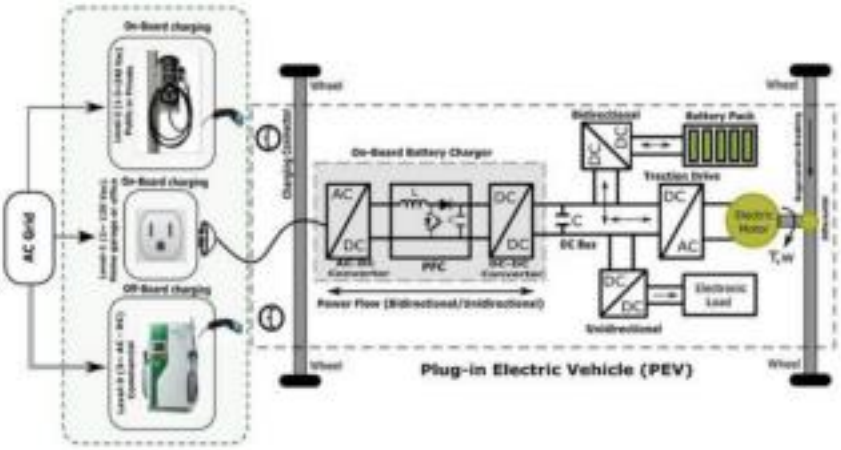

Fig. 11. Unidirectional and bi-directional power flow architecture in V2G technology

V2G technology enables electric vehicles (EVs) to not only draw power from the grid but also to supply energy back to the grid when connected. This technology offers several advantages for power quality improvement:

1. **Load Management:** EVs can serve as mobile energy storage units. During times of peak demand or grid instability, V2G-enabled vehicles can discharge stored energy to support the grid, acting as a distributed energy resource. This helps in load management and grid stability.
2. **Demand Response:** V2G systems can participate in demand response programs by adjusting charging or discharging based on signals from the grid operator. This allows for dynamic management of energy use and grid support during critical periods.
3. **Frequency Regulation:** EVs, when aggregated, can provide frequency regulation services by injecting or absorbing power based on grid frequency fluctuations. This helps in maintaining grid stability and improving power quality.

The synergy of these techniques plays a pivotal role in ensuring a reliable and high-quality power supply to EV charging stations within microgrids. Their integration and optimization contribute significantly to grid stability, reduced power fluctuations, and efficient utilization of renewable energy sources, fostering a sustainable and resilient power infrastructure for future transportation needs.

V. FACTS DEVICES IN POWER QUALITY IMPROVEMENT OF GRID INTEGRATED SYSTEMS

In this section, the authors Lee et al. [37][38] deliberated about voltage quality enrichment using FACTS devices. FACTS (Flexible AC Transmission Systems) devices play a significant role in enhancing power quality in microgrid-connected electric vehicle (EV) charging stations. These devices offer control capabilities to improve grid stability, regulate voltage, and manage power flow. Some prominent FACTS devices used for power quality enhancement include:

SVCs are used to regulate voltage levels by dynamically controlling reactive power flow. In microgrid with EV charging stations, SVCs help stabilize voltage fluctuations caused by varying loads, thereby enhancing power quality [37]. STATCOMs provide reactive power compensation and voltage control. They are utilized to support grid voltage stability and mitigate voltage fluctuations, especially in scenarios where EV charging stations cause intermittent load variations. UPFC is a versatile FACTS device capable of controlling both active and reactive power flow

[37]. It optimizes power flow, enhances voltage stability, and mitigates grid disturbances in microgrid-connected EV charging stations. Similar to STATCOM, a static compensator injects or absorbs reactive power to regulate voltage and improve power factor, ensuring stable voltage levels in microgrids affected by EV charging station dynamics [38]. Devices like Thyristor-Controlled Series Capacitors (TCSC) or Thyristor-Controlled Series Reactors (TCSR) are used to control the impedance of transmission lines. They aid in managing power flow and voltage stability, especially in scenarios where EV charging stations cause line impedance variations [38].

The DVR can reduce potential disruptions in voltage. Utilizing an injection transformer to inject the necessary voltage in series with the mains voltage, DVR is typically located between the load and the source in the distribution system to offer quick voltage assistance [45]. A fuzzy logic control and phase compensation DVR is created and tested in various failure scenarios, including voltage sags and short circuits. As is commonly known, sufficient quick active power recovery is necessary for frequency stability in the overall grid. In contrast, large reactive power absorption may negatively affect voltage recovery or cause a local voltage collapse. Active power recovery and the absence of excessive reactive power absorption are essential for system security. This contribution aims to show that these features can be provided for hybrid PV-wind generators tied to a grid system by the DVR using the suggested control strategy [45].

These FACTS devices offer dynamic control and rapid response capabilities, allowing for real-time adjustments to maintain power quality in microgrid-connected EV charging stations. By enhancing voltage regulation, reactive power compensation, and power flow control, FACTS devices contribute significantly to ensuring grid stability and reliable electricity supply to EVs while optimizing the overall performance of the microgrid system.

VI.OPTIMIZATION TECHNIQUES FOR POWER QUALITY ENHANCEMENT

These techniques aim to improve grid stability, manage power flow, and ensure reliable and high quality power delivery. Optimization techniques are employed for power quality enhancement in microgrid connected electric vehicle (EV) charging stations. Utilization of mathematical optimization models, such as Linear Programming (LP), Nonlinear Programming (NLP), Mixed-Integer Linear Programming (MILP), or Quadratic Programming (QP), to optimize power flow, energy distribution, and resource allocation within the microgrid [42]. These models ensure efficient utilization of resources while meeting power quality constraints. PSO is a heuristic optimization technique inspired by the social behaviour of birds or particles. It's used to optimize various aspects of microgrid operations, such as determining optimal charging schedules for EVs, minimizing power losses, or optimizing the placement and sizing of energy storage systems for power quality improvement [40]. GA mimics the process of natural selection and evolution to find optimal solutions to complex problems. In microgrid-connected EV charging stations, GA can be applied to optimize control strategies, determine optimal charging/discharging profiles of batteries in energy storage systems, or optimize resource utilization for enhanced power quality [42]. Employing machine learning algorithms such as neural networks, support vector machines, or reinforcement learning for predictive maintenance, fault detection, and real-time decision-making in microgrids. These techniques assist in identifying and mitigating power quality issues proactively. Techniques like Ant Colony Optimization (ACO), Simulated Annealing (SA), or Tabu Search (TS) are utilized to optimize various parameters within microgrid-connected EV

charging stations [43]. They assist in finding near-optimal solutions for load balancing, grid stability, and power quality enhancement. Considering multiple conflicting objectives simultaneously, Multi-Objective Optimization (MOO) methods help in balancing trade-offs between different goals, such as minimizing losses, maximizing renewable energy integration, and ensuring power quality in microgrids [44].

The utilization of these optimization techniques allows for the development of efficient and adaptive control strategies, optimal resource allocation, and effective management of the complex interactions within microgrid-connected EV charging stations. These methods contribute to the enhancement of power quality while ensuring reliable and sustainable operation of the integrated systems.

VII. SMART CHARGING AND ADVANCED CONTROL STRATEGIES

Intelligent systems are increasingly utilized to enhance power quality in microgrid-connected electric vehicle (EV) charging stations. These systems leverage advanced technologies and algorithms to optimize grid operations, manage energy flow, and ensure reliable power supply. Some intelligent systems used for power quality enhancement in such settings include:

Predictive Maintenance Systems system use predictive analytics, machine learning, and IoT sensors to anticipate equipment failures or degradation. By predicting potential faults in advance, maintenance can be scheduled proactively, minimizing downtime and enhancing system reliability in microgrid-connected EV charging stations.

Artificial Intelligence (AI) for Fault Detection systems, including neural networks or machine learning algorithms, are employed for real-time fault detection and identification within microgrid systems. They rapidly detect anomalies or disturbances, enabling quick corrective actions to maintain power quality [51].

Smart Grid Management Systems integrate IoT devices, sensors, and data analytics to monitor and manage grid operations. They enable real-time monitoring of power quality parameters, facilitate automated control actions, and optimize grid performance, ensuring stable and high-quality power delivery to EV charging stations [51].

Energy Management Systems (EMS) utilizes optimization algorithms and predictive analytics to manage energy flow, storage, and distribution within microgrids. These systems optimize charging schedules for EVs, control energy storage systems, and balance supply-demand dynamics to enhance power quality and grid stability [43].

Distributed Control Systems (DCS) integrates intelligent control algorithms and distributed computing for coordinated control of multiple grid components. They enable precise control and coordination of various elements within microgrid-connected EV charging stations to ensure efficient and reliable power supply [51].

Cyber-Physical Systems (CPS) integrate physical components with computational and communication systems. These systems facilitate real-time monitoring, control, and coordination of grid components, ensuring optimal performance and power quality in microgrid environments [52].

VIII. FUTURE DIRECTIONS AND RESEARCH GAP

The research gap in "Power Quality Enhancement in Microgrid for Grid-Connected Electric Vehicle (EV) Charging Infrastructure" refers to areas within this domain that require further investigation or exploration due to limited existing research or unresolved issues.

1. Impact of EV Charging on Power Quality: Investigating the specific effects of EV charging on power quality within microgrids. Analysing the harmonics, voltage fluctuations, and power factor issues arising from EV charging activities and their impact on the overall power quality of the microgrid.
2. Optimal Integration of EV Charging Stations: Researching optimal strategies for integrating EV charging infrastructure within microgrids while maintaining or enhancing power quality. This includes studying placement, sizing, and control of charging stations to minimize adverse effects on the grid.
3. Control Strategies for Grid-Connected Charging Systems: Developing advanced control strategies for grid-connected EV charging systems within microgrids. This involves exploring smart charging techniques, load scheduling, and demand response mechanisms to mitigate power quality disturbances caused by charging EVs.
4. Power Electronics and Filtering Solutions: Investigating innovative power electronics and filtering solutions specifically tailored for EV charging infrastructure in microgrids. Developing improved converters, active filters, or other devices to address harmonic distortions and reactive power issues caused by EV charging.
5. Cyber-Physical Security Concerns: Exploring cybersecurity aspects related to EV charging infrastructure within microgrids. Assessing vulnerabilities, implementing secure communication protocols, and investigating potential cyber-attacks that might affect power quality and grid stability.
6. Grid-Interactive EVs for Power Quality Support: Researching the potential role of grid-interactive EVs as resources for power quality support within microgrids. Studying V2G (Vehicle-to-Grid) capabilities and their impact on enhancing power quality during charging and discharging cycles.
7. Integration of Renewable Energy and EV Charging: Investigating the synergies between renewable energy sources, EV charging, and power quality improvement strategies in microgrids. Analysing how the integration of renewables alongside EV charging impacts power quality and exploring optimized configurations.
8. Economic and Regulatory Considerations: Assessing the economic implications and regulatory frameworks associated with implementing power quality enhancement strategies for EV charging infrastructure within microgrids. Evaluating cost-benefit analyses, incentive mechanisms, and policy frameworks to encourage power quality improvements.

Addressing these research gaps would contribute to a more comprehensive understanding of the challenges and opportunities in enhancing power quality within microgrids that incorporate EV charging infrastructure, fostering the development of more efficient, reliable, and sustainable energy systems.

IX. CONCLUSION

The review has provided an in-depth analysis of the critical aspects surrounding power quality enhancement in microgrids concerning grid-connected electric vehicle (EV) charging infrastructure. The findings underscore the importance of addressing power quality issues arising from the integration of EV charging systems into microgrids, given their potential impacts on system stability, reliability, and efficiency. The gaps identified in existing research signal several

potential avenues for future investigation. Focused studies on optimal control strategies, advanced power electronics, cybersecurity frameworks, and the role of grid-interactive EVs can significantly contribute to resolving these challenges.

Thus, improving power quality in microgrids accommodating EV charging infrastructure is a multifaceted endeavour. Addressing these challenges not only ensures grid stability but also supports the seamless integration of clean energy technologies, fostering sustainable and reliable energy systems for the future. This conclusion succinctly summarizes the key findings of the review, emphasizes the significance of the research, and suggests areas for future exploration in the domain of power quality enhancement within microgrids for grid-connected EV charging infrastructure.

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ML-Based Object Recognition and Object Picking Robot using ROS

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Abstract: Machine Learning (ML) based object recognition refers to the use of machine learning techniques to identify and classify objects in images or videos. It plays a crucial role in computer vision, enabling machines to "see" and interpret visual data like humans. The integration of ML and robotics enables robots to perceive, learn, and adapt to their environments dynamically. This synergy enhances robotic capabilities, allowing them to handle complex tasks, make decisions, and interact with humans more effectively. By leveraging ML techniques, particularly Convolutional Neural Networks (CNNs), the system will be trained using YOLO architecture to recognize a diverse range of objects, encompassing various shapes, sizes, and textures. The dataset is meticulously curated and pre-processed to ensure the model receives high-quality input data. The integration with ROS will provide a modular framework, allowing for easy integration of sensors, actuators, and custom control algorithms. This study addresses critical challenges in robotics, such as adaptability in unstructured environments and real-time decision-making. The successful implementation of ML-based object recognition and picking capabilities will not only advance the field of robotics but also have far-reaching implications across Industries, from automated warehousing and manufacturing to assistive healthcare applications. This work marks a significant step towards creating intelligent, adaptable robots capable of complex interactions with their surroundings.

Keywords*: Machine Learning, Object Detection, Robots, Convolution Neural Network(CNN) Data Set and Training*

I. INTRODUCTION

In today's rapidly evolving technological landscape, the integration of Machine Learning (ML) with robotics has paved the way for advanced automation solutions. The integration of Machine Learning and robotics has revolutionized automation, enabling robots to adapt and interact with their environments in increasingly sophisticated ways. The focus is on the development of a cutting-edge robotic system that combines ML-based object recognition with the Robot Operating System (ROS) for seamless control and coordination. The primary goal is to create a versatile platform capable of autonomously identifying objects and efficiently picking them up, demonstrating the potential for advanced automation in various industries.

By leveraging ML techniques, particularly Convolutional Neural Networks (CNNs), the system will be trained using YOLO architecture to recognize a diverse range of objects, encompassing various shapes, sizes, and textures. The dataset is meticulously curated and pre-processed to ensure the model receives high-quality input data. The integration with ROS will provide a modular framework, allowing for easy integration of sensors, actuators, and custom control algorithms.

This study focuses on the development of a robotic system capable of autonomously recognizing objects using ML techniques and efficiently picking them up. The Robot Operating System (ROS) will serve as the foundation for creating a modular and flexible control framework. The successful implementation of ML-based object recognition and picking capabilities will not only advance the field of robotics but also have far-reaching implications across industries, from automated warehousing and manufacturing to assistive healthcare applications [15].

II. REVIEW OF LITERATURE

Ruohuai Sun (2023) introduced a parallel YOLO– deep learning network for collaborative robot target recognition and grasping to enhance the efficiency and precision of visual classification and grasping for collaborative robots [14]. The real-time recognition and grasping network can identify a diverse spectrum of unidentified objects and determine the target type and appropriate capture box using YOLO- deep vision network. The YOLOv3 network uses pre-trained COCO dataset, identifies the object category and position, while the GG-CNN network, trained using the Cornell Grasping dataset, predicts the grasping pose.

Natanael Magno Gomes (2022) uses Reinforcement Learning (RL) to train an Artificial Intelligence (AI) agent to control a Cobot to perform a given pick and-place task, estimating the grasping position without previous knowledge Deep RL applied to a Robotic Pick-and-Place Application [4]. To enable the agent to execute the task, an RGBD camera is used to generate the inputs for the system. An adaptive learning system was implemented to adapt to new situations such as new configurations of robot manipulators and unexpected changes in the environment

Moritz Abdank (2021) proposed a simple colour-based object detection for different robotic tasks, including a linear calibration method, with focus on a specific pick and place use case[1]. A standard RGB-Webcam stream was used to detect a certain colour and obtain information which then was filtered and evaluated based on the predefined conditions of the system. ROS enables the processing of the calibrated camera stream and the interface to the pick and place robot arm.

Humans have a surprising ability for pattern recognition and object identification, in order to mimic this ability different algorithms have been proposed based on deep learning. There are a lot of algorithms for computational vision based on convolutional neural networks, one of the most advanced techniques proposed to classify objects in real time is the You Only Look Once (YOLO) algorithm. This study uses Raspberry pi 4with servo motor control shield as the controller

III.METHODOLOGY

The methodology of this work focuses on developing an object detection system that integrates Raspberry Pi 4, machine learning and neural networks, specifically convolutional neural networks (CNNs), to achieve high accuracy and efficiency [2] [13]. The process begins with data collection and pre-processing, followed by ML Model Selection and Training, ROS Setup and Configuration and concludes with Feedback and Monitoring.

Processor and motor control shields

The Raspberry Pi 4 has a Broadcom BCM2711 processor. This is a 64-bit ARM Cortex-A72 (ARMv8-A) quad-core processor, which allows for parallel processing and improved multi-tasking at 1.5 GHz, providing better performance compared to previous models like the Raspberry Pi 3.The Raspberry Pi 4 uses the VideoCore VI GPU, a powerful graphics processor capable of supporting 4K video output.It can drive two 4K HDMI displays at 60Hz (with dual micro-HDMI

ports). It offers various RAM con**fig**urations, including 2 GB, 4 GB, and 8 GB of LPDDR4-3200 SDRAM. The increased RAM options make it more capable of running memory-intensive applications.

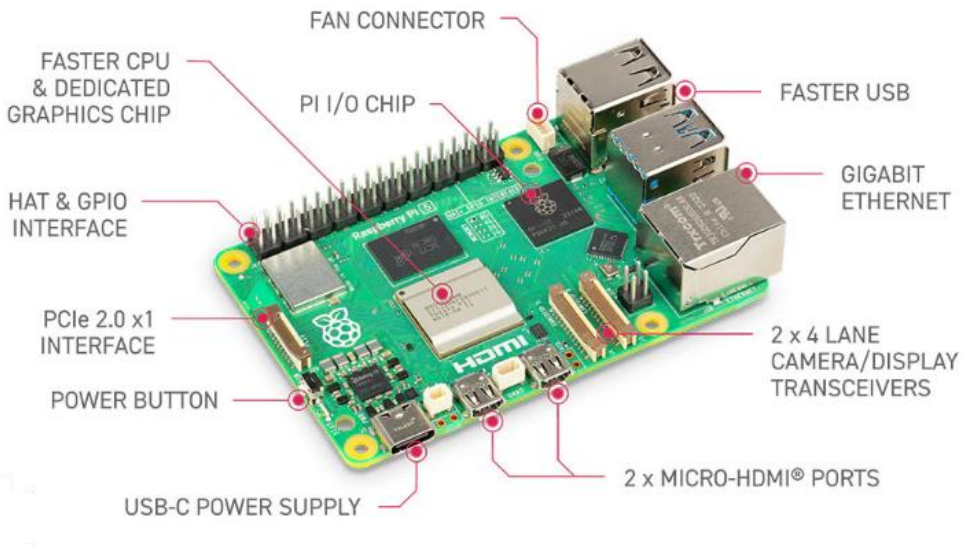

Fig. 1. Shows Raspberry pi 4 with features

I/O and Connectivity: USB Ports: 2 x USB 3.0 ports, 2 x USB 2.0 ports, Ethernet: Gigabit Ethernet for faster networking, Wi-Fi: 802.11ac Wi-Fi for wireless connectivity, Bluetooth: Bluetooth 5.0 for connecting to Bluetooth devices, Storage: MicroSD slot for storage, with support for faster SD cards for quicker boot and data access.

The Servo & Motor Control Shields are designed to simplify the process of controlling motors and servos in robotics and automation projects. These shields come with integrated motor driver circuits (e.g., L298N or similar), allowing the control of forward, reverse, and speed of DC motors. PWM (Pulse Width Modulation): Speed control of DC motors is typically achieved through PWM signals. The shield can generate PWM signals to adjust the speed of the motor by controlling the voltage. Motor Voltage: Typically supports motors running on 5V to 12V or higher.

Data Collection and Pre-processing

A diverse dataset of objects of interest is be collected, encompassing a range of shapes, sizes, and textures. Also, data augmentation is used to further diversify the dataset by applying simple image manipulation such as cropping, blurring and other techniques on the existing images to increase the images in the dataset. Data pre-processing steps be undertaken, including resizing, normalization, and augmentation. This ensures the ML model receives consistent and high-quality input.

ML Model Selection and Training

A Convolutional Neural Network (CNN) based YOLO V5 architecture is be employed for object recognition, owing to its effectiveness in image-related tasks. The chosen CNN model is trained on the pre-processed dataset using a suitable ML framework called PyTorch. This phase involves the iterative process of forward and backward passes to optimize the model's parameters [6] [10].

ROS Setup and Configuration

The ROS environment is configured to support the specific hardware components of the robotic system, including 2D camera, actuators such as servo motors for the manipulator arm and other human machine interfaces. Custom ROS nodes is developed to facilitate seamless communication between the ML model and the robot's control software [3][7].

Object Recognition Module
The trained ML model is deployed on the robot's onboard computer, enabling it to process images captured by the robot's cameras in real time. The ML-based recognition module annotates the video feed with labels indicating recognized objects[5][11].

Object Localization
Using the ML model's predictions, the system determines the spatial coordinates of the recognized objects relative to the robot's coordinate system [12].

Motion Planning
The robot's control system generates a suitable trajectory for the end-effector to approach and pick up the identified object. This involves calculating joint positions and velocities. This can be implemented using ROS package called move it, the inverse kinematics solver used for this manipulator is Kinematics and Dynamics Library (KDL) which is a powerful library for solving both kinematic and dynamic problems in robotic systems, with a focus on the efficient computation of forward and inverse kinematics, as well as dynamics modelling[8][9].

Object Manipulation
Control algorithms is implemented to ensure the robot's end-effector grasps and holds the object securely.

Feedback and Monitoring
Visual and servo feedback mechanisms is implemented to provide real-time information regarding the success or failure of object recognition and picking tasks.

IV. PROPOSED SYSTEM

The proposed system includes robotic system capable of autonomously recognizing objects using ML techniques and efficiently picking them up. The Robot Operating System (ROS) serve as the basis for creating a modular and flexible control framework. The successful operation of ML-based object recognition and picking is implemented using Raspberry pi 4.

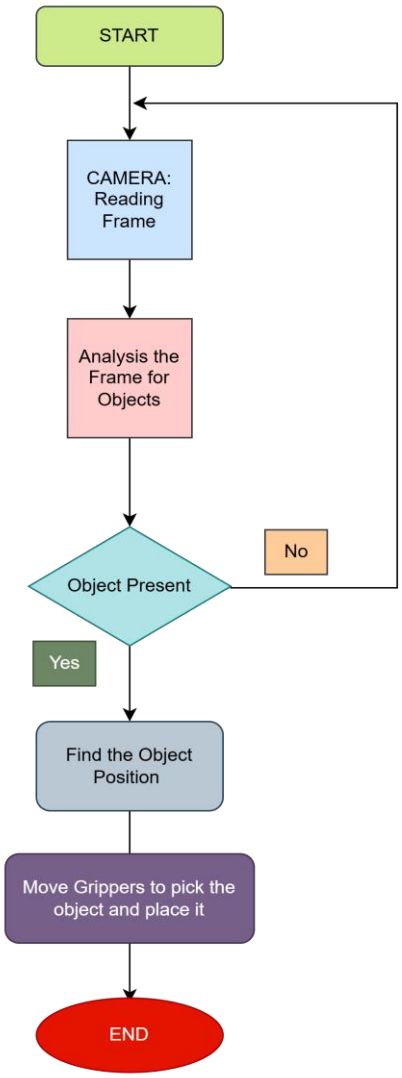

Fig. 2. Flow chart of the Proposed System

Figure 2 shows the flow chart of the proposed object detection system using machine learning technique. The camera captures the image of size as 300 x 300 pixels. Based on the captured image, the boundary box is estimated to pick up the object. After capturing the image, the image is analysed for the presence of the object. If the object is present, the position of the detected object is optimized. Unless the capture process will be repeated.

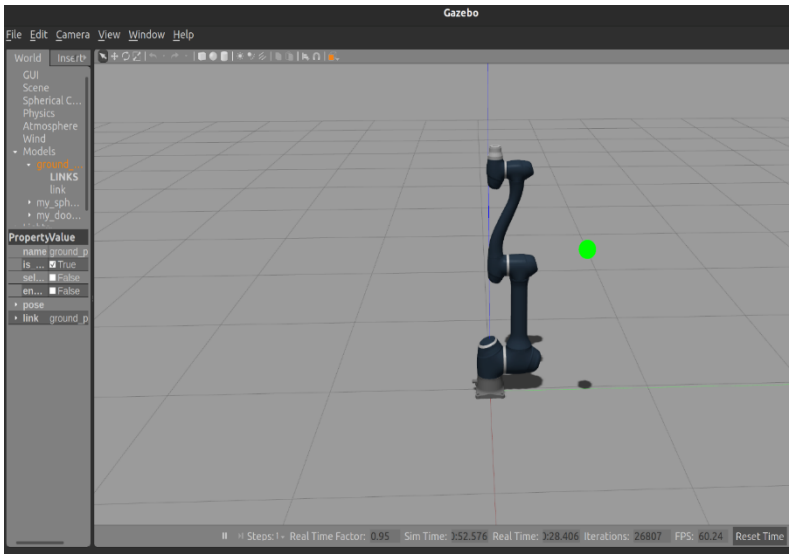

Fig. 3 shows the view of robot simulation using gazebo 3D robot simulation software

Fig. 4 shows the Hardware implementation of Robot manipulator arm with Raspberry Pi 4 and camera

V. PERFORMANCE MATRICES

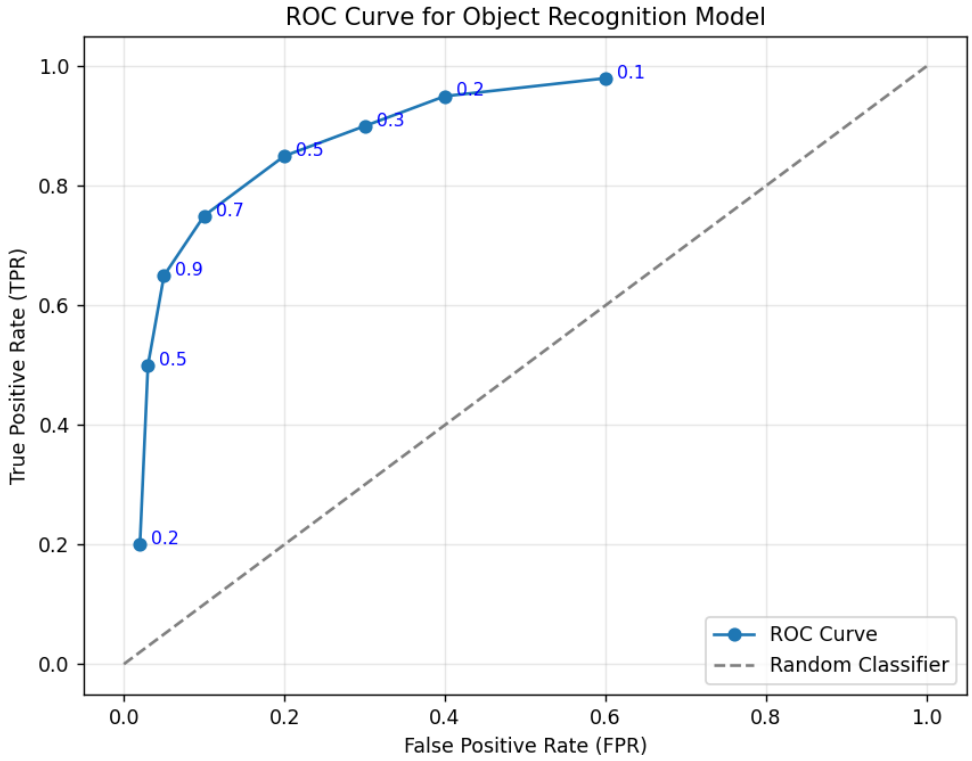

Fig. 5. ROC Curve of proposed object detection model

This ROC curve illustrates the performance of an object detection model. The curve demonstrates the trade-off between the True Positive Rate (TPR) and False Positive Rate (FPR) across different decision thresholds. The model performs significantly better than a random classifier (represented by the diagonal dashed line), as its ROC curve is consistently above this baseline. A high TPR with a relatively low FPR at most thresholds indicates that the model is effective at correctly detecting objects while minimizing false alarms. The curve's shape, particularly the steep ascent near the lower FPR values, highlights the model's strong ability to differentiate between true positives and negatives, affirming its reliability in object detection tasks. The ROC curve is preferred for performance evaluation in tasks like object detection because it provides a comprehensive view of a model's discriminative ability, especially when classifying between true positives and false positives. Unlike metrics such as accuracy, which can be misleading for imbalanced datasets, or precision and recall, which depend on fixed thresholds, the ROC curve evaluates performance across all thresholds. This makes it ideal for highlighting trade-offs between detecting true objects (high TPR) and minimizing false alarms (low FPR).

VI. OUTPUT OF THE PROPOSED SYSTEM

The system provides the following outputs:

- A real-time video feed with annotated object recognition results.
- ROS messages indicating recognized objects and their respective positions.
- Control commands for the robot's manipulator arm to execute picking tasks.

- Status updates indicating the success or failure of object recognition and picking operations.

VII. Conclusion

This study demonstrates the successful integration of ML-based object recognition with a robotic system using ROS, showcasing the potential for sophisticated automation in real-world applications. The ROC curve used for performance evaluation, proves that this model is best fit for object detection using machine learning , especially when classifying between true positives and false positives The developed system lays the foundation for more advanced robotic solutions in industries such as logistics, manufacturing, and healthcare. Future work may involve refining the ML model's accuracy, optimizing motion planning algorithms, and expanding the object dataset for enhanced versatility and adaptability.

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Mathematics Teachers Perceptions in Action research: Functionality in Flipped Classroom Approach

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Abstract: The flipped classroom approach represents a blended learning model that emphasizes the cultivation of 21st-century skills. This study was initiated to explore mathematics teachers' perceptions regarding the functionality of the flipped classroom within the Sri Lankan context. Additionally, it aims to identify the challenges faced by mathematics teachers in implementing the flipped classroom methodology, with the goal of enhancing their instructional experiences. The functionality of the flipped classroom is analyzed through four key dimensions: Flexible Environment, Learning Culture, Intentional Content, and Professional Educator. A mixed-methods research design was employed in this study, utilizing a Likert scale questionnaire distributed to a randomly selected sample of 244 mathematics teachers from schools within the Galle education division of Sri Lanka. Additionally, face-to-face interviews were conducted with 10 randomly selected mathematics teachers from the same sample to facilitate data triangulation. The quantitative data were analyzed using SPSS software (Version 25). The study results reveal that mathematics teachers are highly aware of the importance of using the flipped classroom approach. They express a perception that students in the Sri Lankan context lack access to flexible environments for learning mathematics. However, it emerged that these mathematics teachers maintain positive perceptions regarding the effectiveness of integrating learning culture and professional educator dimensions within the flipped classroom model. Nonetheless, 69.0% of mathematics teachers expressed the belief that the flipped classroom model imposes a significant workload on educators. Additionally, several factors were identified as obstacles to implementing this approach effectively in Sri Lanka, including insufficient technological resources at both schools and homes, inadequate internet connectivity in rural areas, and students' continued reliance on teachers for learning mathematics.

Key words: Dimensions of Flipped Classroom, Mathematics teacher Perceptions

I. INTRODUCTION

A recent transformation in educational practices has emerged due to the introduction of a new instructional approach triggered by technological advancements. Among these, the flipped classroom approach stands out as a blended learning strategy that leverages technology to enrich classroom experiences. As technology continues to evolve, educators are convinced that the flipped classroom approach is steering students' learning towards gaining 21st-century skills. According to the Bergmann and Sams (2012), the flipped classroom approach is facilitating self-directed learning experiences through technology outside the classroom, while allowing for further discussions with the teacher during class time. Mustafa and Argün (2017) emphasized its goal of promoting autonomous learning skills necessary for the 21st century. This approach comprises two main components: engaging interactive learning activities during lessons and individual study utilizing computers and technology outside of class. It is characterized as a model where students

access online videos, lecture notes, images, and other resources uploaded by the teacher prior to class. Subsequently, classroom time is dedicated to meaningful practice and discussions (Hughes, 2016; Fauth, 2015). In this setting, the teacher's role shifts to that of a supporter in the construction of knowledge, as well as a facilitator and collaborator in student learning. Consequently, the flipped classroom is recognized as a student-centered learning method aligned with constructivist theory, transforming teachers' roles into transactional facilitators.

According to the Flipped Learning Network (FLN), the subject-object relationships within the four pillars of the flipped learning approach are represented by various tools, which are illustrated in Figure 1 in the context of this study.

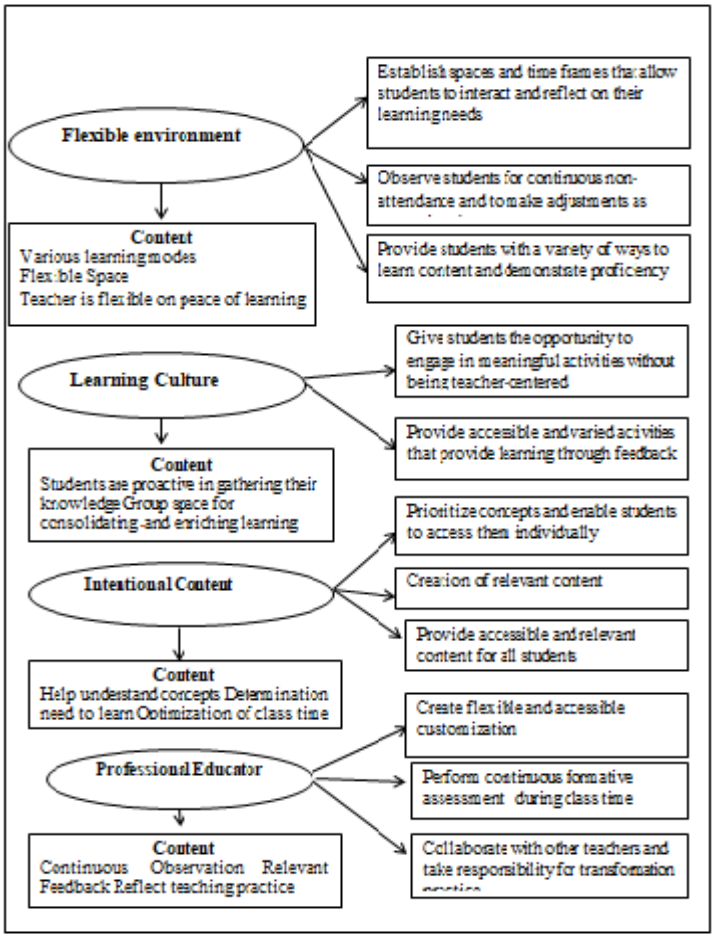

Fig.1: Relationship of four pillars of flipped learning approach

The Flipped Learning Network (2014) outlined four fundamental pillars that facilitate "flip" learning, illustrating the concept of the inverted learning approach. Seasoned educators in the field have recognized the essential characteristics of these pillars as: Flexible Environment, Learning Culture, Intentional Content and the Professional Educator. Many researchers have emphatically recommended for the implementation of the flipped classroom approach in mathematics education, particularly in light of the rapid technological advancements in educational practices within a constructivist learning environment (Overmyer, 2014; Ramakrishnan and Johnsi, 2016; Domingo and Martín, 2020). They revealed that it provides positive results in understanding the concepts of

mathematics at expected levels. Some educators have recommended the inclusion of flipped classroom approach as a teaching method in the mathematics curriculum of teacher training programs (Umam and Mulyono, 2019).

The literature indicates that many educators have effectively adopted the flipped classroom approach in a transactional role, aiming to transform their instructional methods in mathematics education. In this context, it is a timely to investigate how mathematics teachers in Sri Lanka are utilizing the flipped classroom approach in teaching learning process. Therefore, the main purpose of this research is to explore the perceptions of Sri Lankan mathematics teachers regarding the functionality of the flipped classroom approach.

Specific objectives

This study aims to:

1. Find out the mathematic teacher's perceptions of implementation of the flipped classroom approach.
2 Identify the challengers faced by mathematics teachers in applying the flipped classroom approach to improve the learning experience.

Scope and Significance of the Study

This research focuses on examining mathematics teachers' perceptions of the flipped classroom approach and identifying the challenges they encounter in its application. The findings point out that teachers' perceptions indicate a crucial role in enabling and enhancing the adoption of innovative teaching methodology within mathematics education. As such, mathematics teachers are a primary group that stands to benefit significantly from the insights gained through this research.

Additionally, the Higher Education Institutes and Ministry of Education can leverage these findings to create and organize specialized training programs and workshops focused on increasing awareness of the flipped classroom approach's effectiveness. These insights serve as essential guidance for developing professional development initiatives that not only advocate for the approach but also empower educators with the competencies and knowledge required for successful implementation. Consequently, this research has the potential to contribute to a broader dissemination of the flipped classroom model, ultimately fostering more effective teaching practices in mathematics education.

II. THEORETICAL FRAMEWORK AND RESEARCH DESIGN

The flipped classroom approach encourages a shift from traditional practices by fostering the cognitive skills outlined in Bloom's taxonomy, promoting creative development: project-based learning, group work, multimedia presentation and peer teaching. As a result, the concept of flipped classrooms needs teachers to shift from the conventional practice of knowledge transmission to constructivist teaching, in which students are encouraged to generate information autonomously through inquiry-based learning. Following exploring the flipped classroom paradigm, it becomes evident that it physically weaves together the majority of the learning concepts. The model's most significant value is that it allows students to think about and reconstruct their knowledge of assisted learning both outside and inside of the classroom.

The rationale for justification for the flipped classroom approach closely aligns with the principles of a student-centered approach to education. This approach emphasizes active learning and places students at the forefront of their educational experience, allowing them to take greater responsibility for their own learning. According to Magro (2018), teachers play a pivotal role in shaping various educational methodologies, particularly within the frameworks of constructivist, socio-constructivist, and reflective approaches that characterize student-centered pedagogy. These approaches encourage students to engage actively with the material, collaborate with peers, and reflect on their learning processes. By facilitating environments where students can explore concepts in depth and apply their knowledge, teachers can significantly influence the effectiveness of these pedagogical strategies. In this context, the flipped classroom model serves as a powerful tool for enhancing student engagement and promoting deeper understanding. It allows students to learn foundational content at their own pace outside of class, freeing up valuable in-class time for interactive activities that foster collaboration, critical thinking, and creativity. In this way, the flipped classroom not only supports but also enriches the student-centered approach to learning by creating more opportunities for personalized and meaningful educational experiences.

Constructivism theory of teaching mathematics is a philosophical theory concerning how students can enhance skills and grasp mathematical concepts (epistemology). According to most educationists, constructivism has been utilized as a framework to develop a cognitive theory which aims to explain the process of understanding concepts by which students acquire skills and knowledge. The primary principle of constructivist theories is that the individual constructs all knowledge. This is immediately relevant to flipped classroom approach which leads to autonomous learning of students.

Constructivism is an argument that does not concern itself with teaching, but with knowledge and learning. According to Terhart (2003), constructivism is not a recent theory that tries to explain how people learn. This theory has been examined by Piaget (1955); Bruner (1966); Vygotsky (1978) in depth. However, constructivism as a theory was generally recognized in the early 1990s. Basically constructivist learning theory essentially promotes the concept that knowledge is constructed from existing or pioneering knowledge. Constructivists' view of learning is that the students use their models of knowledge construct new knowledge of the things they learn. They build new knowledge on their existing knowledge. According to William & Burden (1997), the primary principle of constructivism is that individuals should be free to interpret the theories and concepts that are offered in ways that are unique to them.
This observation seems to emphasize one important aspect of learning, that is, various people construct understanding and knowledge in different ways. This scenario may be connected to the techniques for learning that students engage in flipped classes. Hence, it can be decided that constructivism theory can be utilized to explain the mechanism for flipped classroom instruction. Therefore, the Vygotskian socio-cultural learning theory is chosen as the theoretical framework for the research.

III. DATA COLLECTION AND ANALYSIS

The research utilized a mixed-methods design to comprehensively explore mathematics teachers' perceptions on the flipped classroom approach. Data were gathered through a combination of a structured questionnaire and in-depth face-to-face interviews, allowing for a well-rounded and

detailed analysis. A Likert-scale questionnaire, which demonstrated a strong reliability coefficient of 0.911, was distributed to a randomly chosen sample of 244 mathematics teachers. These teachers had received prior training in the flipped classroom approach and represented 141 schools across various school types in the Galle Education Division, Sri Lanka.

The questionnaire included twelve items organized into four key dimensions of the flipped classroom approach, divided into sections A through D. Section A addressed the effectiveness of the flipped classroom in creating a flexible learning environment, emphasizing its capacity to meet diverse learning needs and foster adaptability. Section B investigated its impact on cultivating a positive learning culture, highlighting aspects such as collaboration, student engagement, and active participation. Section C focused on the flipped classroom's role in delivering content intentionally, ensuring that instructional materials are aligned with both learning objectives and the specific needs of students. Section D assessed how the approach enhances the effectiveness of professional educators, particularly regarding their instructional strategies, facilitation skills, and ability to offer personalized support.

Face-to-face interviews were conducted with 10 mathematics teachers randomly selected from the questionnaire sample to complement the quantitative data and provide a deeper understanding. This qualitative approach facilitated data triangulation, enhancing the reliability and credibility of the findings by incorporating diverse perspectives. Using SPSS (Version 25) software, quantitative data were analyzed to uncover patterns, trends, and relationships within the responses. By integrating both qualitative and quantitative methods, the study offered a comprehensive view of teachers' experiences and perceptions, resulting in insights that are not only statistically sound but also rich in context.

Table 1:Sample of the teachers

Type of school	Number of teachers		Total
	Male	Female	
1AB	31	97	128
1C	22	48	70
Type 2	31	15	46
Total	84	160	244

XI. DISCUSSION

The key findings of this study align with two main aspects: the perceptions of mathematics teachers regarding the functionality of the flipped classroom within the Sri Lankan context and the challenges they face in implementing this approach to enhance their teaching experiences. The functionality of the flipped classroom was examined through four distinct dimensions.

Mathematics teachers' perceptions of the flipped classroom approach in relation to towards a flexible learning environment.

Table 2: Teachers' perceptions regarding the role of functionality within the flipped classroom: A Flexible Environment.

Items	Agreed Frequency	Percentages (%)	Means	S.D.
Flipped classroom approach leads to independent learning	94	38.5	.39	.488
The flipped classroom approach hinders the creation of a democratic learning environment for students in mathematics.	38	15.6	.16	.365
There are opportunities for students to offers varies learning methods in the he flipped classroom	236	96.7	.97	.168

A significant minority of teachers, specifically 38.5%, indicated that the flipped approach leads to autonomous learning atmospheres among students within the Sri Lankan context. Additionally, only 15.6% of teachers agreed that flipped classroom approach hinders the creation of a democratic flexible learning environment for students in mathematics. But the result showed that the 96.7% of teachers indicated there are opportunities for students to explore various learning methods in the flipped classroom. Furthermore, it was revealed from interviews with teachers that there was a prevalent tendency among Sri Lankan students to depend heavily on teacher guidance during the teaching-learning process, consequently diminishing their propensity for self-directed learning within the framework of the flipped classroom pedagogy.

Table 3: Teachers' perceptions on the role of the functionality in the flipped classroom: Learning Culture

Items	Agreed Frequency	Percentage (%)	Means	S.D.
Do you think the teacher at the flipped classroom (FC) approach performs on the students' prior knowledge?	187	76.6	0.77	0.424
Do you think the teacher creates a conducive learning environment in the flipped classroom approach?	221	90.6	0.91	0.293
Do you think the flipped classroom increased students' higher order thinking?	216	88.5	0.89	0.319

It is evidenced from Table 3 that 76.6% of the mathematics teachers indicated the flipped classroom approach performs on the prior knowledge of students. Furthermore, 88.5% of teachers stated that flipped classroom approach can increase students' higher-order thinking. and it creates a conducive learning environment for students. Additionally, 90.6% of the respondents agreed that teachers foster a conducive learning environment in the flipped classroom approach. This indicates that a significant majority viewed the functionality of the flipped classroom as a means of enhancing the learning culture.

Table 4: Teachers' perceptions on the role of the functionality in the flipped classroom: Intentional Content

Items	Agreed Frequency	Percentages (%)	Means	S.D.
The teacher creates a logical learning environment within the flipped classroom	217	89.0	.89	.301
I believe that the flipped classroom enhances interactions between students and teachers	219	89.8	.90	.304
I think the flipped classroom approach will increase ability to do inquiry-based activities in mathematics	223	91.4	.91	.281

A significant 89% of the teachers highlighted that this teaching approach fosters a structured and engaging environment conducive to deeper understanding. Furthermore, 89.8% of respondents emphasized that the flipped classroom approach significantly enhances interactions between students and teachers. This increased interaction allows for more dynamic and personalized learning experiences, enabling educators to deals with individual student needs more effectively. Additionally, 91.4% of the teachers agreed that this approach promotes inquiry-based activities, particularly in mathematics. The flipped classroom approach provides students with the opportunity to explore mathematical concepts actively, encouraging curiosity and critical thinking. By engaging with pre-class content and utilizing class time for hands-on problem-solving, students can develop a stronger grasp of mathematical concepts and their applications.

These findings clearly illustrate that teachers perceive the intentional content design in the flipped classroom approach as highly effective. By enabling active participation, fostering collaboration, and supporting inquiry-based learning, this teaching method aligns with modern educational goals of developing critical thinkers and independent learners. The overwhelmingly positive perceptions among teachers enhance the potential of the flipped classroom to transform traditional learning environments into dynamic and exploration.

Table 5: Teachers' perceptions on the role of the functionality in the flipped classroom: Professional Educator

Items	Agreed Frequency	Percentages (%)	Means	S.D.

I think the flipped classroom approach make a heavy workload load on mathematics teachers.	168	69.0	.16	.167
I think the flipped classroom can increase your efficiency as a mathematics teacher.	237	97.1	.97	.167
I think the flipped classroom promotes teachers' computer literacy skills.	234	95.9	.96	.199

It is evidenced from Table 5, 95.9% of teachers agreed that the flipped classroom approach enhances their computer literacy skills. This finding highlights the potential of the flipped classroom as a professional development tool, promoting effective technology integration in teachers' instructional practices. The increased use of digital platforms for delivering content, designing activities, and assessing student progress allows educators to build confidence and proficiency in using technological tools.

When inquired about teacher's role as professional educators, 97.1% of teachers stated that the flipped classroom significantly enhances their efficiency as mathematics teachers. This improvement in efficiency likely stems from the ability to use class time more strategically for hands-on learning, personalized instruction, and addressing students' individual challenges. These results reflect a strong positive perception among teachers regarding the suitability of the flipped classroom for advancing their professional competencies and maximizing their impact in the classroom.

However, the flipped classroom approach does come with its challenges. A notable 69.0% of mathematics teachers indicated that implementing this approach results in a heavier workload. This increased workload can be attributed to the time and effort required to create high-quality pre-class materials, such as videos and interactive content, as well as the additional preparation needed to facilitate meaningful in-class activities. Despite these challenges, the overall positive attitudes towards the flipped classroom approach suggest that many teachers view the benefits for both their students and their professional growth—as outweighing the drawbacks. These findings revealed that the dual impact of the flipped classroom: while it places greater demands on teachers, it also empowers them with new skills and strategies that can enhance their teaching effectiveness and professional development.

Statistically Significant Variations in Teachers' Perceptions of Functionality in the Flipped Classroom Approach

The study identified statistically significant variations in teachers' perceptions of the flipped classroom's functionality, influenced by two key factors: gender and the current workplace environment. These results indicate that both gender and the specific context of teachers' workplaces can affect their views on the effectiveness of the flipped classroom approach. This aligns with research by Gasparc et al., (2024), which also emphasized the impact of demographic and workplace factors on teachers' attitudes toward innovative teaching methods.

Significant Differences by Current Workplace

The results of the statistical ANOVA test reveal that there are significant differences in the perceptions of mathematics teachers regarding the functionality of the flipped classroom approach, based on the type of school where they currently work. This is illustrated in Table 6, with F = 3.409 and p = .010, which is less than .05.

Table 6: ANOVA- Test of Mathematics teachers' perceptions on functionality in the flipped classroom approach based on school type

	Sum of Squares	Df	Mean Square	F	Sig.
Between Groups	.145	2	.076	3.309	.010
Within Groups	40.113	241	.1667		
Total	40.361	243			

The results highlight the considerable impact and significant influence of the educational environment on teachers' perceptions, stressing how the institutional context affects their readiness to embrace innovative teaching methods like the flipped classroom (FC) approach. This observation is consistent with earlier studies, including those by Johnson et al. (2016). which underscores how workplace settings and institutional support impact educators' readiness to embrace technology integration and digital literacy initiatives. Interviews with teachers further revealed that the unequal provision of technical facilities and equipment across schools in Sri Lanka, influenced by school classification, poses a major challenge to the effective implementation of the flipped classroom approach. Teachers from less-equipped schools expressed concerns about the lack of resources necessary to support this pedagogical approach, thereby limiting its functionality and effectiveness. Moreover, the study revealed statistically significant differences in teachers' perceptions of the flipped classroom approach based on gender. Female teachers, in particular, cited inadequate training in the use of technological tools as a barrier, further underscoring the need for equitable resource distribution and targeted professional development programs to bridge these gaps and promote the successful adoption of the flipped classroom methodology.

Statistically Significant Differences by Gender

The quantitative findings from the independent samples t-test, detailed in Table 3, indicate a statistically significant difference in mathematics teachers' perceptions regarding the effectiveness of the flipped classroom (FC) approach, differentiated by gender. The two-tailed significance value of 0.000 is below the 0.05 threshold, suggesting that gender significantly influences teachers' views on delivering digital literacy skills through the flipped classroom approach.

Table 7: T-Test Results for Independent Samples Examining Gender Differences in Mathematics Teachers' Perceptions of the Flipped Classroom Approach

Teachers' Perceptions Towards Flipped Classroom (FC)	Gender	N	Mean	S. D	T	Sig.*
Total	Male	84	2.3866	.41894	4.320	.000
	Female	160	2.1590	.37477		

The comparison of means and standard deviations reveals significant differences in perceptions of the functionality of the flipped classroom approach between male and female teachers. Male teachers exhibited a higher mean perception (M = 2.3866, SD = 0.41894) than female teachers (M = 2.1590, SD = 0.37477). This disparity, supported by a p-value of 0.000, indicates a statistically significant difference in perceptions between the two groups.

The qualitative findings from interviews with female teachers provide further context to these results. Many female participants identified inadequate training in the use of technological tools as a key challenge affecting their ability to effectively implement the flipped classroom approach. They highlighted that the lack of technical proficiency and support hinders the seamless integration of digital tools into their teaching practices, thereby impacting the functionality of the flipped classroom model.

Common Challenges in Adopting the Flipped Classroom Approach

The main challenges identified in the study were the need for target professional development for gender-specific barriers and the disparity in technical resources available under school classification.

Implementing the flipped classroom approach faces significant challenges in Sri Lanka, particularly when addressing gender barriers among teachers and the disparities in technical resources across different school classifications. Gender-based biases and stereotypes can influence how teachers adopt and adapt to technology-based teaching methods, with women in some contexts facing societal or institutional constraints that limit their access to training and resources. These barriers may stem from preconceived notions about technological proficiency or unequal opportunities for professional development, leading to hesitation or lack of confidence in utilizing flipped classroom techniques. Furthermore, disparities in technical resources available under school classifications exacerbate the challenges of adopting this approach. Schools in urban areas are often better equipped with advanced infrastructure, such as reliable internet, modern devices, and adequate technical support, making it easier to implement technology-driven educational models. In contrast, under-resourced schools, particularly those in rural or economically disadvantaged regions, may lack basic technological necessities, creating a significant digital divide.
This discrepancy has a direct effect on the extent to which the flipped classroom approach functions since teachers and students in economically disadvantaged schools face difficulties accessing pre-class materials, such as videos or interactive content, which are critical to the approach.

Challenges in implementing the flipped classroom approach to improve the experience of mathematics teachers

This study identified several challenges impacting teachers' experiences in implementing the flipped classroom approach in Sri Lanka. Key challengers include negative attitudes among teachers, principals, and administrative staff; the heavy workloads carried by educators; and cultural issues within schools that discourage innovation. Additionally, the lack of adequate technological resources for both teachers and students, especially at home, coupled with poor internet connectivity in rural areas, presents significant barriers. Many students still depend on traditional teacher-led instruction to learn mathematics heavily, further hindering the adoption of the flipped classroom approach because of it was autonomous learning modal. Furthermore, interview results also revealed that teachers are often uninterested in using this method due to a lack of motivation and support from school administrations. School administrations do little to encourage alternative teaching methods beyond the standard methods introduced in professional development workshops conducted by the Ministry of Education or outlined in the teacher's guidelines for teaching mathematics. Without institutional support and a cultural shift within schools, teachers were not motivated to explore innovative strategies as the flipped classroom.

XII. CONCLUSION

To conclude, this study provides light on mathematics teachers' perceptions of the effectiveness of the flipped classroom approach, offering valuable insights into its functionality. The findings reveal that the mathematics teachers in the sample recognized the significance and potential of this approach. However, they identified significant barriers to creating a flexible learning environment for students within the Sri Lankan context. Despite these challenges, the study revealed that mathematics teachers hold positive perceptions of the role of a supportive learning culture and professional educator development in enhancing the potential of the flipped classroom approach. The study also found statistically significant differences ($\alpha \leq 0.05$) in teachers' perceptions of the functionality of the flipped classroom based on gender and the type of school where they currently work. The study also identified statistically significant differences ($\alpha \leq 0.05$) in teachers' perceptions of the effectiveness of the flipped classroom, influenced by their gender and the type of school where they currently work.

The differences highlight the impact of contextual and demographic factors on teachers' experiences and attitudes. On the other hand, several challenges were identified as obstacles to fully implementing the flipped classroom approach. These include negative attitudes among teachers, insufficient teacher training and refresher courses, heavy workloads for both teachers and principals, and school cultural issues that resist innovation. Additionally, the lack of adequate technological resources at schools and in homes, coupled with poor internet connectivity in rural areas, further hinders the adoption of this method. Another critical challenge is the persistent dependency of students on teacher-led instruction to learn mathematics, which limits the flexibility and autonomy that the flipped classroom aims to promote.

The findings highlight the necessity for targeted interventions to address these challenges and improve the implementation of the flipped classroom approach in mathematics education. Ensuring access to sufficient technical resources, enhancing internet connectivity, providing consistent teacher training programs, and cultivating a supportive school environment are crucial steps to overcoming these challenges. These interventions could not only improve teachers' experiences but also enable students to benefit from the innovative and flexible learning

opportunities in the flipped classroom approach.

XIII. RECOMMENDATIONS

Consequently, practice-based strategies should be employed to enhance the implementation of mathematics teaching in Sri Lanka. Based on the results of this study, the researcher recommends the following:

Changing teachers' perceptions is critical to addressing concerns about the lack of advanced technology for implementing the flipped classroom approach. By reorienting these concerns, educators can focus on utilizing simpler, more accessible tools to facilitate learning. For instance, basic learning management systems (LMS), worksheets aligned with textbook content, or structured study guides can be introduced as effective alternatives for delivering pre-class materials and supporting student engagement. These cost-effective solutions can bridge the gap until more advanced technological resources become available, enabling a gradual transition toward fully leveraging the flipped classroom approach. Developing appropriate and comprehensive strategies to develop teacher training workshop in the flipped classroom approach is essential for its success in Sri Lanka. Training programs should prioritize equipping teachers with the knowledge and competences necessary to create engaging pre-class materials, effectively oversee in-class activities, and make the best use of available technology. These programs should also emphasize the basic pedagogical principles underlying the flipped classroom to ensure teachers understand how to adapt the method to their specific teaching contexts. Additionally, refresher courses and continuous professional development opportunities should be provided to help teachers stay updated on new techniques, and best practices in flipped classroom implementation.

State policies should be established to promote the equitable distribution of technological resources among schools. These policies could mandate the direct sharing of resources between technologically enriched schools and under-resourced ones, fostering collaboration and resource optimization. For example, schools with advanced infrastructure could share digital tools, online content, or even host joint training sessions for teachers in nearby schools. Partnerships between schools, supported by government initiatives, can help reduce the digital divide and ensure that all students, regardless of their school’s classification or location, have access to the resources needed for a successful flipped classroom experience. By addressing resource disparities through policy-driven collaboration, Sri Lanka can create a more equitable and supportive environment for implementing innovative teaching approaches. Encouraging teachers to conduct action research studies is vital for examining the impact and functionality of the flipped classroom approach. By engaging in such research, teachers can explore the practical application of this method in their specific educational contexts, gather evidence on its effectiveness, and identify areas for improvement. Action research enables educators to systematically evaluate the impact of the flipped classroom approach on student engagement, classroom dynamics and overall learning outcomes.

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A Social Philosophical Study on Gender and Vocational Training of Persons with Disability

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Abstract: The research focuses on the intersection of gender and disability within the context of vocational training, specifically examining the Department of Social Services and Vocational Training Centres in Sri Lanka. The study aims to understand the experiences and challenges faced by individuals with disabilities, particularly regarding gender-related issues, in accessing vocational training programs. It also analyzes the policies and practices of the Department in addressing gender-specific needs and proposes recommendations for fostering inclusivity and equity. The methodology involves qualitative research methods such as interviews and focus group discussions. The findings highlight the vulnerabilities and insecurities faced by disabled persons and emphasize the importance of promoting gender inclusivity and equitable opportunities for both men and women with disabilities. The recommendations include developing gender-responsive policies, conducting awareness programs, and strengthening collaboration with stakeholders. Overall, the study aims to contribute to knowledge and policy improvements for creating an inclusive society.

Keywords: *Gender, Disability, Vocational Training, Rights to Persons with Disability, Equity*

I. INTRODUCTION

The intersection of gender and disability within the context of vocational training represents a critical area of study within social philosophy. In Sri Lanka, the Department of Social Services plays a significant role in providing vocational training opportunities for persons with disabilities according to the policies which was introduced by global national contexts. The Sri Lankan Protection of the Rights of Persons with Disabilities Act, No. 28 of 1996 defines a person with a disability as "any person who, as a result of any deficiency in his physical or mental capabilities, whether congenital or not, is unable by himself to ensure for himself, wholly or partly, the necessities of life (Sri-Lanka_1996-Protection-of-the-Rights-of-Persons-with-Disabilities-Act-No.-28.pdf). Disability issues are primarily the responsibility of the Ministry of Social Welfare. Specific functions are undertaken by various government sections, including, the Department of Social Services, which has the primary responsibility for providing disability services including disability benefits, provision of assistive devices, vocational training and employment and grants to NGOs. Some of these services are decentralized to the Provincial Council level. Understanding how gender influences access to and experiences within vocational training programs is crucial for

promoting inclusivity and equitable opportunities without marginalization or discrimination. This study aims to explore the social and philosophical dimensions of gender and vocational training of persons with disabilities, specifically focusing on the Department of Social Services in Sri Lanka. By undertaking this research, we seek to deepen our understanding of the challenges faced by individuals with disabilities, particularly concerning gender issues, and provide insights for policy improvements. According to the 2011 population and statistics reports of Sri Lanka, 8.6% of the population are disabled people, and according to the data of the Ministry of Social Empowerment and Welfare's Community-Based Rehabilitation (CBR) program, that number is more than 03% of the population. Sri Lanka is taking actions according to the Millennium Goals for sustainable development as a developing country. The primary aspiration of development is to secure individual rights and make every person the pilot of sustainable development. People should be treated with equality in terms of gender as well as physical or mental.

II. OBJECTIVES OF THE STUDY

The major objective of this study is to investigate the intersectionality of gender and vocational training for persons with disabilities in Sri Lanka. By examining the socio-cultural and institutional dynamics at play, this research aims to contribute to existing knowledge on the subject and provide recommendations for enhancing inclusivity and equitable opportunities in vocational training. Accordingly, examine the experiences and challenges faced by individuals with disabilities regarding gender-related issues in accessing vocational training programs provided by the Department of Social Services, analyze the policies and practices in addressing the gender-specific needs of persons with disabilities in vocational training and identify areas for improvement and explore the social and philosophical implications of the gender-disability intersection in vocational training and propose recommendations for fostering inclusivity and equity within the Department of Social Services as authorized government body of Sri Lanka investigate as specific objectives of the research.

III. IMPORTANCE AND BACKGROUND OF THE STUDY

The census provides adequate evidence that most rather than females, males are vulnerable in the context of disability. Vocational training is a crucial avenue for empowering individuals with disabilities and facilitating their integration into the workforce. However, gender-related barriers and biases can significantly affect the access and experiences of persons with disabilities in vocational training programs. In Sri Lanka, the Department of Social Services plays a pivotal role in providing vocational training opportunities and support for persons with disabilities. Understanding the specific challenges faced by individuals with disabilities, particularly regarding gender issues, within the vocational training programs offered by the Department is essential for promoting inclusive practices and ensuring equitable opportunities.

By undertaking this study, we aim to shed light on the unique experiences of persons with disabilities in accessing vocational training, with a specific focus on the gender-related challenges they encounter within the Sri Lankan context. Additionally, this research seeks to identify gaps in the policies and practices of the Department of Social Services to provide recommendations for improving support services and fostering greater inclusivity.

IV. THEORETICAL FRAMEWORK

This study draws on social justice theory, the capabilities approach, structural functionalism, and feminist disability theory to explore the intersection of gender, disability, and vocational training. Each theoretical framework contributes a unique perspective on how societal norms, institutional structures and gendered expectations affect the vocational training experiences of disabled individuals.

Social justice theory, which emphasizes fairness, equity and respect for all individuals, provides a lens to analyze access to vocational training for disabled individuals. According to Rawls (1971), social justice requires that social and institutional arrangements be organized in a way that guarantees equality of opportunity. This theory is instrumental in critiquing existing vocational training policies and practices to assess whether they genuinely offer equal access for disabled men and women or if they inadvertently uphold traditional gender norms and able-bodied ideals. According to Sen (1999) and further expanded by Nussbaum (2000), focuses on what individuals are able to *do* and *be*, emphasizing personal agency and the opportunity to pursue a fulfilling life. This theory challenges vocational training programs to support the diverse capabilities of disabled individuals by addressing their unique gender-specific and disability-related needs, thus empowering them to reach their full potential.

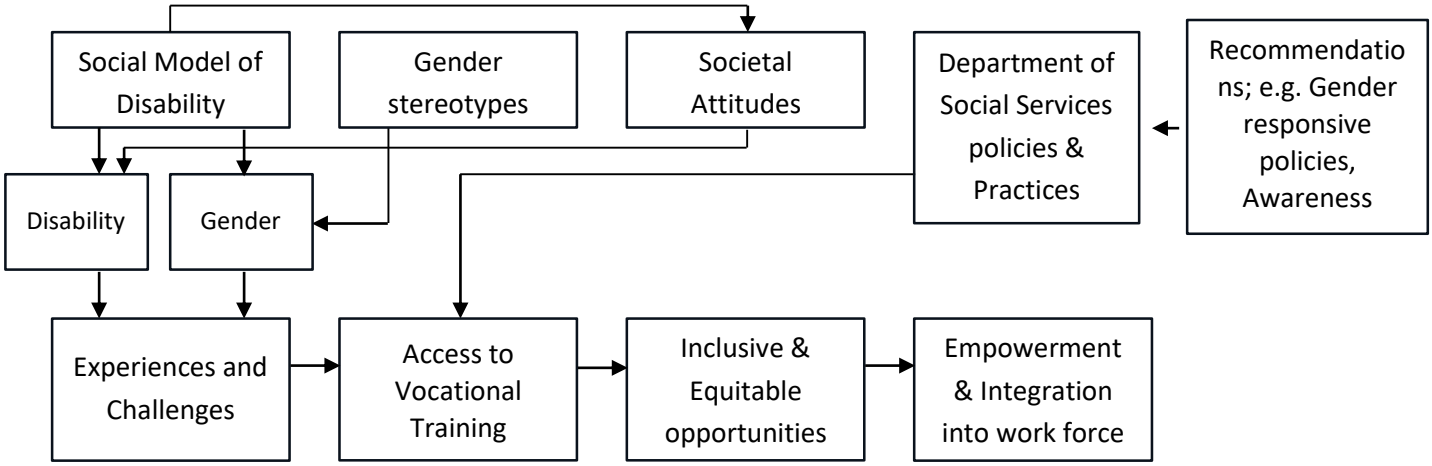
Structural functionalism, as articulated by Parsons (1951), examines the interdependent roles within a societal structure and how they contribute to stability and continuity. This framework helps in analyzing how vocational training centres and societal expectations assign roles to disabled individuals based on gender norms. It is relevant in identifying how structural norms influence gendered expectations and vocational training opportunities for disabled individuals, potentially limiting their employment options and social mobility. The feminist theory (hooks, 1984) and disability theory (Garland-Thomson, 1997) together provide a critical perspective on how gender and disability intersect to shape vocational training experiences. Feminist theory challenges gender biases that limit opportunities for disabled women, while disability theory focuses on promoting accessibility and inclusivity. This combined framework is essential in understanding how stereotypes and ableism create additional barriers in vocational training environments, advocating for gender- and disability-sensitive approaches.

According to the theoretical perspectives, the study provides a comprehensive framework for analyzing the social and institutional factors affecting vocational training for disabled individuals. These frameworks inform recommendations aimed at fostering an inclusive and equitable environment that respects the rights and dignity of all individuals, ultimately contributing to social justice and inclusivity in vocational training.

In additionally, this study draws on two key theoretical frameworks: Social Model of Disability which views disability as a social construct resulting from the interaction between impairments and environmental barriers. It emphasizes that societal attitudes and physical barriers disable individuals rather than the impairment itself. Intersectionality theory recognizes that people experience oppression based on the complex interplay of their social identities (e.g., gender,

disability, ethnicity). In this study, it highlights how gender and disability intersect to create unique challenges for persons with disabilities in accessing vocational training.

The following graph depicts the key elements of the study and their relationships:



This graph illustrates how various factors, including societal models, social identities, and institutional practices, work together to shape the experiences of persons with disabilities in vocational training.

V. METHODOLOGY

Social Science research methodology is indispensable in this study as it enables a rigorous exploration of the intersectional, structural, and philosophical dimensions of gender and disability in vocational training. This methodological rigor provides depth, contextual understanding, and actionable insights that are vital for fostering an inclusive, equitable vocational training environment.

Research Design

This study employed a mono-qualitative research design to gain an in-depth understanding of the intersection of gender and vocational training for persons with disabilities in Sri Lanka. Qualitative methods such as interviews and focus groups were used to gather rich and detailed data.

Sample Selection

The sample was purposefully selected to include individuals with disabilities who had participated in vocational training programs offered by the Department of Social Services, related government bodies, and non-governmental organizations in Sri Lanka. The sample included individuals of different genders and disability types to capture diverse perspectives. Additionally, key informants from the Department of Social Services and relevant stakeholders, such as vocational training instructors and disability advocates, were included in the sample.

Sample Matrix

Category	Sub-category	Description	Sample	Method of

			Size	**Data Collection**
Persons with Disabilities	Gender (Male/Female)	Participants of different genders to explore gender-specific challenges in vocational training.	15-25 individuals	Semi-structured interviews, Focus groups
	Disability Type (Physical, Sensory, Intellectual)	Inclusion of participants with different disability types to capture diverse perspectives.	15-25 individuals	Semi-structured interviews, Focus groups
	Type of Vocational Training (Government, NGO, Mixed)	Participants who have received training from different sources (government bodies and NGOs).	15-25 individuals	Semi-structured interviews
Key Informants	Vocational Training Instructors	Instructors who provide vocational training to individuals with disabilities and can provide insights into inclusivity.	5-8 key informants	Focus groups, Interviews
	Policy Makers/Department Representatives	Officials from the Department of Social Services or related government bodies who influence vocational training policies.	5-8 key informants	Interviews, Focus groups
	Disability Advocates	Experts or advocates for persons with disabilities who can speak to the broader systemic challenges and advocacy issues.	5-8 key informants	Focus groups, Interviews
Inclusion Criteria	Experience in Vocational Training Programs	Individuals who have participated in vocational training programs offered by the Department, NGOs, or related bodies.	N/A	N/A
Exclusion Criteria	No Participation in Vocational Training	Individuals who have not been involved in vocational training programs will not be included.	N/A	N/A

This sample matrix provides a structured and purposeful selection of participants, including individuals with disabilities from various backgrounds and stakeholders involved in vocational

training. It ensures diversity in perspectives by considering different genders, disability types, and training sources, allowing for a comprehensive analysis of the challenges faced in vocational training. The inclusion of key informants further strengthens the study by providing insights into institutional and policy aspects of vocational training for persons with disabilities in Sri Lanka.

VI. DATA COLLECTION

Semi-structured interviews were conducted with individuals with disabilities who had experienced vocational training programs provided by the Department of Social Services and other vocational training centers. The interviews explored their experiences, challenges, and perceptions regarding gender-related issues in accessing and participating in vocational training. Focus group discussions were conducted with vocational training instructors and key informants from the Department to gain insights into the existing policies, practices, and challenges related to gender inclusivity in vocational training.

The qualitative data collected from interviews and focus group discussions was transcribed and analyzed thematically. A thematic analysis approach was used to identify patterns, themes, and categories related to the intersection of gender and vocational training for persons with disabilities. The data was coded and organized into themes, and relationships between themes were explored to develop a comprehensive understanding of the research questions.

XIV. LIMITATIONS

This study acknowledges certain limitations that may influence the findings and generalizability of the research. Firstly, the sample size may be limited due to the availability and accessibility of individuals willing to participate in the study. This could impact the representation of diverse perspectives within the disability community. Additionally, the study's reliance on self-reported data may introduce biases or limitations related to recall or social desirability. Furthermore, the research is constrained by time and resource limitations, which may impact the depth of analysis and the ability to explore all relevant dimensions of the topic.

XV. FINDINGS

The findings of this study were presented in detail, analyzing the experiences of individuals with disabilities regarding gender-related issues in accessing vocational training programs within the Department of Social Services. The examination of existing policies and practices identified areas for improvement and provided insights into the social and philosophical implications of the gender-disability intersection in vocational training. The findings contributed to a deeper understanding of the challenges faced by persons with disabilities in Sri Lanka and provided recommendations for enhancing inclusivity and equitable opportunities within the Department of Social Services.

The Department of Social Services in Sri Lanka operated Vocational Training Institutes (VTIs) that catered specifically to persons with disabilities. These VTIs provided specialized vocational training programs to empower individuals with disabilities and enhance their employability.

Vocational Training Centers under the Department of Social Services, Sri Lanka were identified

as follows:

1. Seeduwa Vocational Training Center
2. Amunukumbura Vocational Training Center
3. Ketawala Vocational Training Center
4. Wattegama Vocational Training Center
5. Thelembuyaya Vocational Training Center
6. Ragama Vocational Training Center
7. Madampe Vocational Training Center
8. Kalawana Vocational Training Center

Visually impaired, speech impaired, physically disabled, intellectually disabled, hearing impaired, and multi-disabled individuals could take admission for the above vocational training institutes. It was also noteworthy that there was a limited age group (under 18) eligible to enter the courses.

According to the World Bank's World Development Indicators, in 2011, the estimated prevalence of disability in Sri Lanka was approximately 9.2% of the total population. In terms of gender and disability, according to Sri Lanka's 2001 statistical data (http://www.statistics.gov.lk/Resource/en/Population/PopHouStat/PDF/Disability/p11d2DisabledpersonsbyAgeandSex.pdf), it appeared that men suffered from disabilities more than women. The findings revealed that several vocational training centers in Sri Lanka provided gender-based vocational training programs specifically targeted towards men. These centers aimed to address the specific needs and challenges faced by men in accessing skill development opportunities, such as the Vocational Training Authority (VTA), National Institute of Business Management (NIBM), Department of Technical Education and Training (DTET), Industrial Training Institute (ITI), Women's Bureau Vocational Training Centers (under the Ministry of Women and Child Affairs), and the National Apprentice and Industrial Training Authority (NAITA), among others. Accordingly, the Department of Social Services was recommended to create a mechanism in connection with the above vocational training centers, with a focus on gender equity, to secure and protect the equal rights of both men and women with disabilities.

It was important to note that while these vocational training centers might attract more male participants, they were open to individuals of all genders. The goal was to provide equal opportunities for all interested individuals to acquire vocational skills and enhance their employability. According to the findings, the insecurity faced by disabled men compared to disabled women indicated that experiences varied significantly among individuals due to the intersection of disability and gender, as well as other factors such as societal norms, cultural context, and personal circumstances. However, certain broad observations were made regarding the challenges faced by disabled men, such as:

1. Social Expectations: Disabled men faced additional pressure to conform to traditional masculine stereotypes and societal expectations. Societal beliefs often associated masculinity with

physical strength, independence, and providing for others. This pressure led to feelings of inadequacy and a sense of insecurity when disabled men were unable to meet these expectations.

2. Employment and Economic Factors: Disabled men encountered difficulties in securing stable employment opportunities due to physical limitations or societal biases. This resulted in economic insecurity, affecting their financial independence and overall well-being. Limited employment prospects also impacted their self-esteem and contributed to a sense of vulnerability.

3. Access to Support Networks: Disabled men faced challenges in accessing support networks and resources designed to address their specific needs. Support systems often focused more on the needs of disabled women, leaving disabled men with fewer avenues for assistance and community engagement. This lack of support contributed to feelings of isolation and insecurity.

4. Intersectionality and Multiple Marginalization: Disabled men belonging to marginalized communities, such as those from lower socioeconomic backgrounds or ethnic minorities, faced compounded challenges and insecurities. The intersectionality of disability with other identities exacerbated the discrimination and barriers they encountered, making it more challenging to overcome their insecurities.

It was crucial to emphasize that while disabled men faced unique challenges, disabled women also experienced their own distinct set of insecurities and barriers. Both groups deserved equal recognition and support in addressing their specific needs and promoting inclusivity and empowerment. To foster a more inclusive society, it was important to promote awareness, challenge gender stereotypes, and ensure that disability-related support systems and resources were accessible and available to all individuals, regardless of gender. By addressing the insecurities and vulnerabilities faced by disabled men and women, progress could be made towards creating a more equitable and inclusive environment for all members of society. The main factor identified in this study was that in the case of disability, both women and men should be equally given space and attention.

XVI. RECOMMENDATIONS

Based on the findings of this study, several recommendations can be made to enhance the gender inclusivity and equitable opportunities in vocational training for persons with disabilities within the Department of Social Services and other interconnected Institutions in Sri Lanka. These recommendations include:

1. Developing gender-responsive policies and guidelines that address the specific needs and challenges faced by individuals with disabilities in vocational training.
2. Conducting gender sensitization and awareness programs for vocational training staff to promote inclusive practices and challenge gender biases.
3. Strengthening collaboration with relevant stakeholders, including disability advocacy groups and employers, to foster gender-inclusive vocational training programs and create employment opportunities for persons with disabilities.

These recommendations will consider the identified challenges and align with the principles of inclusivity and equity.

XVII. CONCLUSION

This social philosophical study on gender and vocational training of persons with disabilities, with a special focus on the Department of Social Services in Sri Lanka, aims to shed light on the experiences and challenges faced by individuals with disabilities regarding gender issues within vocational training programs. By exploring the intersectionality of gender and vocational training, this study seeks to contribute to knowledge and provide recommendations for policy improvements, fostering a more inclusive and equitable society for all.

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Position and Velocity Analysis of Open and Closed loop system using various Controllers in Underwater ROV - ORCA for Stabilized Navigation

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***Abstract*:** Remotely Operated Vehicle (ROV) is an unmanned vehicle operated using a tether for navigation, control and underwater missions. ORCA is a student developed budgetary ROV which was indigenously developed exclusively for the underwater inspection and survey application purpose. Due to unstable operating environments, dynamic modeling, simulation of the ROV is essential in order to understand the stabilized navigation and movements of the vehicle at required depth of operation. ORCA has been mathematically modeled based on Newtonian dynamics in the Simulink platform to simulate the position and velocity responses of the vehicle. Different control system models were compared - open loop and closed loop systems (with controllers P, PI, PID). To investigate the impact of different underwater forces on the vehicle, an open loop system was employed. The closed loop system was designed to enhance the ROV's navigation capabilities. Finally, the closed loop system proposed with a PID controller was found to be more suitable for stabilizing the ORCA ROV.

Keywords: *ROV, Controller, P, PI, PID, Degrees of Freedom, Open Loop System, Closed Loop System*

I. INTRODUCTION

Remotely Operated Vehicles

There are several types of underwater robots including Autonomous Underwater Vehicles (AUVs), Remotely Operated Vehicles (ROVs), Solar-powered Autonomous Underwater Vehicles (SAUVs) etc. ROV are underwater robots controlled using tethers widely used for underwater missions, survey and inspections. There are two types of undersea vehicles, according to the Committee on Undersea Vehicles and National Needs. The first is a vehicle that is capable of carrying people, or what the Committee refers to as a "manned" vehicle. The second vehicle is incapable of transporting either "unmanned" or human vehicles. [6]. The exploration of ocean depths can be carried using an unmanned ROV which is a highly maneuverable vehicle. The ROV are operated remotely from the sink vessel floating on the ocean water surface. In addition to a wide range of scientific applications and expeditions like ocean exploration, they are commonly employed for industrial objectives like the structural testing of offshore platforms and the internal and external inspection of underwater pipelines. Because ROVs can do tasks that need a high degree of precision, they are now receiving more attention in the development of underwater robots

than AUVs.

ROVs consist of multiple propeller thrusters pointing in various directions [10] for a desired fixed directional movement according to the user's input. The direction of rotation of these thruster blades influences the movement of the vehicle. The driven force of backward and forward, right and left turn, downward and upward is supplied by the thrusters, also known as the six degrees of freedom. The power supply's capacity is influenced by the number of thrusters; thus an underwater robot weighs more when its power supply is huge. There are various subsystems in an ROV [9]. The primary component includes the main processing unit, where instructions are fed and then converted into a physical output - positions and movements of the ROV. The size of the ROV varies as micro ROV, mini ROV, general ROV, inspection class ROV, heavy work class ROV with respect to various applications [13-14].

About the ORCA ROV

ORCA is an ROV with dimensions of 500 x 350 x 210 mm which weighs about 10.247 kg. It is equipped with sensors like temperature sensor, pressure sensor, leak sensor, Inertial Measurement Unit and a camera for underwater inspection and survey applications of up to a depth of 300 meters. The vehicle's body consists of two sealed acrylic enclosures, carrying the electronics systems and the battery. The embedded electronic system integrated with sensors provides the desired motion of the ROV in underwater that controls and achieves the desired movement of the vehicle as per the joystick command to the thrusters through the tether cable. The whole ROV system is powered using the 14.8V,18Ah Li-ion battery enclosed in the sealed hull. A high performance HG1120 micro-electro-mechanical system (MEMS) inertial measurement unit (IMU) is used. The HG1120 includes MEMS gyroscopes, accelerometers and magnetometers, making it a 9 Degrees Of Freedom (DOF) IMU. In addition, the HG1120 employs an internal environmental isolation system to attenuate unwanted inputs commonly encountered in real world applications. Figure 1 shows the top view of ORCA inland and waterbody.

Fig. 1: ORCA ROV structure

Navigation of A Remotely Operated Vehicle

The two frames of reference that are typically taken into account by all systems are the fixed or inertial frame [8] and the frame that is attached to the moving body and is presumed to move with it. The ROV can move in six degrees of freedom - three translational motions and three rotational motions. Translation motions involve moving along the different axes X, Y and Z

- Heave: Moving up and down along the Y axis,
- Surge: Moving forwards and backwards along the X axis.
- Sway: Moving left and right along the Z axis.

The rotational motions involve turning in order to face a different axis.

- Pitch: Moving between X and Y,
- Yaw: Moving between X and Z,
- Roll: Moving between Z and Y [7].

The pilot can then perform manoeuvres by combining any of these movement characteristics.

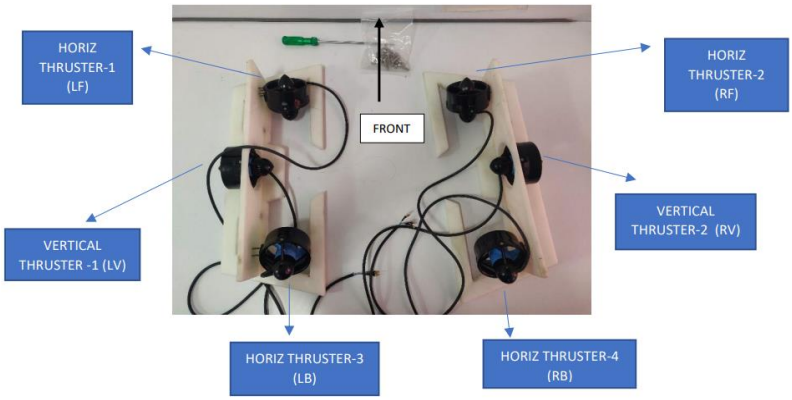

Fig. 2: Positioning of thrusters in ORCA ROV

The thrusters utilize a vector-based approach in most of the ROVs based on the rotational movement of the thrusters' blades as shown in Figure 2. The DOF of the ROVs depend on the arrangement of thrusters in the structure. Underwater robots are frequently shaped like torpedoes, with a cylindrical form. Underwater robots may move at high speeds down the horizontal axis and drop diagonally with the use of rudders when they adopt this design, which is more commonly utilized. Certain additional kinds of torpedo-shaped underwater robots use extra thrusters in place of rudders [11,12]. Table 1 shows the six degrees of freedom of ORCA.

Table 1: Depicts the 6 Degrees of Freedom of ORCA with respect to the thruster blades direction of rotation(Anticlockwise - ACW and Clockwise - CW)

DoF	Left Front	Right Front	Left Back	Right Back	Right Vertical	Left Vertical
Surge - Forward	CW	CW	CW	CW	0	0
Surge - Backward	ACW	ACW	ACW	ACW	0	0
Sway - Left	ACW	CW	CW	ACW	0	0
Sway - Right	CW	ACW	ACW	CW	0	0
Heave - Upward	0	0	0	0	CW	CW

Heave - Downward	0	0	0	0	ACW	ACW
Roll - Clockwise	0	0	0	0	CW	ACW
Roll - Anti Clockwise	0	0	0	0	ACW	CW
Yaw - Clockwise	CW	ACW	CW	ACW	0	0
Yaw - Anti Clockwise	ACW	CW	ACW	CW	0	0

Stability of the Underwater Vehicle

The most important component for a stabilized movement of the ROV is the controller. The controller tends to reduce the variations and deviations in the untargeted DOF other than principle direction of motion given by the pilot. The mechanism of a controller is to minimize the difference between the system's actual input and the feedback value. By lowering the steady-state error, controllers typically increase steady-state accuracy. Stability increases in tandem with improvements in steady-state accuracy. Additionally, they aid in lessening the undesired offsets generated by the system, which cause the ROV to move in an undesirable direction.

Effectiveness of P, PI, PD and PID controllers in the Pressure Regulating Valve of a trisonic blowdown wind tunnel was studied [1]. The major objectives in the study included reducing the overshoot and undershoot conditions and to improve the settling time, rise time, steady state error etc. The usage of the PID controller achieved the objectives and was more efficient than the others.

A comparative study of Proportional (P), Proportional Integral (PI), and Proportional Integral Derivative (PID) controllers were carried for speed control of induction motor [2]. It was concluded that P controllers can stabilize only the 1st order unstable processes. PID controllers can be utilised for higher order capacitive processes, while PI controllers can be used to prevent significant noise. PID achieved the best response among all. In [4], Hybrid Fuzzy PI controller was proposed. The controller was tested on a Brushless DC motor (BLDC motor) which improved the performance of motor and operating conditions such as settling time, rise time, overshoot percentage and stability phenomenon etc. A PI-PD control methodology was used in [5]. These controllers were found to be spontaneous, since it incorporates two different control modes together. This controller was then further tuned using a proposed tuning method in the study to achieve the desired control objectives. There are various controllers used nowadays for different real-time applications. This study focuses on the P, PI and PID controllers used in closed loop control systems for underwater ROV.

Proportional (P) controller:
It is the most straightforward and user-friendly structure for putting linear control systems into practice. P-only control reduces output fluctuations, but it doesn't always move the system in the

desired direction. In comparison to most other controllers, it offers a quicker response [3].This controller is useful when the error is under a specific limit. A proportional controller is insufficient to handle the error generated if the error surpasses the threshold. Equ. (1) shows the mathematical modeling of the P controller. It generates an output that is proportionate to the current error value by using the gain Gp. When the proportionate gain (Gp) is elevated, the system experiences instability.

$$O(t) = Gp * [i(t) - f(t)] \qquad (1)$$

Where,

$i(t)$ = Reference Input Signal
$f(t)$ = Feedback Signal
Gp= Proportional Gain

However, P controllers do not have memory or forecasting ability to improve the regulation.

The Advantages of P - mode controller is: Easy implementation, High loop gain is obtained, Faster response obtained even from slower and damped response and reduces the steady state error.Similarly, the disadvantages of P - mode controller are,offset error is present, for a large gain, instability is increased, Increases the maximum overshot of the system.

Proportional-Integral (PI) controllers:
These are more widely used. If the proportional gain is high in case of P-mode controller, then the system becomes unstable. To make the system performance stable, integral action is to be considered as in the PI-mode controller. It considers both the magnitude of the system error signal and the integral of this error also.When a process returns the same result with the same set of inputs and disturbances taken into account, it is considered non-integrating and requires a PI control model [4]. The value of the controller output O(t) is fed into the system as the manipulated variable input as shown in Equ. (2).The integral controller is used to reduce the steady state error. However, a P controller is essential for integrating processes.

$$O(t) = Gp * \{e(t)\} + Gi * \{\int e(t)\, dt\} \qquad (2)$$

where,

$e(t)$ = Error signal = $i(t) - f(t)$
$i(t)$ = Reference Input Signal
$f(t)$ = Feedback Signal
Gp = Proportional Gain
Gi = Integral Gain

The Advantages of PI-mode controllers are: Reset controllers, as they are often called, reduce steady-state error and enable the controlled variable to be brought back to the precise position, they respond to deviations continuously and Higher sensitivity.The disadvantages of PI-mode controller are,high initial overshoot, slower response to input than P controllers, unstable if there are sudden disturbances.

Proportional-Integral-Derivative (PID) controllers:
This is the most commonly used controllers in many industries for real time applications. A PID controller combines the benefits of proportional, derivative and integral control actions. Various advantageous features are obtained through this combination

- fast response if the input of controller is changed (D mode feature),
- error tends to towards zero with increase in control signal (I mode feature) and
- suitable action inside control error area to eliminate the oscillations and fluctuations (P mode feature).

The proposed PID controller block diagram is shown in Figure 3 below

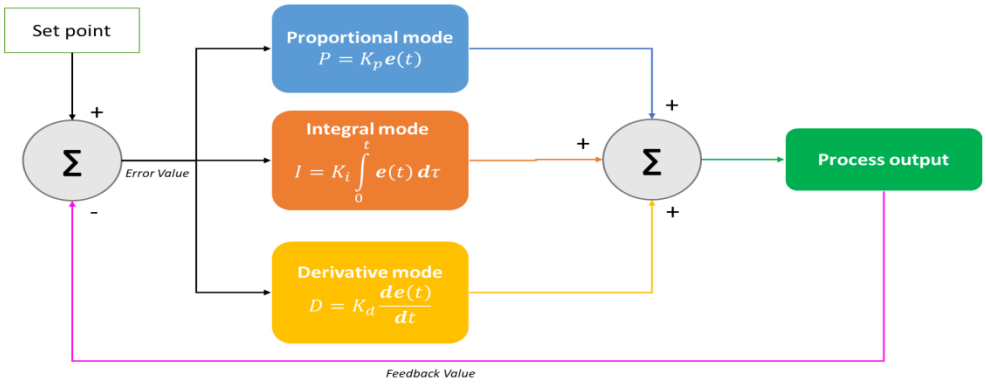

Fig. 3: Schematic representation of the proposed PID controller.

The controller can be mathematically modeled using Equ (3).

$$O(t) = Gp * (e(t)) + Gi * \int e(t)dt + Gd * d(e(t))/dt) + C \quad (3)$$

Where,

Gp = Proportional Gain
Gi = Integral Gain
Gd = Derivative Gain

The advantages of PID - mode controller are, reduced overshoot, control loop response is faster, more robust to tuning errors and mismatches, Faster reaction to even unknown disturbances. The disadvantages of PID - mode controller are, it cannot be used in processes with abundant noise, cannot incorporate ramp-type set-point deviations, improper response to slow disturbances at the input end.

II. METHODOLOGY

The ORCA ROV is modeled based on Newtonian Dynamics in order to study the effects of various forces like centripetal force and Coriolis, restoring forces, hydrodynamic damping force and added mass in underwater. The position and velocity responses of the system are then simulated to understand the performance of the open loop system subjected to various perturbed conditions underwater.

Mathematical Modeling of ROV

Open Loop System:

The assumptions taken in account for mathematical modeling of the ORCA are

- The ROV is fully submerged in water with a rigid body.
- The effect of waves is neglected as the ROV is considered to be at a certain depth of the water body.
- The earth fixed frame of reference is inertial.
- It is assumed that the ROV is being used in inspection operation and ensure moving slowly at the required depth of operation.

The six degree of operation (6DOF) nonlinear equation of motion of ROV in body fixed frame required to mathematically model ORCA is given by

$$\mathbf{M}\dot{i} + (i)i + \mathbf{D}(i)i + \mathbf{H_f}(\boldsymbol{\eta}) = \boldsymbol{\tau} \quad (4)$$

where

M is the matrix of mass inertia. This is sum of the added fluid inertia mass and rigid body inertia mass matrix.(i.e)$\mathbf{M} = \mathbf{M}_A + \mathbf{M}_{RB} \in \mathbf{R^{6\times6}}$

$\mathbf{C}(i)$ is the centripetal force matrix and Coriolis which contains the added mass and rigid body terms respectively, (i.e) $\mathbf{C}(i) = \mathbf{C}_A(i) + \mathbf{C}_{RB}(i) \in \mathbf{R^{6\times6}}$

$(i) \in \mathbf{R^{6\times6}}$ is the Damping matrix due to the surrounding fluid.

$\mathbf{H}(\boldsymbol{\eta}) \in \mathbf{R^{6\times1}}$ is used to describe the buoyancy and gravitational force on the ROV.

$\boldsymbol{\tau} \in \mathbf{R^{6\times1}}$ is the thrust vector or total force in a given DoF.

$\mathbf{i} = [\,\mathbf{u\ v\ w\ p\ q\ r}\,]^{\mathbf{T}}$ is the body-fixed velocity vector and

$\boldsymbol{\eta} = [\boldsymbol{\eta}1\ \boldsymbol{\eta}2]^{\mathbf{T}}$ is the orientation vector and Earth-fixed position

where

$\boldsymbol{\eta}2 = [\varphi\ \theta\ \psi\ ]^{\mathbf{T}}$ is the orientation vector of Euler angles and

$\boldsymbol{\eta}1 = [\mathbf{x\ y\ z}\,]^{\mathbf{T}}$ is the position vector.

The mass of the ROV is represented by rigid body mass inertia matrix (M_{RB}) which in turn represents the mass of the ROV and spread of the mass in different directions in terms of moment of inertia.

The inertial force acting on a rotating ROV within an earthly frame of reference is known as the Coriolis force. The ROV will move more slowly because of the hydrodynamic negating force created by the fluid moving around the vehicle as a result of the ROV's motion. When the fluid particles come into contact with the vehicle, they accelerate, which creates these forces and moments. Like "added" mass and inertia, their effect seems to be.

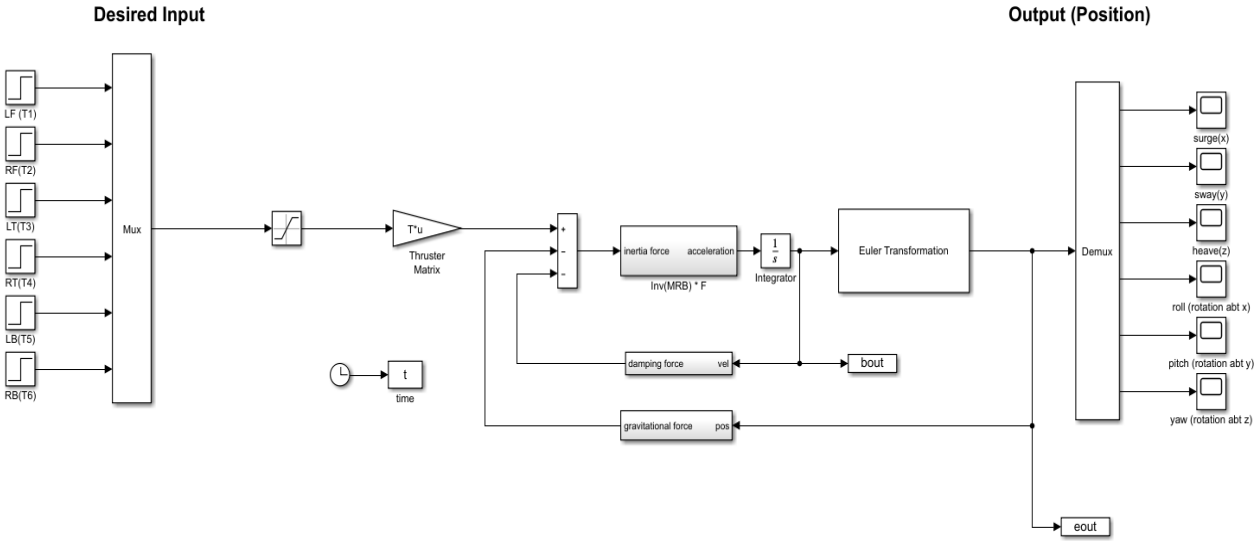

Fig. 4: Block diagram of the Open loop system of the ORCA in SIMULINK

The open loop system is modeled using MATLAB SIMULINK platform as shown in Figure 3. The proposed block diagram consists of

- Thrust configuration block,
- Inertial and added mass block,
- Coriolis and centripetal block,
- Gravitational force block and
- Euler transformation block.

The cause of nonlinearity of the model is because of the external forces that affect the stability and navigation of the system in the underwater environment.

$$\mathbf{i = M{-}1\{\tau - [C}(\mathrm{i})\mathrm{i} + \mathbf{D}(\mathrm{i})\mathrm{i} + \mathbf{H}_{\mathrm{f}}\mathbf{(\eta)]\}} \qquad (5)$$

Equation (5) depicts the subsystems of the model in Figure 4. The acceleration vector is integrated to form the body-frame velocity vector and then further transformed into inertial frame position and orientation vector. By giving the input to the thrusters with their thrust values in kgf, the velocity and position responses are obtained for each of the DOF. These responses are analyzed to study the movement and deviations from the desired set value of the ORCA underwater system when inputs are provided through the joystick control.

Closed Loop System:

A PID controller (with P, I and D control modes) is added to the modeled Open Loop System to make it a closed loop system. The major difference between a closed loop and an open loop system is the presence of a negative feedback loop in the closed loop system which is absent in the open loop system model. Through comparison with the actual situation, closed loop systems are built to automatically achieve and maintain the intended output condition. This is achieved through the generation of an error signal which is the difference between the actual output obtained and the feedback signal.

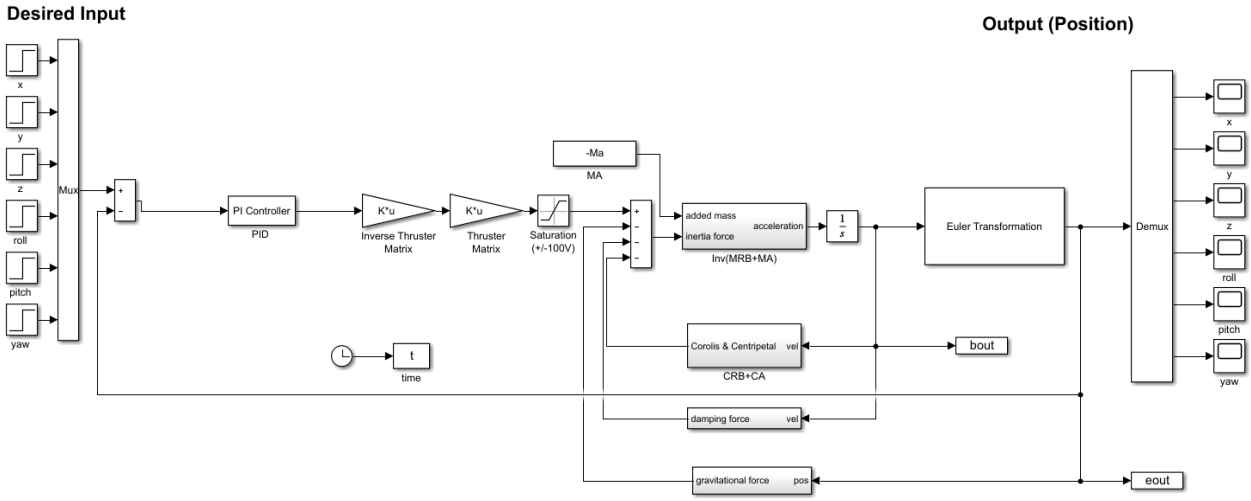

Fig. 5: Block diagram of the Closed loop system of the ORCA in SIMULINK.

The above Figure 5 shows the block diagram of a closed loop system with an additional component of a feedback system from the output to the input side - differing from the open loop system.

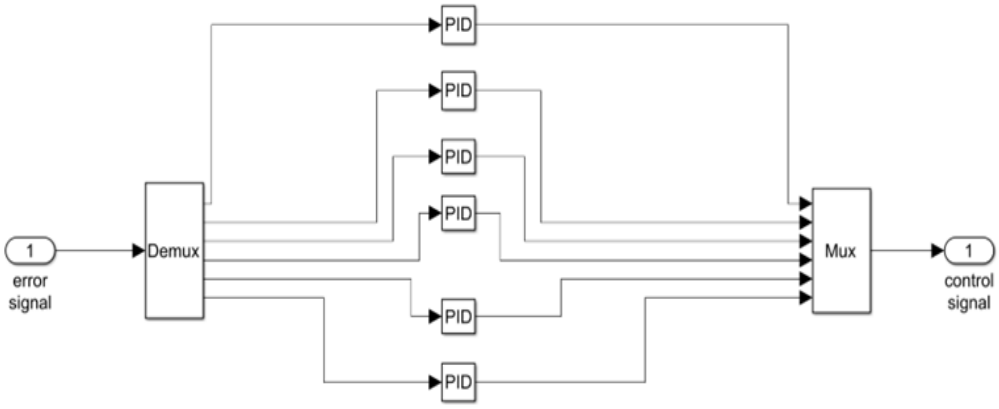

Fig. 6: Elaborated PID controller

All the three modes of the controllers were used to test the position and velocity responses of the closed loop system. The elaborated PID controller of figure 3 is shown in figure 6 below and is used for the study and analysis.

III. TUNING

For a PID controller, the tuning constant "K" depends on the response characteristics of the complete loop external to the controller. Thus, these parameters must be tuned for each application. The method of finding appropriate values for the integral, proportional, and derivative gains of a PID controller to satisfy the design requirements and attain the desired performance is called PID tuning.

Process of Tuning:

Keeping Ki and Kd in Equ (3) as zero, start with a low Kp value (P-gain) and increase it slowly until the performance of the system starts to deteriorate. Back off to a point just below this point. Examine the response obtained with the final Kp value to check for the problems of instability and steady-state error. The Dgain should be tuned if stability issues are the main concern while looking for a P-gain; if steady-state error issues are the main concern, the I-gain should be tuned.

IV. RESULTS AND DISCUSSION

Nonlinear Open Loop Position and Velocity Responses of ORCA

The ORCA system consists of six thrusters for providing movements in the horizontal and vertical plane. These thrusters are T200 models, and their maximum rotational forces are 4.53 kgf and 3.5 kgf in a clockwise direction & anticlockwise direction. For the simulations, shallow water channel is considered with density of 998.2 kg/m^3, a viscosity of 0.001003 Ns/m^2 and pressure 1.02 bar at 25℃ (room temperature). The inputs were given to the thrusters in the SIMULINK model (as kgf values) to simulate the different movements of the ORCA. Input was given at 25%, 50%, 75% and 90% of the maximum possible thrust value. For every input the time variation is from 10 seconds to 300 seconds, and the responses were obtained.

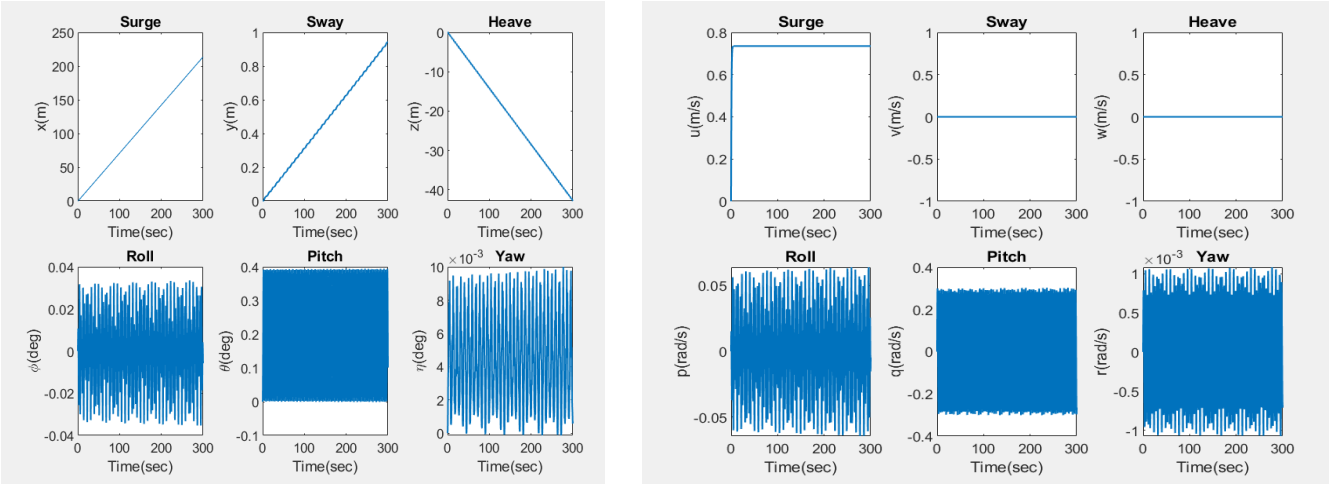

Fig. 7: Position and Velocity responses of Surge forward motion in an open loop system with 50% thrust values.

From Figure 7, it can be observed that the deviations are significantly higher in the untargeted degrees of freedom. This was simulated with 2.265 kgf thrust values given to the thrusters for a period of 300 seconds. The vehicle has moved about 210m in the targeted direction of motion - surge forward. In the other degrees of freedom, significant values and deviations were observed. Similarly, the same can be analyzed for the velocity response. The ORCA maintained a velocity of 0.75m/s from time 0 to 300s and minor disturbances were observed in the untargeted degrees of freedom as shown in Figure 7. A similar pattern was observed when simulated for other directions too.

Nonlinear Closed Loop Position and Velocity Responses of ORCA

ORCA simulations were performed with different controller modes (P, PI, PID) to obtain the velocity and position responses for the different DOF. The closed loop system provides a feedback loop mechanism to minimize the deviations in the output in the non-target degrees of freedom. The feedback system helps in reducing the errors generated in the output in comparison to the actual input provided.

From Figure 8, using the P controller, from the position response ORCA's movement was significant in the surge forward direction and only negligible variations in the other degrees of freedom from 0 to 300 seconds. Similar pattern can be seen in the velocity response - with significant contribution in the surge forward direction. Minor results were also observed in the other degrees of freedom.

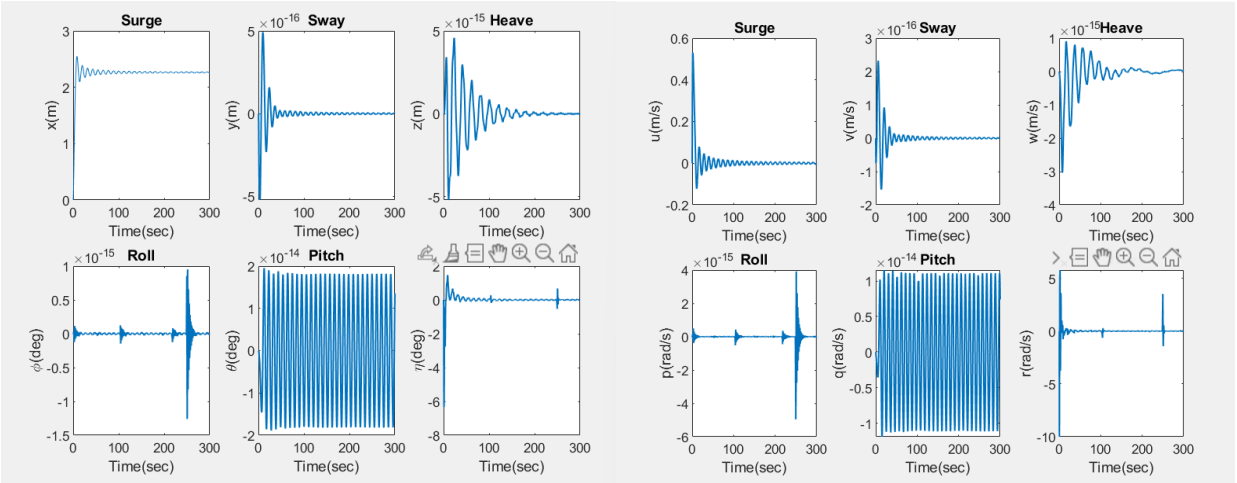

Fig. 8: Shows the position and velocity responses of Surge forward motion in a closed loop system (P controller (Kp = 4)) with 50% thrust values.

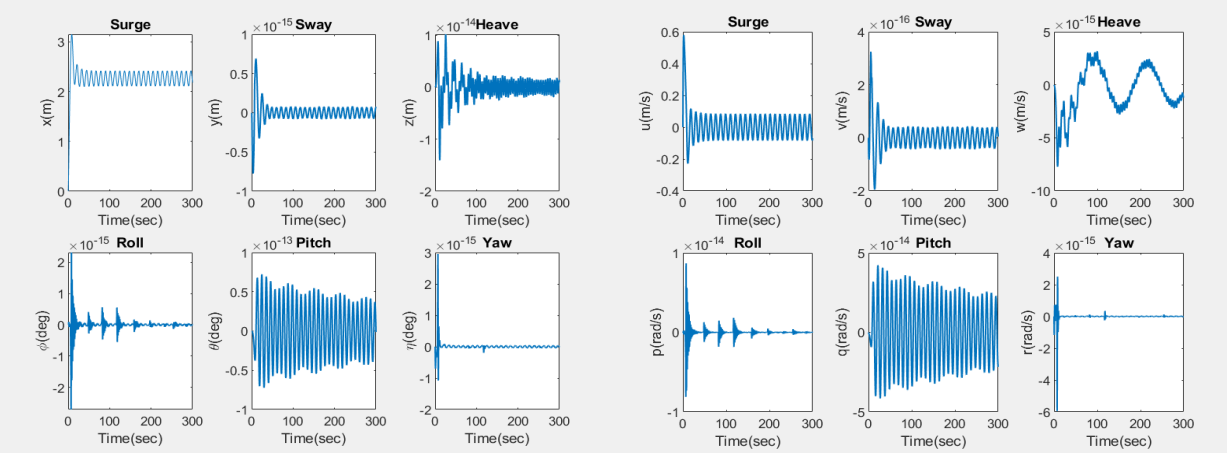

Figure 9: Shows the position and velocity responses of Surge Forward motion in a closed loop system (PI controller (Kp = 4, Ki = 0.5)) with 50% thrust values.

From Figure 9 the response of position and velocity of surge using the PI controller, it is seen that the results are continuous with respect to some oscillations.

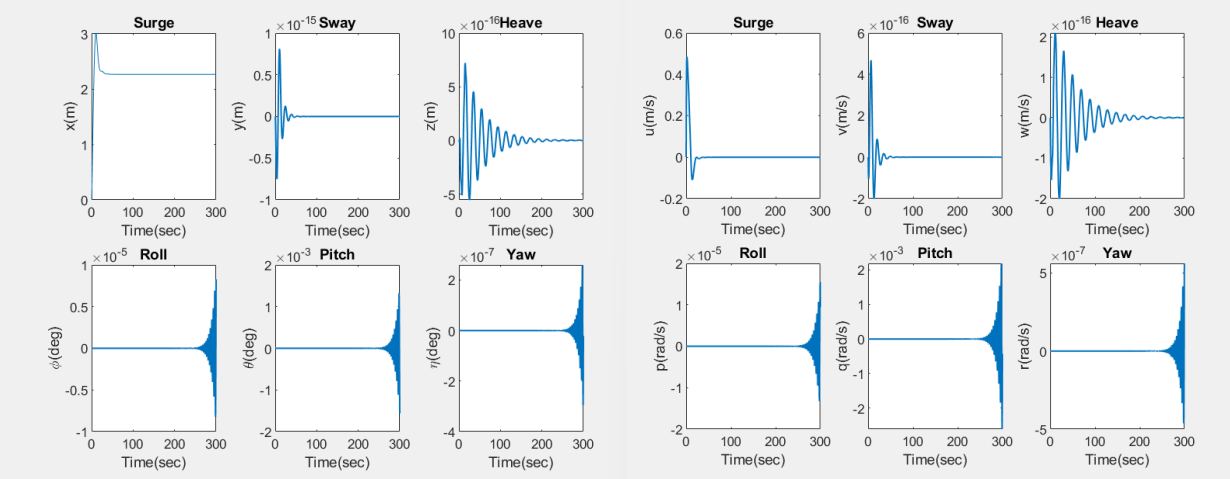

Fig. 10: Shows the position and velocity responses of Surge Forward motion in a closed loop system (Using PID controller, Kp=4, Ki=0.5 and Kd= 6) with 50% thrust values.

From figure 10, the simulations it is observed that the optimal stabilization is obtained through closed loop system with the PID controller with respect to the navigation of the ORCA in the desired direction of movement controlled by the pilot. Similar analysis was performed for all the other sway, heave, roll, yaw and pitch and almost the same results were observed. Hence it is proved and validated that the PID controller closed loop system performs best in for the navigation of the underwater ROV.

V. CONCLUSION

This study presents an analysis of the open loop and closed loop system for an indigenously developed low-cost ROV for inspection applications. The effect of various controllers on the velocity and position responses of ORCA is studied. The different response analysis of an open loop system suggests that, with 50% thrust to the respective thrusters in order to obtain a specified direction of motion, the ROV movement is observed in other directions too. After incorporating the controllers in the system, the analysis shows that these control systems improve the navigation

of the ROV and minimize the changes caused by the external forces in underwater. In additional, a comparison has been performed among P, PI and PID controllers. The PID Controller was found to be optimal and has been successfully implemented in ORCA with feedback from the IMU (Inertial Measurement Unit) about its current position and hence reduce the error and obtains a stabilized navigation.

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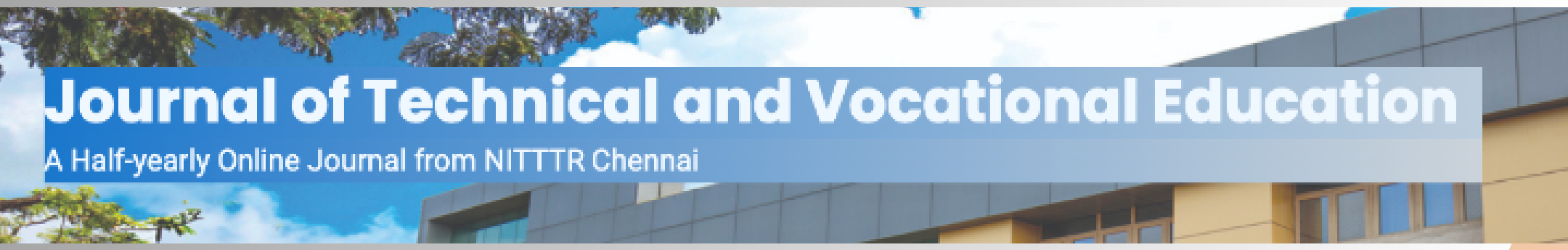

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