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1 Chapter 1

1.1 Introduction

Through the last ten years, the definition of education has been constantly changing. With emerging technology, education has been able to take various forms. Due to the unforeseen events in early 2020, all forms of education had to adapt to the online medium using distance learning platforms such as Zoom, Google meet and Microsoft Teams (Pal et al., 2021). The transition from full-time learning to distance learning is shown to produce a certain "stress" that can hamper the students' learning outcome (Zinovieva et al., 2021). Good teaching itself doesn't vary as the mediums changes but translating these teachings over to a online medium brings unique challenges (Driscoll et al., 2012).

According to a survey at Kyiv National Economic university, of the bachelor level computer science students, it was discovered that 73% of the students had problems with distance learning (Zinovieva et al., 2021). Figure 1.1 shows the most common problems the students faced. Interaction has been deemed as an essential component for online education to succeed (Driscoll et al., 2012). Figure 1.1 highlights support and consulting from teacher as the main problem among students of online education which supports the importance of interaction in an online setting.

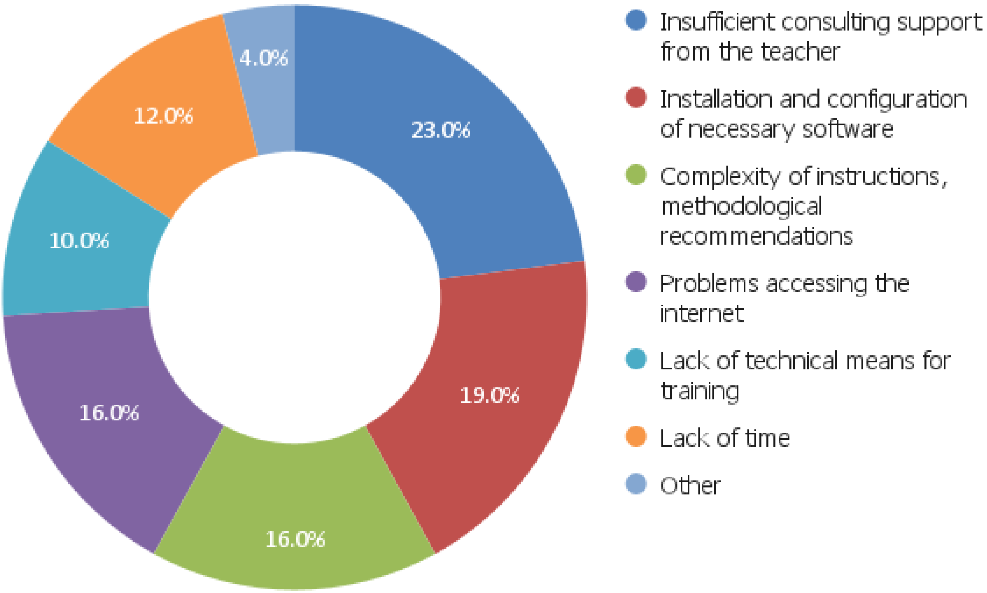


Figure 1.1.1: Problems faced by students of computer science during distance learning (Zinovieva et al., 2021)

Online education for programming produces outcomes worse than that of regular classes. It has been proven that students that learn programming through online education or E-learning have outcomes that lag behind students learning the same course in regular classes

(Fojtik, 2017). As shown in Figure 1.1, online education for computer science brings along challenges that results into difference in outcomes against full-time students. Online education looses the spontaneous feedback between instructors and learners (Martin, 2019)

The main scope of the system will be in the online education field targeting the programming courses. There will be two users facilitated by the system, instructors and learners. It has been found that online course when designed with maximizing interaction between instructors and learners in mind can be as effective as face to face classes (Driscoll et al., 2012). Therefore, this system aims to provide a platform to learn coding online with a focus on interaction and communication between instructors and learners.

1.2 Problem Statement

- Existing applications used to learn to code online provide fewer features for real-time editing of code.
- Existing applications have fewer models for users to pass on notifications to their instructors by highlighting the point at which they encounter anomalies in their code.
- Existing application require users to install and configure necessary software before they can learn to code online.
- Fewer systems have diverse accessibility control options such as view only and can edit.

1.3 Objectives

- To create a real-time application using WebRTC and Websockets.
- To provide the feature of real-time editing that an instructor can access to solve a learner's problem.
- To make use of flags with the help of which learners can notify any problem.
- To provide a platform for learning to code without having the need to setup and configure programming environments.
- To execute the written code with Judge0 API (Application Programming Interface) and display the output.
- To create an audio channel of communication between instructors and learners.
- To include diverse control options within the system.

1.4 Scope

1.4.1 User scope

- Users will be able to host a room where learners can join in if the user is an instructor.
- Users will be able to communicate through text and audio interfaces.
- Users will be able to execute code within the system.
- Users will be able to share their code with other users in the system with varying permissions.
- Users will be able to edit code of their learners in real time.

1.4.2 System Scope

- System will provide users to communicate through text and audio interfaces.
- System will allow users to share their code with others with permissions such as can edit and can view.
- System will provide users to code online without any previous setup.
- System will enable real time editing of code.
- System will allow instructors to create a room for learners to join in.

1.5 Constraints

- The system will use Monaco Editor as the code editor which is not supported in mobile browsers or mobile web frameworks.
- Access to internet itself can be a limitation to the system as it is a web application and uses UDP protocols and sockets to form the communication bridge between instructors and learners.
- The support for WebRTC can be a limitation to the system as it is not supported in browsers such as Internet Explorer (IE), Opera Mini and UC browser for Android (*"web Rtc " | Can I Use... Support Tables for HTML5, CSS3, Etc*, n.d.).

1.6 Methodology

Real-time features implemented with optimized resource consumption will ensure that the communication between the instructor and learner remains stable. WebSockets are known to work with better network performance and greater throughput when comparing against AJAX (Asynchronous JavaScript and XML) (Puranik et al., 2013). Therefore, the real-time editing feature will be implemented using WebSockets through socket.io library and the communication channel with the audio interface will be implemented through WebRTC (Web Real-Time Communication) using the UDP protocol (User Datagram Protocol). This application will make use of an event-driven programming paradigm as every change made in a user's editor will trigger an event that can be broadcasted with the help of WebSockets using Socket.IO. The project will be using a signaling server to initiate a connection between the users while the real-time data exchange for communication will be done through peer-to-peer communication through WebRTC.

1.7 Development tools

The development tools to be used in the system are as follows:

1. Socket.IO library: This library provides higher level API (Application Programming Interface) to work with WebSockets. This library will be used to facilitate real time editing of code by broadcasting the changes made in the Monaco editor.
2. NestJS: It is a framework for building scalable server-side Node.js application. The project will use this framework to create the back-end and its API.
3. Next.js: It is a React framework that allows users to choose between Server Side Rendered (SSR) or Static Site Generation (SSG) strategy on a per page basis. The project will use this framework for creating the user interface of the system.
4. Monaco editor: This library provides a text editor similar to that of Visual Studio Code for the web. The project will use this library to create text editor for users to write code in and the library also provides events for when the code written changes which can be used to broadcast the changes for real time editing feature.
5. PeerJS: This library is a higher level wrapper over the WebRTC API that simplifies peer-to-peer (P2P) data, video and audio calls. The project will use this library to establish the P2P connection between the users for text and audio communication.

1.8 Structure of Report

The structure of report outlines the entire format of the paper. The paper consists of six chapters and the contents of the chapters are described below:

1. Chapter 1: This chapter gives a brief outline about the methodology used in the system, and gives description about the problem and objective the project is trying to achieve.

2. Chapter 2: This chapter provides review about the literature that has already been written in the related field of the paper topic.
3. Chapter 3: This chapter gives detailed description about the methodology used to achieve the paper's objective and the different software tools and the reasons behind using the said tools.

1.9 Conclusion

There exist a gap between distance learners and face-to-face learners specially in terms of programming subjects. It has also been proven that interaction plays a major role in success of distance learning. Taking this problem into consideration this project aims to facilitate better communication between instructors and learners in the context of learning to code online. The project will provide real-time interaction using WebSockets and communication channel with audio interface through WebRTC.

2 Chapter 2

2.1 Background study

Education in virtual classroom requires higher effort to remain motivated to learn when compared to a face-to-face classroom (Mihai, 2014). Due to the lack of real presence of learners, instructors in virtual classroom require more effort to gather attention of learners (Mihai, 2014). This problem is present in online education of every study but it is amplified in the field of studies that emphasizes more on practical aspects like computer science (Zinovieva et al., 2021). The author also presents that the transition to online education from a face-to-face lecture further distances students from the course, their peers and teachers ultimately introducing a certain “stress” that affects their learning. It has been noted that the presence of a community and its support is essential to maintain students’ engagement in virtual education programs (Berry, 2017; Rovai, 2003). Past literature have defined community as a social group that is credited to managing stress and decreasing isolation (Pyhältö et al., 2009; Stubb et al., 2011; Berry, 2017). Emphasis on building a community gives rise to a collaborative learning process. It has been proven that collaborative learning provides benefits over individual learning (Nokes-Malach et al., 2015). Collaborative learning enables communication between peers, discussion of ideas and the opportunity to question and exchange ideas which motivates learners to be active (Laal, 2013). Collaborative learning will be focused on the system through the use of audio and text communication with real-time editing features that will encourage students to take direct feedback from their peers and their teachers.

2.1.1 Virtual classroom and collaborative learning

Past literature in the field of education comparing virtual and face-to-face classrooms have shown dissimilarities. Some literature suggests virtual classrooms cannot be considered equal to face-to-face classrooms due to its lack of non-verbal communication and real presence that affects motivation levels (Mihai, 2014). In contrast, other suggest that with the proper teaching strategies online learning can be very effective (Berry, 2019). It has been agreed that collaborative approach to learning is the key to succeed in both online and face-to-face classrooms (Laal, 2013; Laal & Laal, 2012). In both environment, students try to seek out entertainment and social interaction which can directly affect their motivation to learn in the said environment (Fisher & Coleman, 2001). While designing a platform to enable distance learning, the aspect of social interaction must be considered and can be facilitated through e-mail attachments, instant messaging, newsgroups, synchronous real-time environments, and personal Web pages (Fisher & Coleman, 2001). Instant messaging and audio/video conferencing can be the tools needed for replicating verbal interaction and allow better collaborative work (Repman et al., 2005). Due to the importance of audio and video conferencing it has been deemed as a functional requirement of every virtual classroom (Rehman & Khan, 2016).

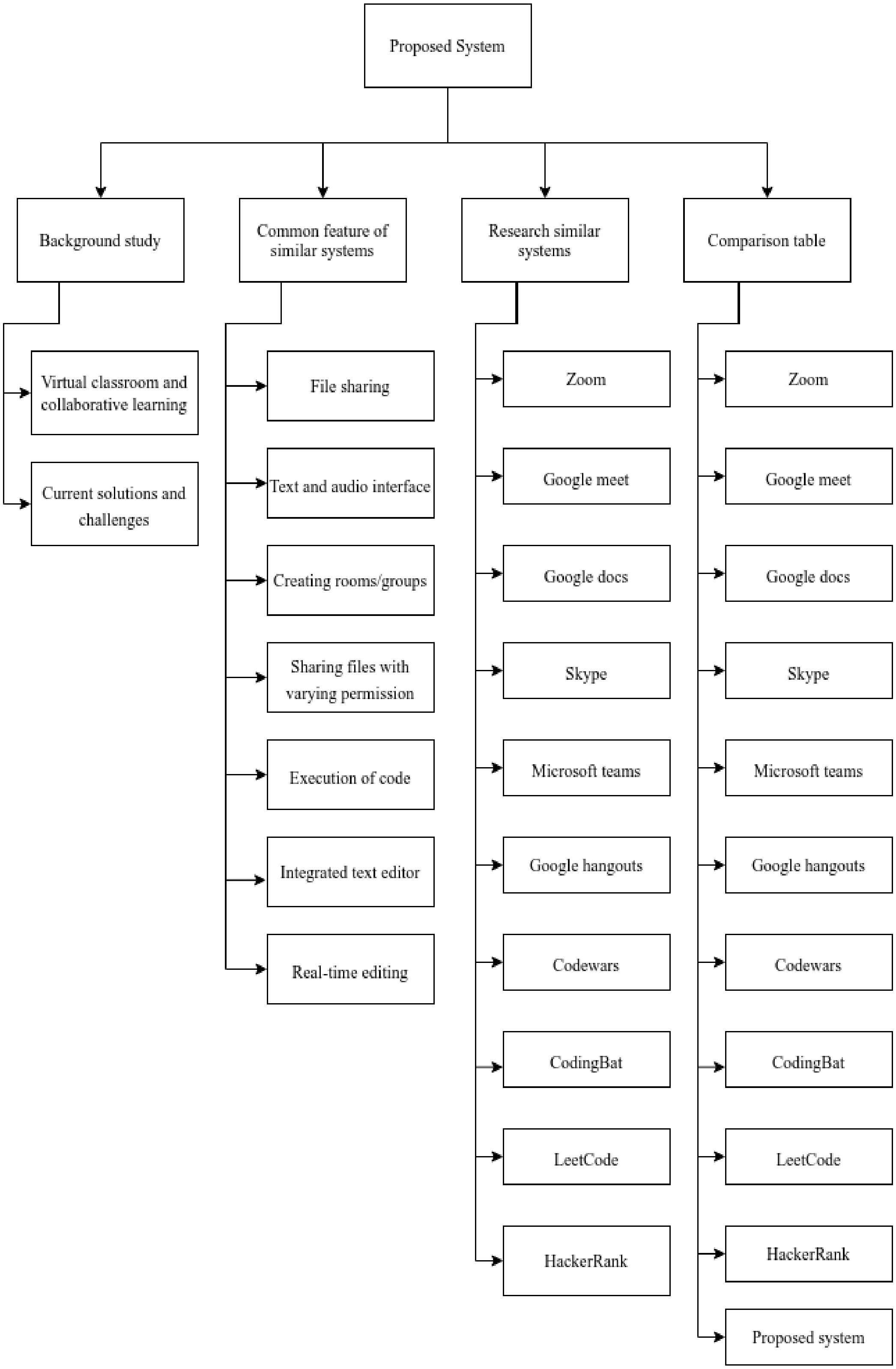


Figure 2.1.1: Literature Framework

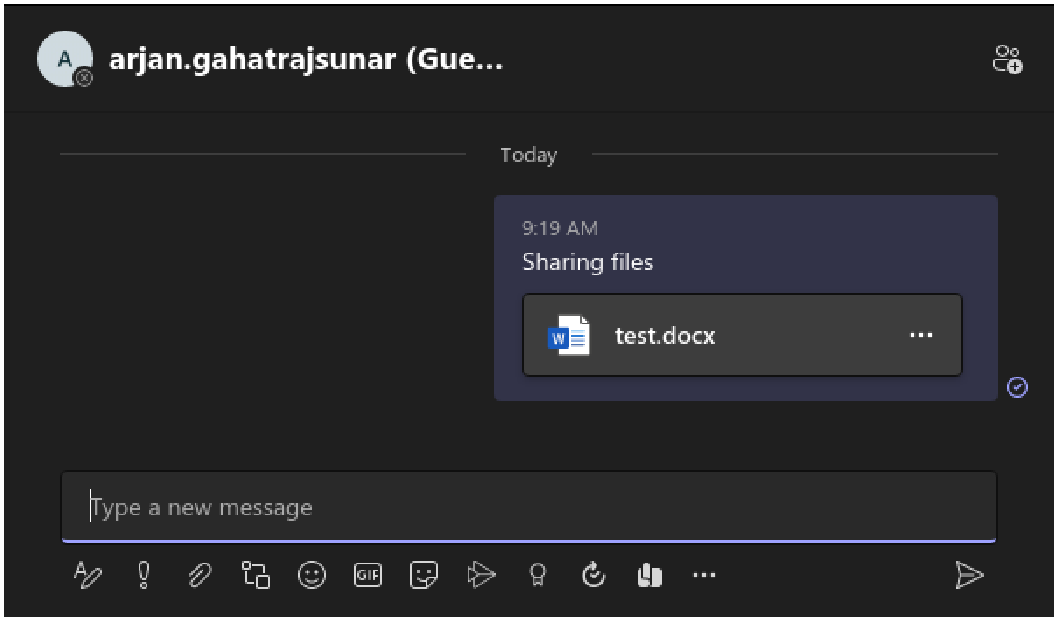
2.1.2 Current solutions and challenges

The synchronous meeting applications such as Zoom, Google meet, Cisco Webex, Skype, ClickMeeting, Adobe Connect, Free Conference, Big Blue Button, Microsoft teams, VEDAMO virtual classroom, Google Hangouts are being used for virtual classrooms (Deepika et al., 2021). During the process of adapting to the virtual environment several challenges emerged. From the side of students it was discovered that they had a tendency for isolation and lack of motivation and from the side of teachers they experienced lack of control over learners and couldn't use their communication skills (Deepika et al., 2021). Also during the use of Zoom for distance learning, students were less willing to nominate themselves to respond to questions and it was hard to monitor learners engagement with larger classes (Moorhouse, 2020). This method for distance learning had potential security issues. In case of Zoom, 'Zoombombing' where a live class gets intentionally hacked was a major security issue (Kohnke & Moorhouse, 2020). While meeting applications have been the main substitute for classrooms, judge applications such as codewars, codehunt, codingbat. Codeboard, pythonchallenge, Leetcode, Hackerrank have been advantageous for online learning at one's own pace (Wasik et al., 2018).

2.2 Common features of similar systems

The similar features of existing systems used to educate programming online are follows:

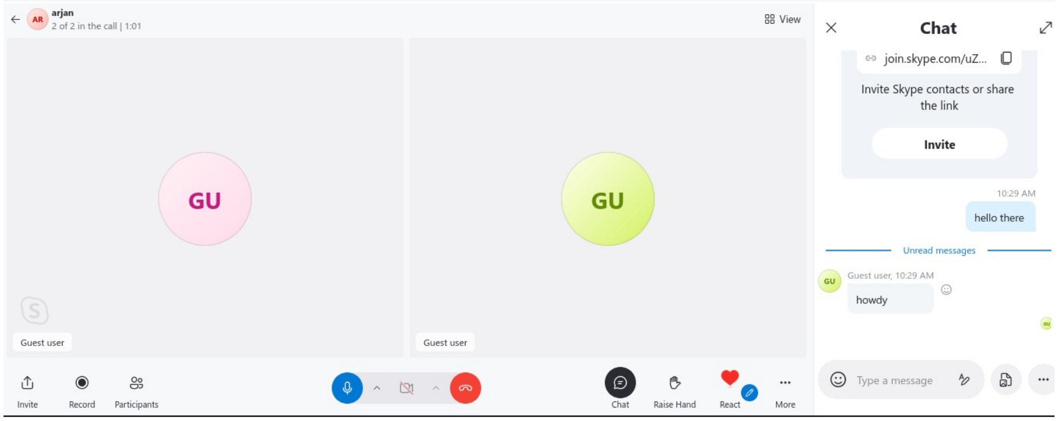
a) File sharing: Systems that support online education enable users to share files with other users allowing users to share their solution and promote collaborative learning.



9:19 AM
Sharing files
test.docx

Figure 2.2.1: Sharing files in Microsoft teams (*Video Conferencing, Meetings, Calling | Microsoft Teams*, n.d.)

b) Text and audio interface: This feature enables communication and interaction between users of the system.



Invite Skype contacts or share the link

10:29 AM

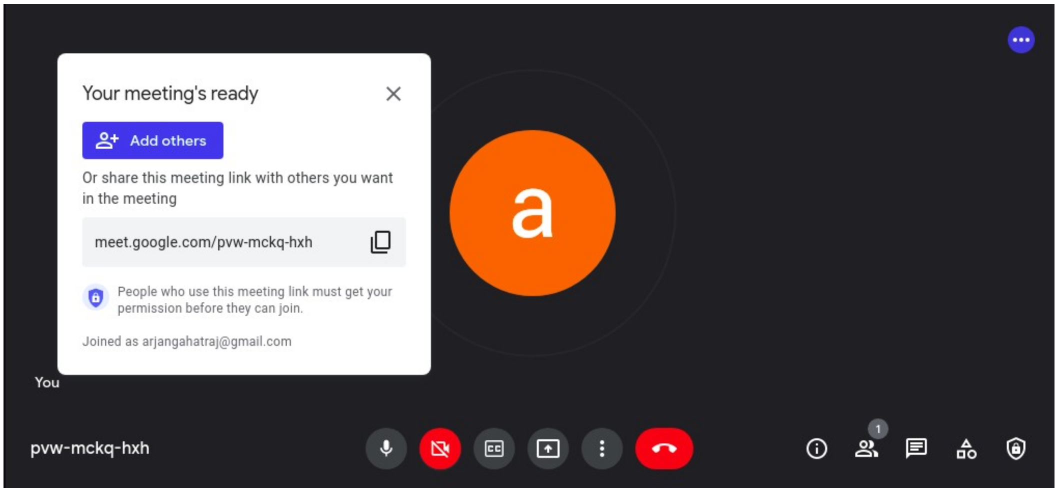
hello there

Guest user, 10:29 AM

howdy

Figure 2.2.2 : Skype's Audio and text interface (*Skype | Stay Connected with Free Video Calls Worldwide*, n.d.)

c) Creating rooms/groups: This feature enables users to create groups or rooms to schedule a meeting for a class.



Your meeting's ready

Or share this meeting link with others you want in the meeting

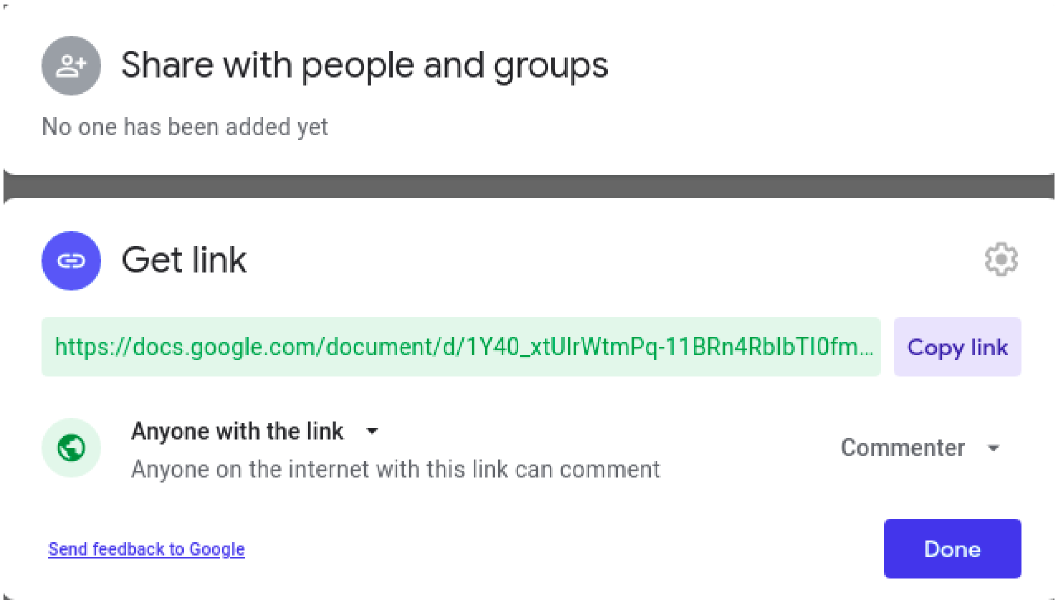
meet.google.com/pvw-mckq-hxh

People who use this meeting link must get your permission before they can join.

Joined as arjangahatraj@gmail.com

Figure 2.2.3: Creation of a meeting room in Google meet(*Video Conferencing, Meetings, Calling | Microsoft Teams*, n.d.)

d) Sharing files with varying permission: Systems allow users to share files with varying permissions. Allowing certain users full rights to edit, view or share while limiting other users.



Share with people and groups

No one has been added yet

Get link

https://docs.google.com/document/d/1Y40_xtUlrWtmPq-11BRn4RblbTI0fm...

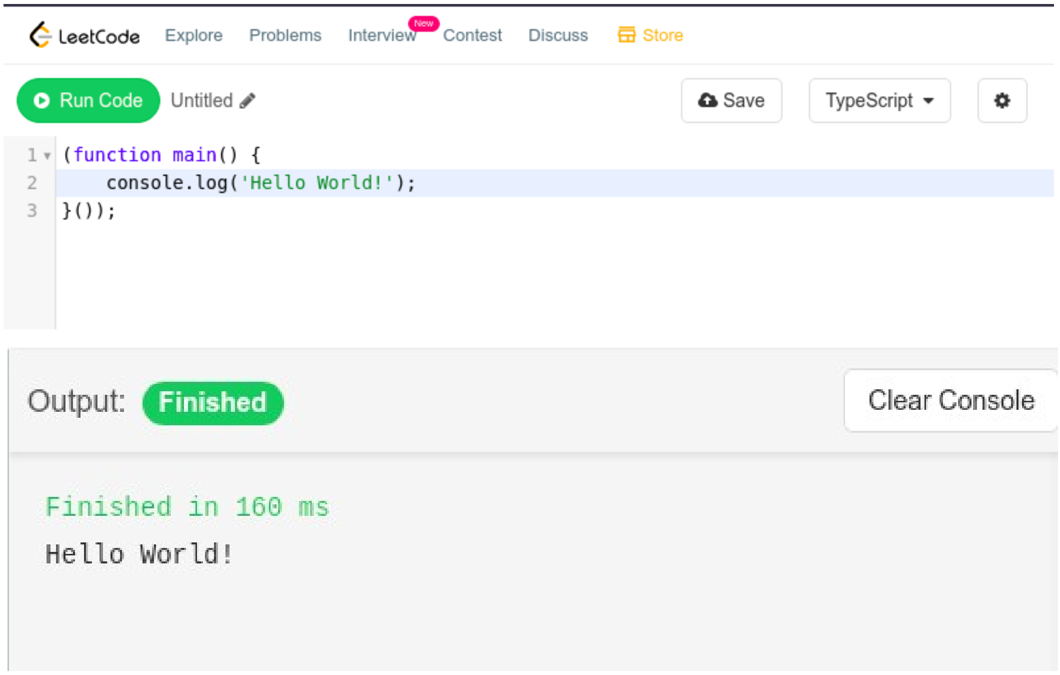
Anyone with the link

Anyone on the internet with this link can comment

Commenter

Figure 2.2.4: Sharing files in Google Docs with different permission (*Google Docs*, n.d.)

e) Execution of code: This feature enables users to execute their code or solution to a given problem and view their results.

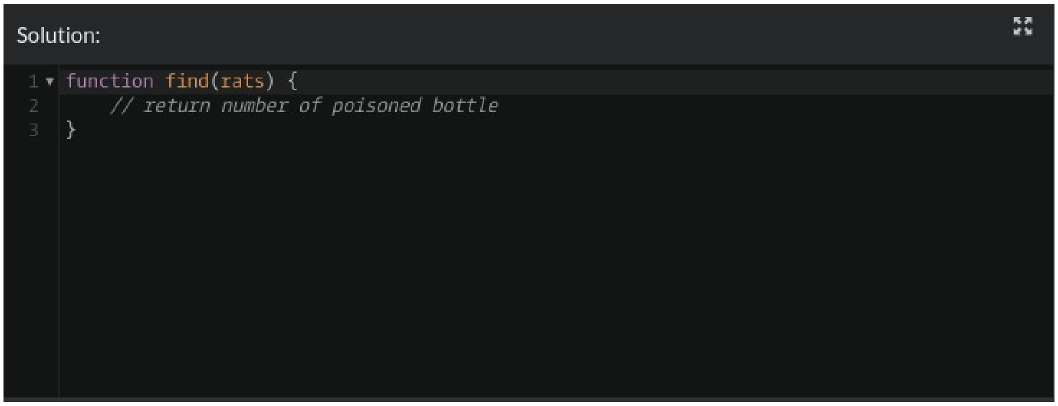


```
(function main() {
    console.log('Hello World!');
}());
```

```
Finished in 160 ms
Hello World!
```

Figure 2.2.5: Executing code in LeetCode (*LeetCode - The World's Leading Online Programming Learning Platform*, n.d.)

f) Integrated text editor: This features enables users to create and modify their code or solution within the system.



Solution:

```
function find(rats) {
    // return number of poisoned bottle
}
```

Figure 2.2.6: Integrated text editor in Codewars (*Codewars*, n.d.)

g) Real-time editing: This feature enables users to share their solution to other users and get feedback and help through real-time modifications.

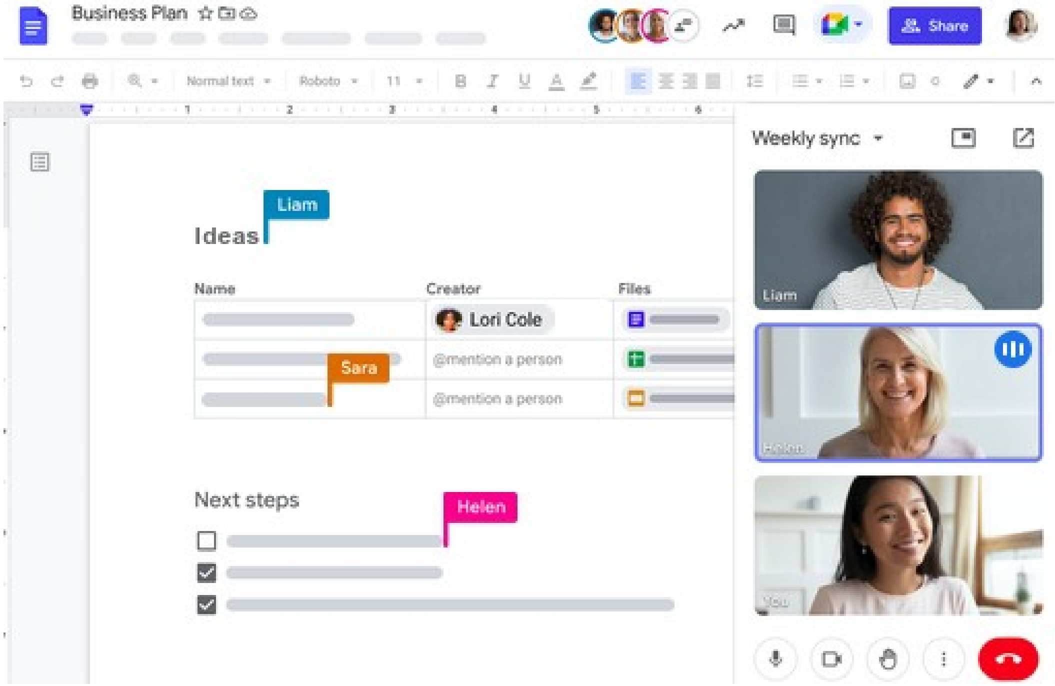
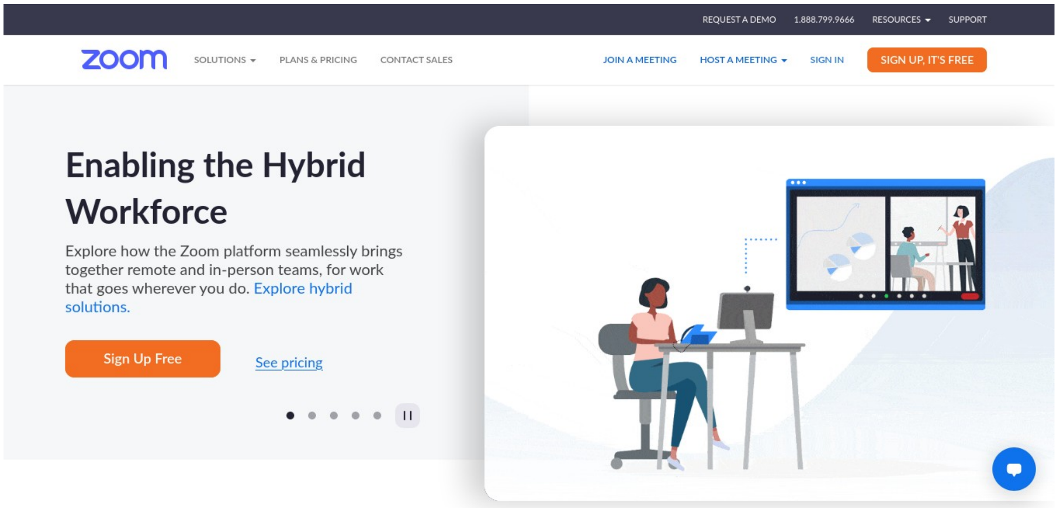


Figure 2.2.7 : Real time editing in google docs (*Google Docs*, n.d.)

2.3 Research similar systems

a) Zoom: Zoom is a secure and reliable video platform that provides services including meetings, chat, phone, webinars, and online events.

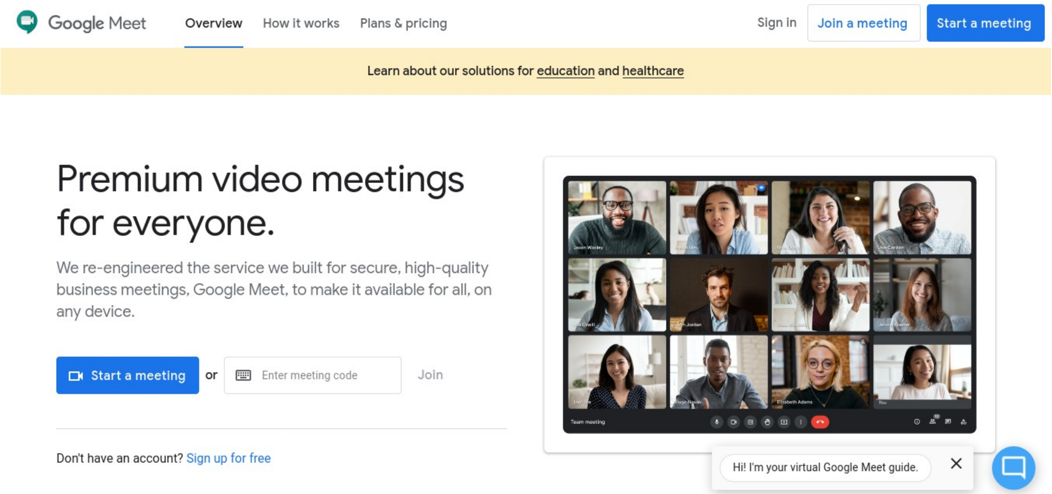


Enabling the Hybrid Workforce

Explore how the Zoom platform seamlessly brings together remote and in-person teams, for work that goes wherever you do. Explore hybrid solutions.

Figure 2.3.1: Zoom's Website (*Video Conferencing, Cloud Phone, Webinars, Chat, Virtual Events | Zoom*, n.d.)

b) Google meet: Google meet is a real-time meeting application by Google that allows users to share video, desktop, presentations using web browser.



Learn about our solutions for education and healthcare

Premium video meetings for everyone.

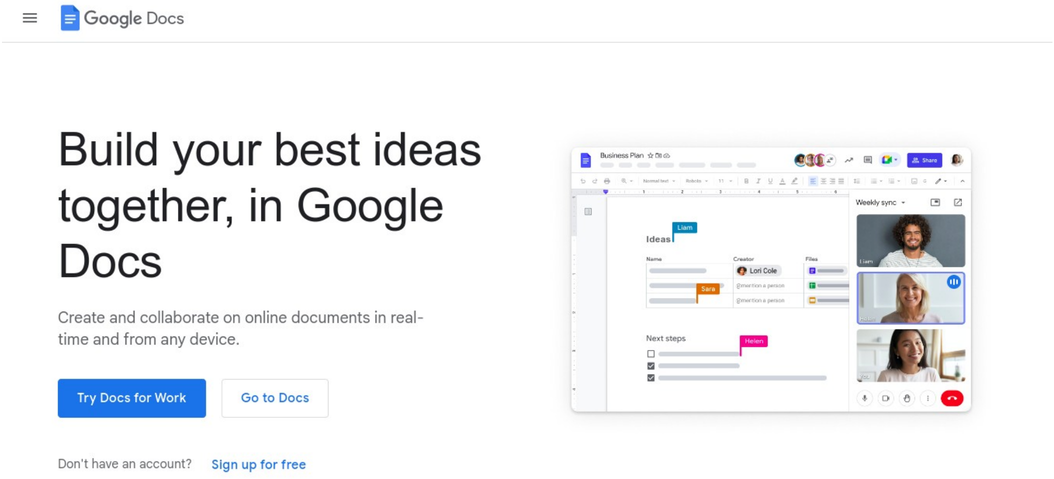
We re-engineered the service we built for secure, high-quality business meetings, Google Meet, to make it available for all, on any device.

Don't have an account? Sign up for free

Hi! I'm your virtual Google Meet guide.

Figure 2.3.2: Google Meet's Website (*Google Meet*, n.d.)

c) Google docs: Google Docs is an online word processing application that is part of Google's free, web-based Google Docs Editors package.



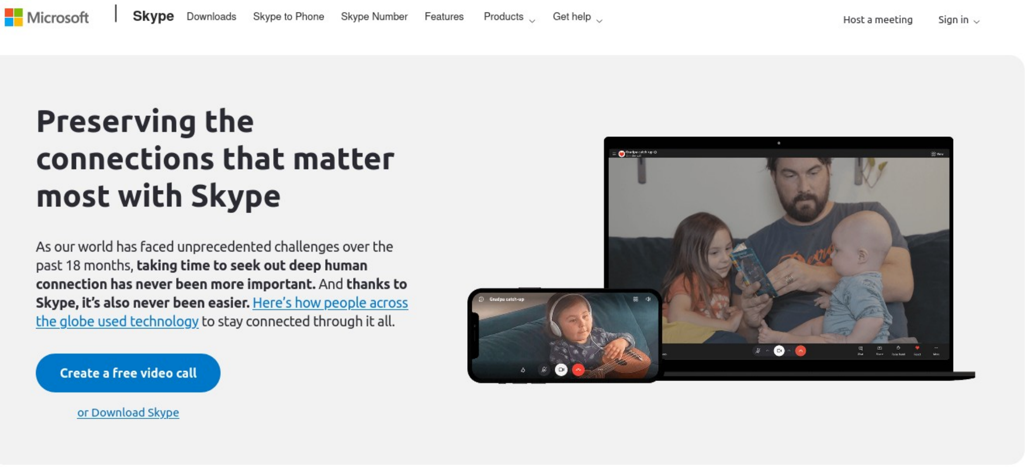
Build your best ideas together, in Google Docs

Create and collaborate on online documents in real-time and from any device.

Don't have an account? Sign up for free

Figure 2.3.3: Google Doc’s Website (*Google Docs*, n.d.)

d) Skype: Skype is a proprietary telecommunications service that includes VoIP-based video telephony, video and voice conferencing.

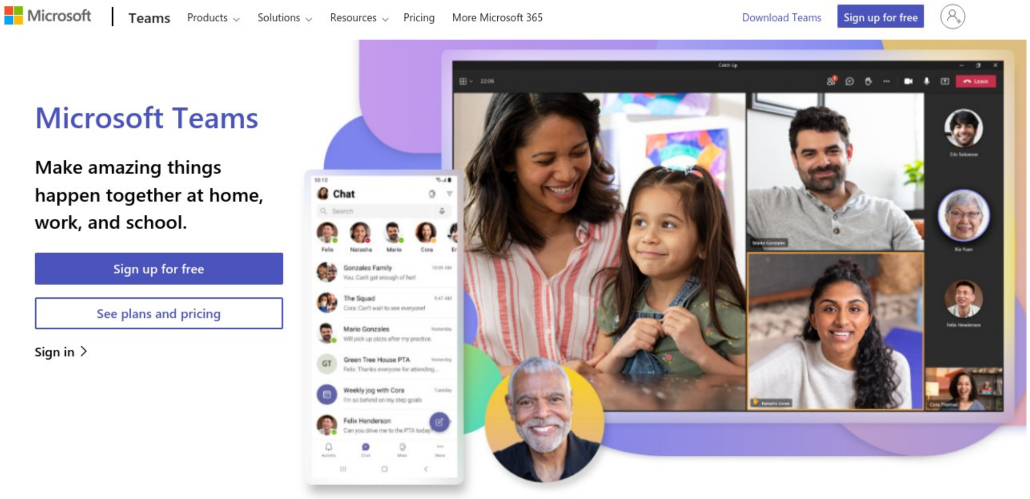


Preserving the connections that matter most with Skype

As our world has faced unprecedented challenges over the past 18 months, **taking time to seek out deep human connection has never been more important.** And **thanks to Skype, it’s also never been easier.** Here’s how people across the globe used technology to stay connected through it all.

Figure 2.3.4: Skype’s Website (*Skype | Stay Connected with Free Video Calls Worldwide*, n.d.)

e) Microsoft teams: Microsoft Teams is a specialized business communication platform that includes workplace chat and videoconferencing, file storage, and application integration.



Microsoft Teams

Make amazing things happen together at home, work, and school.

Gonzales Family — You: Can't get enough of her!

The Squad — Cora: Can't wait to see everyone!

Mario Gonzales — Will pick up pizza after my practice

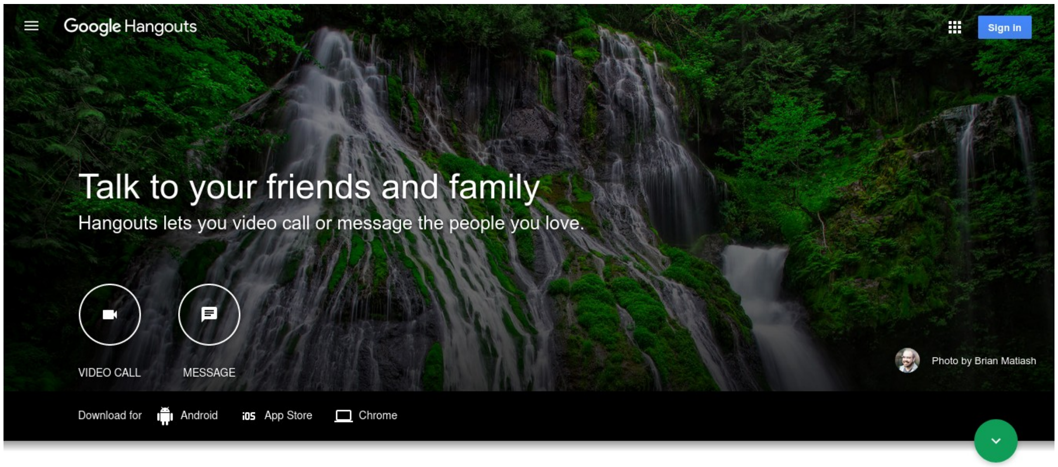
Green Tree House PTA — Felix: Thanks everyone for attending...

Weekly jog with Cora — I'm so behind on my step goals

Felix Henderson — Can you drive me to the PTA today?

Figure 2.3.5: Microsoft Teams' Website (*Video Conferencing, Meetings, Calling | Microsoft Teams*, n.d.)

f) Google Hangouts: Google Hangouts is a cross-platform instant messaging application created by Google that allows users to form groups and hold meetings through video/audio conferencing.

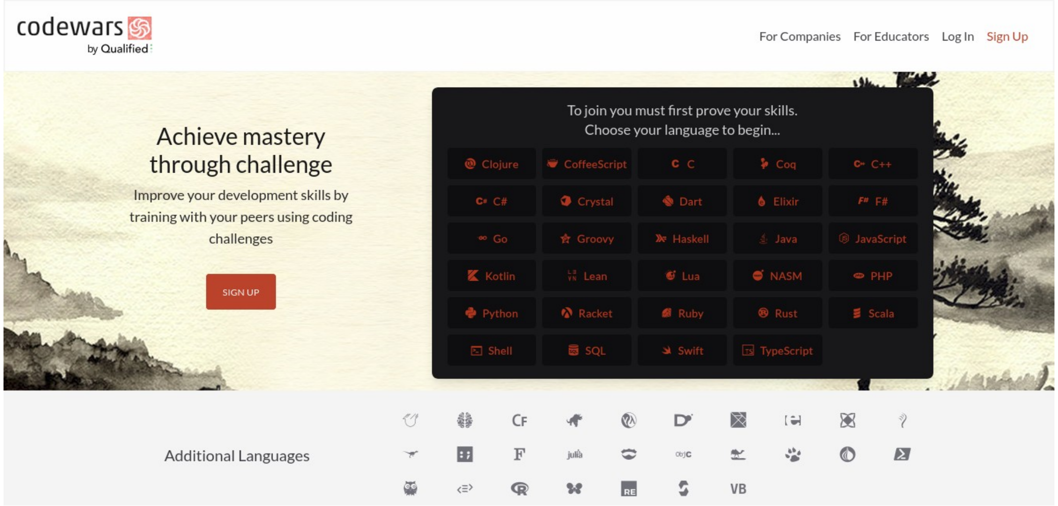


Talk to your friends and family

Hangouts lets you video call or message the people you love.

Figure 2.3.6: Google Hangouts' Website (*Google Hangouts*, n.d.)

g) Codewars: Codewars is a coding practice site for all programmers that assists in the learning of various programming languages.



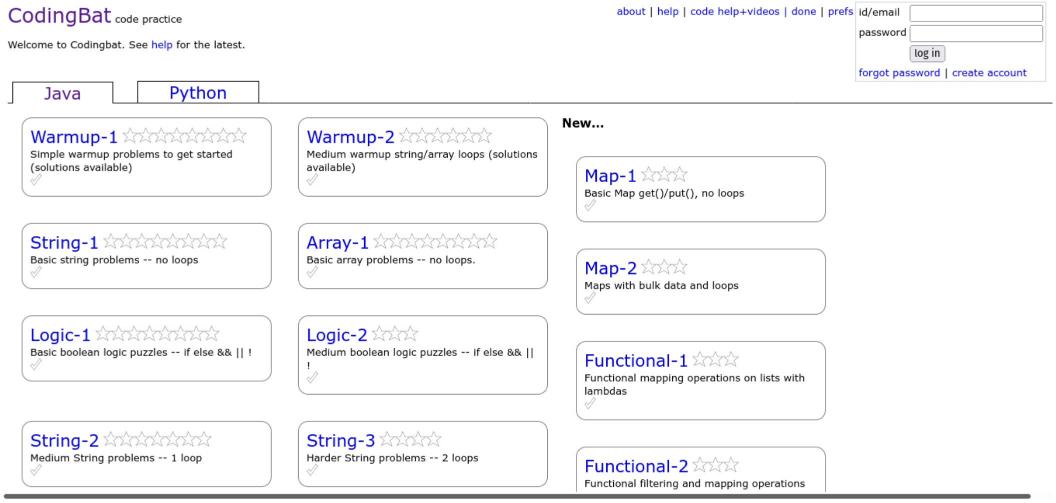
Achieve mastery through challenge

Improve your development skills by training with your peers using coding challenges

To join you must first prove your skills. Choose your language to begin...

Figure 2.3.7 : Codewars website (*Codewars*, n.d.)

h) Coding-bat: CodingBat is a free website with a large number of live coding problems. The site's goal is to help people learn to code in Python and Java.


about | help | code help+videos | done | prefs
id/email
password
log in
forgot password | create account
Java
Python

CodingBat code practice

Welcome to Codingbat. See help for the latest.

Warmup-1
Simple warmup problems to get started (solutions available)

Warmup-2
Medium warmup string/array loops (solutions available)

New...

Map-1
Basic Map get()/put(), no loops

String-1
Basic string problems -- no loops

Array-1
Basic array problems -- no loops.

Map-2
Maps with bulk data and loops

Logic-1
Basic boolean logic puzzles -- if else && || !

Logic-2
Medium boolean logic puzzles -- if else && || !

Functional-1
Functional mapping operations on lists with lambdas

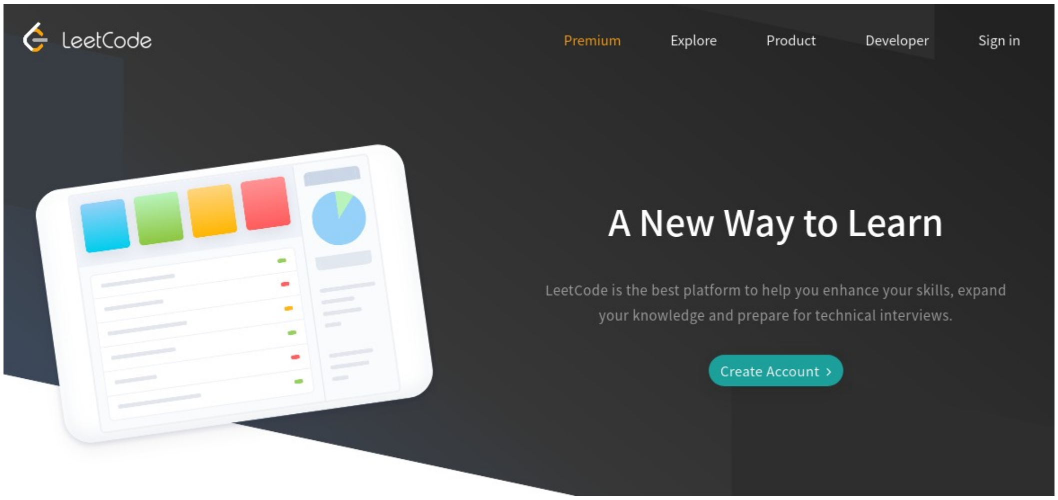
String-2
Medium String problems -- 1 loop

String-3
Harder String problems -- 2 loops

Functional-2
Functional filtering and mapping operations

Figure 2.3.8: CodingBat's Website (*CodingBat Java*, n.d.)

i) LeetCode: LeetCode is a web-based platform that helps to improve coding abilities, broaden technical knowledge, and prepare for technical interviews.

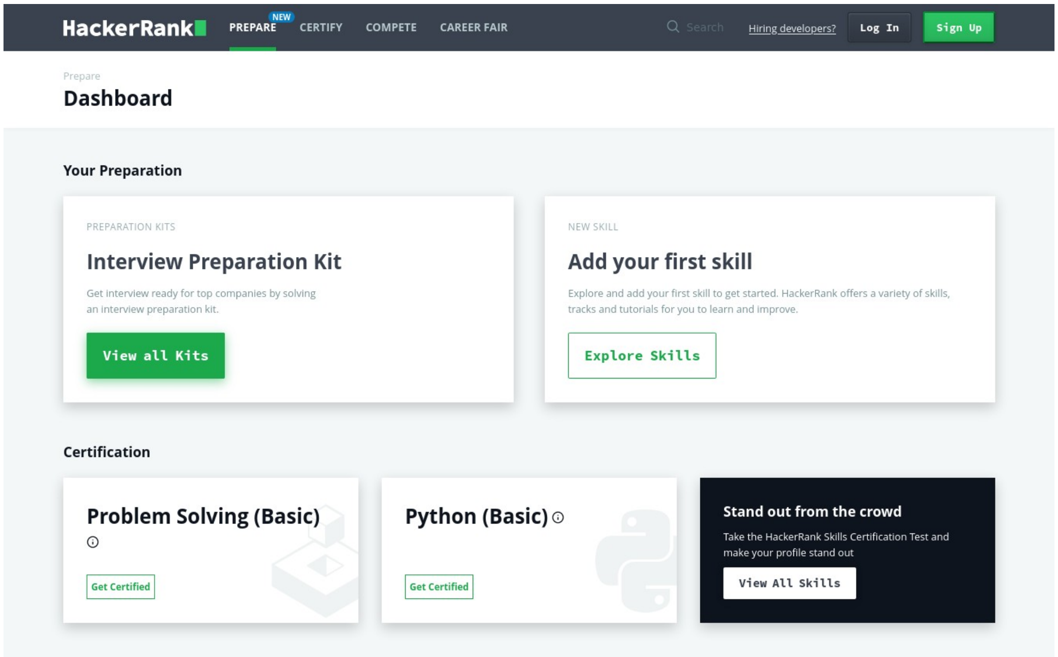


A New Way to Learn

LeetCode is the best platform to help you enhance your skills, expand your knowledge and prepare for technical interviews.

Figure 2.3.9: LeetCode's Website (*LeetCode - The World's Leading Online Programming Learning Platform*, n.d.)

j) HackerRank: HackerRank is a digital company that focuses on competitive programming challenges for both individuals and corporations, in which programmers compete by attempting to program according to given parameters.



Prepare

Dashboard

Your Preparation

PREPARATION KITS

Interview Preparation Kit

Get interview ready for top companies by solving an interview preparation kit.

NEW SKILL

Add your first skill

Explore and add your first skill to get started. HackerRank offers a variety of skills, tracks and tutorials for you to learn and improve.

Certification

Problem Solving (Basic)

Python (Basic)

Stand out from the crowd

Take the HackerRank Skills Certification Test and make your profile stand out

Figure 2.3.10: HackerRank's Website (*HackerRank*, n.d.)

2.4 Feature Comparison

Table 2.4.1: Comparison table

Feature	Zoom	Google meet/ docs	Skype	Micros-oft teams	Google Hangou-ts	Code wars	Coding Bat	Leet Code	Hacker Rank	Propos-ed system
File sharing	✓	✓	✓	✓	✓	✗	✗	✗	✗	✓
Voice chat	✓	✓	✓	✓	✓	✗	✗	✗	✗	✓
Text chat	✓	✓	✓	✓	✓	✗	✗	✗	✓	✓
Creating rooms/ groups	✓	✓	✓	✓	✓	✗	✗	✗	✗	✓
Sharing files with varying permission	✗	✓	✗	✗	✗	✗	✗	✗	✗	✓
Execution of code	✗	✗	✗	✗	✗	✓	✓	✓	✓	✓
Integrate-d text editor	✗	✓	✗	✗	✗	✓	✓	✓	✓	✓
Real-time editing	✗	✓	✗	✓	✗	✗	✗	✗	✗	✓

As shown in Table 2.4.1, the proposed system will include all the features combining features from synchronous online meeting applications and online judge system to enable a platform to learn programming online with integrated meeting features and text editing features. The proposed system will include the functionality to send notifications to instructors when encountering errors.

2.5 Conclusion

There are problems in online education and questions related to its effectiveness but these problems can be minimized by using proper teaching strategies. Focus on collaborative learning and interaction can be the strategy to improve online education. Synchronous meeting apps help to provide the collaboration and interactive elements to online learning while online judge apps provide platform for users to gain technical knowledge. Therefore, taking elements from both these application will enable better technical online education in the field of computer science.

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