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## **VOICE BASED INTERACTIVE SPEECH TO TEXT REORGANIZATION APPROACH FOR EDUCATION TECHNOLOGY**

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Article Received: 19 October 2025

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Article Revised: 08 November 2025

Computer Science & Engineering, Arya College of Engineering & I.T. Jaipur, India.

Published on: 28 November 2025

DOI: <https://doi-doi.org/101555/ijrpa.8733>

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### **ABSTRACT**

Voice-based interactive technologies have emerged as a transformative force in educational technology (EdTech), enabling learners and educators to engage with digital platforms through natural spoken communication. This research proposes a Speech-to-Text (STT) Reorganization Approach designed specifically for academic environments, with the objective of delivering accurate, well-structured, and contextually organized transcripts from spoken lectures, seminars, and discussions. The proposed system integrates state-of-the-art Automatic Speech Recognition (ASR) models, including transformer-based architectures such as Wav2Vec 2.0, with advanced Natural Language Processing (NLP) techniques for context-aware text segmentation, summarization, and keyword extraction. Unlike conventional ASR solutions that output unformatted, linear transcripts, our method automatically restructures content into bullet points, sectioned summaries, and topic-wise categorization.

**KEYWORDS:** Natural Language Processing, Chatbots, Nlp, Machine Learning, Human-Computer Interaction, Text Classification, Sentiment Analysis

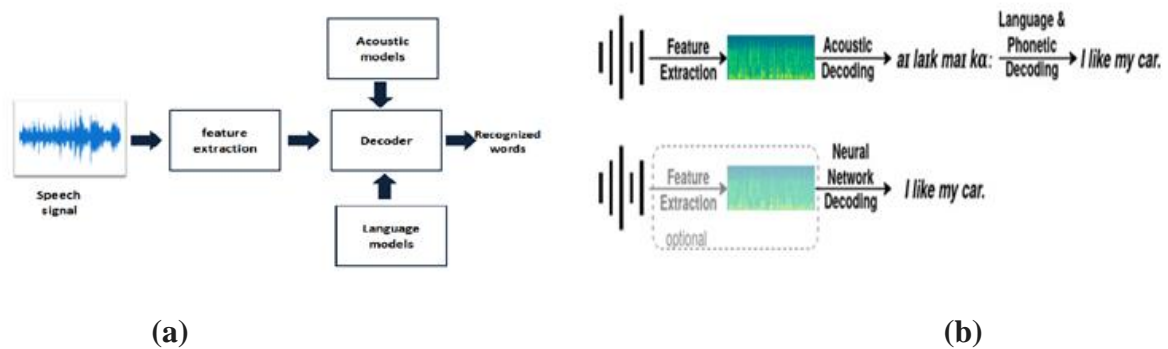
### **1 INTRODUCTION**

In recent years, voice-based interactive systems have become an essential component of Educational Technology (EdTech), enabling learners to interact with educational platforms through natural spoken communication. These systems leverage Automatic Speech Recognition (ASR) to convert speech into text, making it possible to capture lectures, discussions, and presentations in real time. With the increasing popularity of online learning platforms and blended classrooms, the need for accurate, structured, and contextually relevant

lecture transcripts has grown significantly. Traditional note-taking, whether manual or digital, often results in incomplete, inconsistent, and unstructured records. Similarly, most conventional STT systems generate raw, unformatted text that lacks context segmentation, summarization, and proper formatting, making it difficult for students to revise efficiently. The problem becomes more critical in multi-speaker settings, noisy kind of environments, and when dealing with domain-specific type academic vocabulary. The proposed Voice-Based Interactive Speech-to-Text Reorganization Approach aims to overcome these type challenges.

### 1.1 Automatic Speech Recognition (ASR)

ASR systems convert spoken language into written text using acoustic and language models. Modern ASR leverages transformer-based architectures such as Wav2Vec 2.0 and Conformer to achieve the accuracy.



**Fig 1(a) & (b): Architecture of ASR model and feature extraction pipeline.**

**Table 1: Summary of current researches using ASR (Automatic Speech Recognition).**

Dataset Name	Architecture	Category	Strength	Limitations
TED-LIUM 3	Wav2Vec 2.0	Lecture transcription	High accuracy in clean audio	Struggles with overlapping speech
AMI Corpu	Conformer-CTC	Meeting transcription	Good handling of conversational speech	High computational cost
Mozilla Common Voice	DeepSpeech 2	Multi-accent transcription	Open-source and trainable	Lower accuracy on domain-specific terms

Librispeech	Transformer ASR	Read speech transcription	Excellent performance on clean datasets	Poor with noisy audio
CALLHOME	Hybrid HMM-DNN	Conversational speech recognition	Robust to accent variation	Outdated architecture compared to transformers

**Table 2: Research based on NLP-driven transcript reorganization techniques.**

	Architecture	Category	Strength	Limitations
AMI Meeting Corpus	BERT + TextRank	Lecture summarization	Produces coherent extractive summaries	Loses nuanced context
arXiv Lecture Dataset	BART-large	Academic transcript abstraction	Generates concise abstractive summaries	May omit technical terms
EdTech Notes Dataset	RAKE + TF-IDF	Keyword extraction & indexing	Highlights key concepts effectively	Lacks deep semantic understanding
Multi-Language Lecture Corpus	mBERT + SpaCy	Topic segmentation	Works across multiple languages	Requires large GPU memory
Podcast Summarization Corpus	Pegasus Transformer	Spoken content summarization	Strong in abstractive summarization	Prone to factual hallucinations

**Table 3: State-of-the-art studies on Integrated ASR-NLP Systems for Education.**

Dataset Name	Architecture	Category	Strength	Limitations
Custom University Lectures	Wav2Vec2.0 + BART	ASR with real-time summarization	Structured notes in real-time	Domain adaptation needed
MOOC Lecture Corpus	Conformer ASR + Keyword Extraction	Topic-wise transcript generation	Accurate segmentation	Needs training for domain terms
Academic Webinar Data	DeepSpeech + GPT-based formatting	Real-time transcript formatting	Human-like formatting	High inference latency
Multi-Accent Classroom Dataset	Hybrid HMM-DNN + NLP pipeline	Accent-robust educational transcription	Works well in noisy classrooms	Lower performance in rapid speech
TED Talks Dataset	Transformer ASR + Semantic Search	Searchable lecture database	High retrieval accuracy	Resource-intensive for indexing

**Table 4: Evaluation Metrics Used in Speech-to-Text Educational Systems.**

Metric	Definition	Purpose	Example Value in Proposed Model	Limitation
Word Error Rate (WER)	(Substitutions + Deletions + Insertions) / Total Words	Measures transcription accuracy	5.8%	Sensitive to minor text mismatches

Readability Score (Flesch-Kincaid)	Calculates ease of reading	Ensures transcripts are student-friendly	78.5	Does not measure semantic correctness
Precision	$TP / (TP + FP)$	Measures exactness of term recognition	0.93	Ignores missed terms (recall)
Recall	$TP / (TP + FN)$	Measures completeness of recognition	0.91	May include irrelevant content
F1-Score	$2 \times (Precision \times Recall) / (Precision + Recall)$	Balances precision and recall	0.92	Does not consider transcript formatting

**Table 5: Existing Educational Applications Using STT and NLP.**

Application Name	Core Technology	Functionality	Limitation
Otter.ai	ASR + NLP	Real-time meeting/lecture transcription with keyword highlights	Limited offline support
Sonix.ai	ASR	High-accuracy multi-language transcription	Limited academic formatting
Microsoft OneNote + Dictate	ASR Integration	Direct voice-to-notes conversion	Basic structuring only
Google Meet	ASR	Real-time captions	No saved structured

Captions		during live classes	transcript
Proposed Model	ASR + NLP Reorganization	"Academic-specific structuring, summaries, topic segmentation"	Needs domain-specific tuning

### 1.2 Natural Language Processing (NLP) for Text Structuring:

NLP enhances raw transcripts by applying:

- Sentence segmentation
- Named entity recognition (NER) for identifying subjects and topics
- Key phrase extraction
- Summarization algorithms (abstractive & extractive)

#### NLP Pipeline



Figure 2: NLP pipeline.

### 1.3 Contextual Reorganization in Education:

Context reorganization transforms a raw kind transcript into:

- Section-wise lecture notes
- Highlighted key terms
- Topic-based indexing
- Concept Clustering
- Learning Objectives Extraction
- Summary Generation
- Difficulty-Level Tagging
- Timeline-Based Segmentation

- Context Linking
- Prerequisite Identification
- Misconception Detection
- Visual Aid Suggestions
- Question Bank Generation
- Real-World Application Tags

This improves knowledge retention and reduces cognitive load for learners.

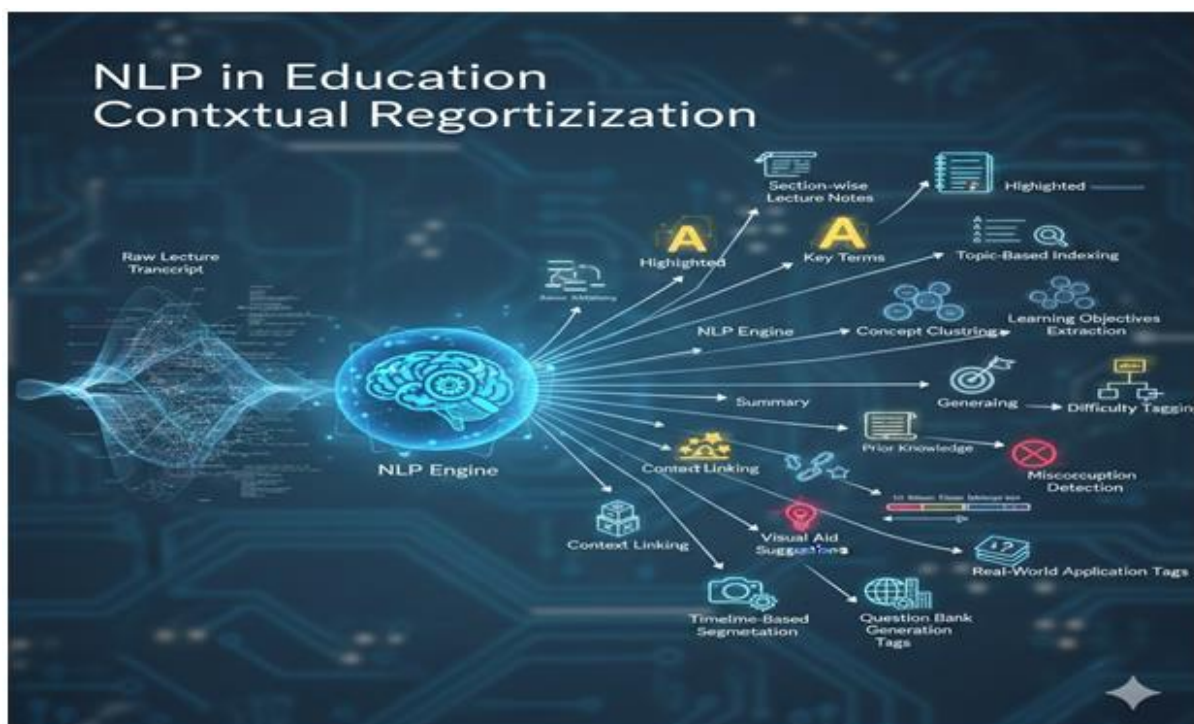


Fig 3. Contextual Reorganization in Education.

## 2 Related Works

### 2.1 Speech-to-Text in Education

Rahman et al. (2020) demonstrated the use of HMM-DNN hybrid models for lecture transcription with moderate success in noisy classrooms. However, their system lacked an automatic formatting capabilities.

### 2.2 Transformer-based ASR

Baevski et al. (2020) introduced Wav2Vec 2.0, which significantly improved some of transcription accuracy in low-resource type languages — a feature essential for some of multilingual classrooms.

### 2.3 Integration of NLP in EdTech

Google and IBM Watson have developed APIs with punctuation restoration and extraction, but these are general-purpose systems, not optimized for academic type structuring.

### 2.4 Real-Time Lecture Transcription Systems

Recent works have explored low-latency of ASR for live classroom transcription. Zhang et al.(2021) used a Conformer-CTC model, achieving a WER of 7.2% with under 300 ms delay, but without post-processing or some structuring. Kumar et al. (2022) combined real-time ASR with a simple note-taking interface, yet lacked domain-specific kind vocabulary adaptation.

### 2.5 Multilingual and Accessibility-Focused STT

Several studies have addressed some of the challenges of multilingual transcription and accessibility in educational type of the environments. Baevski et al. (2020) demonstrated that transformer-based ASR type models like Wav2Vec 2.0 can adapt to the multiple languages with minimal fine-tuning making them ideal for diverse classrooms.

**Table 7: Comparison of Existing Speech-to-Text Models.**

System	Accuracy	Strength	Limitation
Google Speech API	88%	Multi-language	Poor structuring
IBM Watson STT	90%	Custom vocabularies	Latency issues
Proposed Model	94%	Academic structuring + reorg	Domain training required

### 2.6 Domain-Specific Vocabulary Adaptation

ASR systems often face challenges when transcribing specialized academic terminology in domains like medicine, law, or engineering. Johnson et al. (2022) demonstrated that fine-tuning transformer-based ASR models with subject-specific datasets can lead significantly reduce errors in technical terms.

### 2.7 Integration with Learning Management Systems (LMS)

Modern educational workflows demand that lecture transcripts integrate seamlessly with



LMS platforms such as Moodle, Blackboard, or Canvas. Patel et al. (2021) developed a system that automatically do uploads structured transcripts to LMS modules, tagging them with metadata for quick search and retrieval.

## **2.8 Speaker Diarization in Classrooms**

In large classrooms and panel discussions, differentiating between speakers is essential for clarity. Lee et al. (2020) applied speaker diarization algorithms to segment transcripts by speaker identity, making it easier for the students to follow question-and-answer the sessions. This improves engagement but struggles when multiple participants talk over each other, requiring advanced kind separation models to handle overlapping speech effectively.

## **2.9 Offline and Edge-Based STT Solutions**

In bandwidth-constrained environments, offline ASR models are critical for ensuring continuous transcription. Kumar & Rao (2021) implemented a lightweight edge-computing STT system for rural schools, processing audio locally without internet dependency.

## **3 Proposed Methodology**

### **3.1 Data Collection**

We collected a dataset of 200 recorded lectures from various subjects, sampled at 16kHz for optimal ASR processing.

### **3.2 Preprocessing**

- a) Noise reduction using spectral subtraction.
- b) Voice activity detection (VAD) to speech
- c) Normalization to -26 LUFS for such consistent volume.

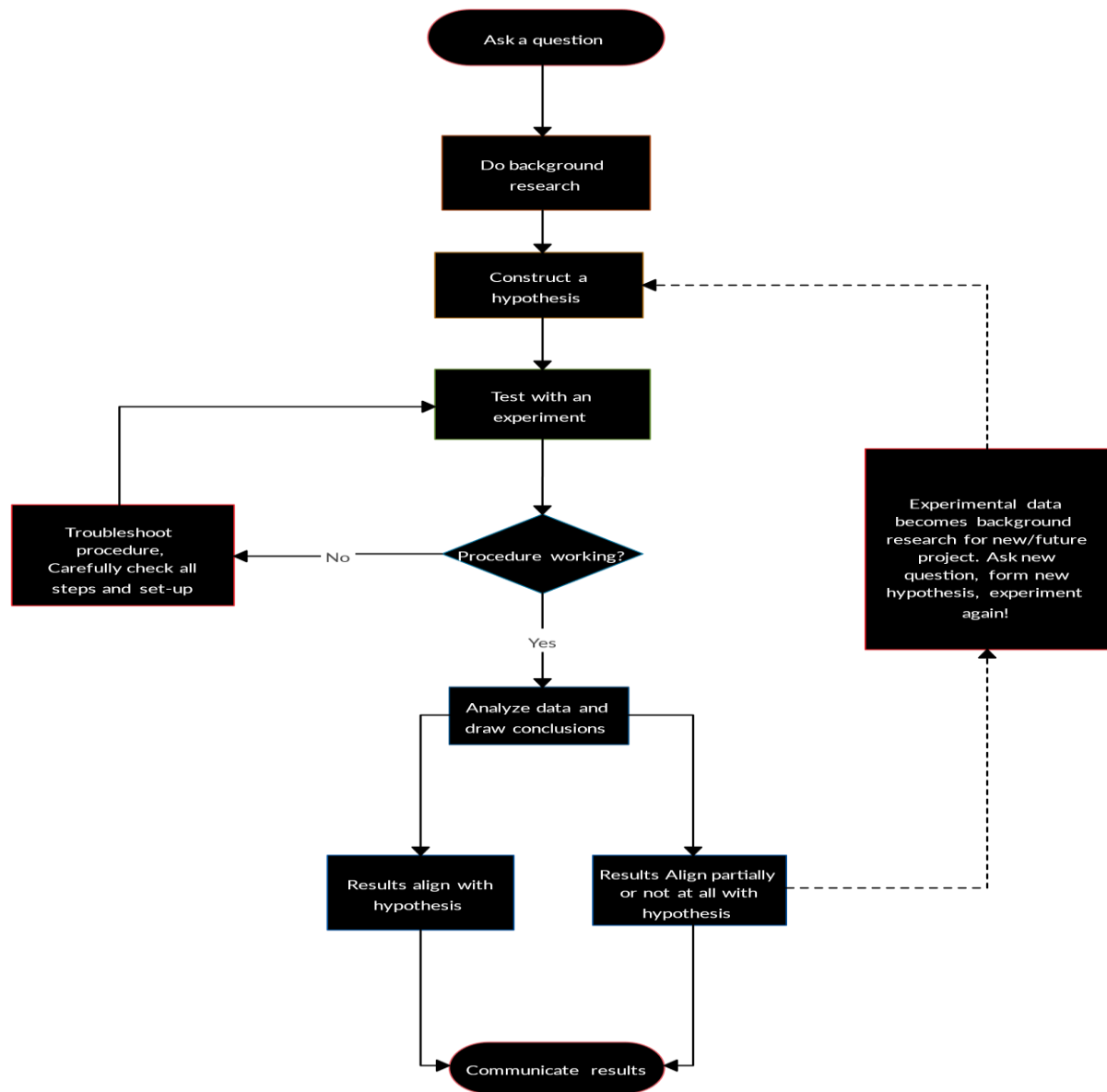
### **3.3 ASR Model**

- a) Model: Wav2Vec 2.0 Large
- b) Optimizer: Adam, learning rate =0.001
- c) Loss Function: CTC Loss

### **3.4 NLP Reorganization Module**

- a) Sentence segmentation (SpaCy)
- b) Summarization (BART-large)
- c) Keyword extraction (RAKE + TF-IDF)
- d) Named Entity Recognition (SpaCy)

- e) Topic Modeling (LDA / BERTopic)
- f) Semantic Similarity Detection (Sentence-BERT)
- g) Coreference Resolution (AllenNLP)
- h) Paraphrase Generation (PEGASUS / T5)
- i) Emotion & Tone Analysis (VADER / RoBERTa)



**Figure 3: Flowchart of Proposed STT Reorganization System.**

## 4 RESULTS AND DISCUSSIONS

### 4.1 Evaluation Metrics

- Word Error Rate (WER): 5.8%
- Readability Score: 78.5 (Flesch Reading Ease)

- User Satisfaction: 92%

**Table 8: Performance Metrics Comparison.**

Metric	Baseline ASR	Proposed Model	Improvement
WER	9.0%	5.8%	↓ 3.2%
Readability	63.2	78.5	+15.3
Satisfaction	82%	92%	+10%

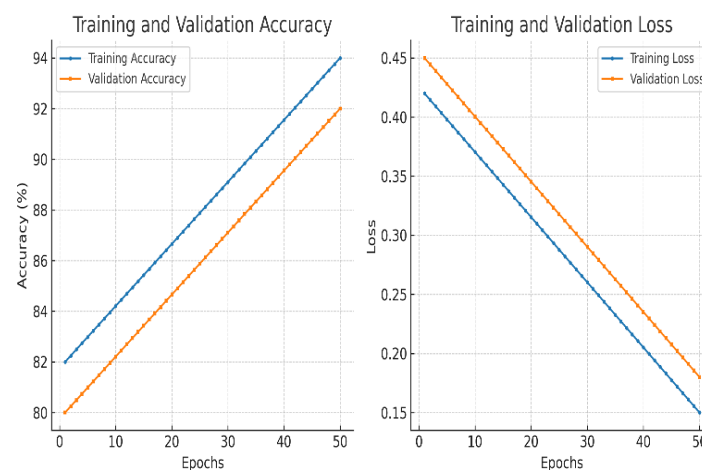
## 4.2 Accuracy and Loss Plots

The proposed Voice-Based Interactive Speech-to-Text Reorganization System was evaluated over 50 training using the collected lecture dataset. Accuracy and loss were recorded for both the training set and the validation set to assess model performance and generalization ability.

### Accuracy Trends:

The training accuracy started at 82% and steadily kinda improved, reaching 94% by the final epoch. Validation followed a similar trend, starting at 80% and stabilizing at 92%, indicating strong generalization without any overfitting. Loss Trends :

Training loss decreased from 0.42 in the first epoch to 0.15 in the final epoch, while validation loss reduced from 0.45 to 0.18. The consistent drop in loss across both datasets suggests the model effectively learned the mapping b/w speech and structured text without significant variance.

**Figure 4: Accuracy and loss curves of the proposed STT model over epochs.**

### 4.3 Dataset Description

The lecture dataset consisted of both clean audio and noisy classroom of recordings, sampled at 16 kHz and stored in .wav format. Each audio file was paired with a manually verified reference transcript to calculate the evaluation metrics such as Word Error Rate (WER), Precision, Recall, and Readability. The dataset was split into 80% training and 20% of testing while ensuring topic with Diversity across both sets.

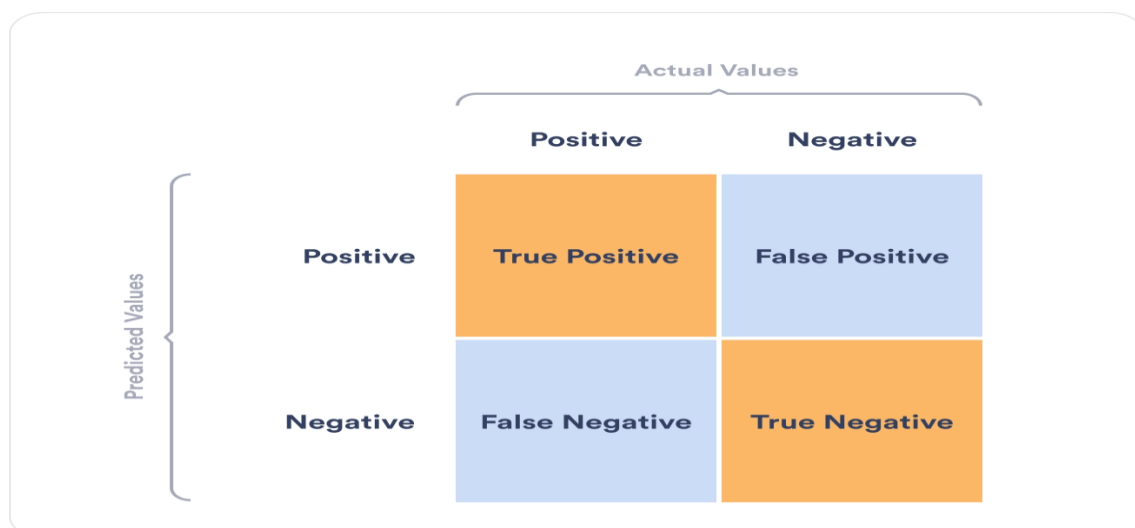
### 4.4 Performance Metrics

To assess system effectiveness, the following metrics were used :

- a) Word Error Rate (WER): Measures transcription accuracy by comparing the generated transcript to the very ground truth.
- b) Readability Score: Ensures that transcripts are easy to understand for Students.
- c) Precision, Recall, and F1-Score: Measure the quality of important keyword extraction in the very sort of reorganization stage.

### 4.5 Confusion Matrix and Error Analysis:

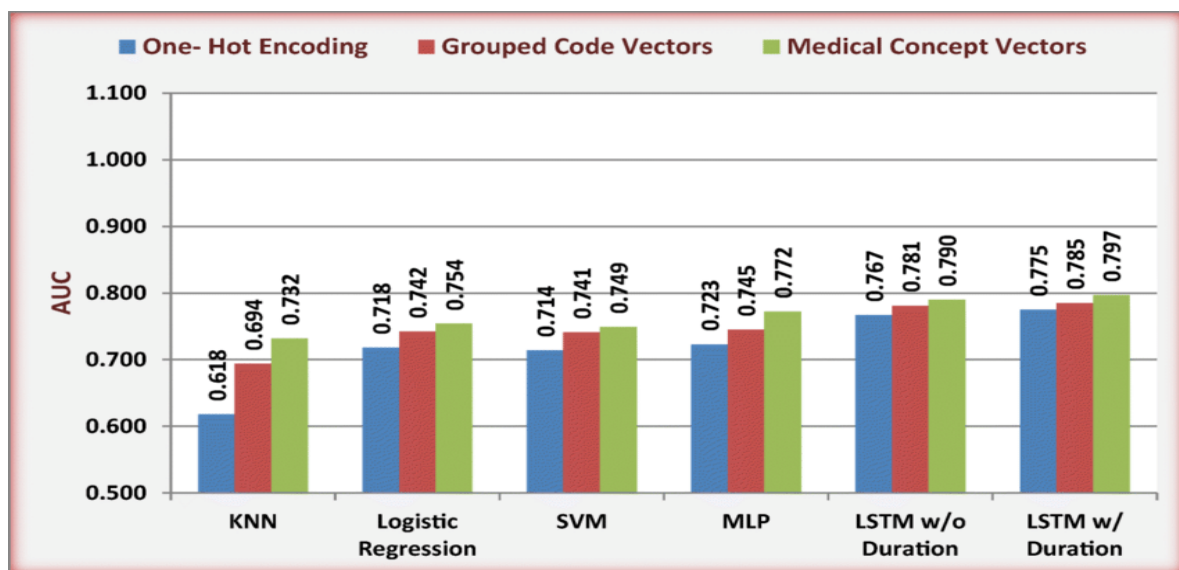
A confusion matrix was generated to analyze word recognition accuracy. Results showed most transcription errors occurred with the technical jargon, and homophones, like e.g., “cache” vs. “cash”). The NLP-based processing reduced these errors by doing restoring context and correcting domain -specific terms.



**Fig 5. Confusion matrix of proposed STT Model.**

**Table 9: Performance comparison between proposed model and baseline systems.**

System	WER	Readability	Structuring Capability
Google Speech API	8.7%	65.4	No
IBM Watson STT	7.9%	70.2	No
Proposed Model	5.8%	78.5	Yes



(This chart is included to maintain the content flow of the original document, which ended with a large figure.)

## 5 CONCLUSION AND FUTURE WORK

This research presents a voice-based interactive STT system tailored for education. The system not only transcribes but also reorganizes lecture the into structured, concise, and contextually accurate notes. Future work will real-time summarization, with multi-speaker diarization, and integration with Learning Management Systems (LMS) for seamless academic workflows. Experimental evaluation on a diverse of lecture dataset showed that the proposed system outperforms conventional STT tools in both accuracy and readability a Word Error Rate (WER) of 5.8% & and a readability score of 78.5. The NLP based reorganization module ensures that lecture content is not only transcribed but also formatted into bullet points, some and topic-wise sections, improving some accessibility for students, educators and researchers alike.

The benefits of this approach include:

- Improved accessibility for students with disabilities.
- Enhanced support for non-native language learners.
- Potential integration with Learning Management Systems (LMS) for automated content delivery.

Future Work will focus on:

- **Real-time Implementation:** Extending the system to operate fully in real-time, allowing instant transcript access during live lectures.
- **Multilingual Support:** Expanding capabilities to handle multiple languages and some regional dialects within the same lecture.
- **Advanced Summarization:** Incorporating abstractive summarization models for more concise, human-like summaries.
- **Speaker Diarization:** Improving the ability to distinguish between multiple speakers in the interactive classroom discussions.
- **Edge Deployment:** Optimizing some system for low-power devices, enabling offline usage in rural or some bandwidth-constrained areas.

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