Introduction/Background (10 points):

Project Objectives

There were a handful of objectives for SkillSwitch. The team wanted to develop an educational platform first and foremost. However, the team also wanted the platform to foster engagement between students and teachers. SkillSwitch was also intended to motivate users to continue learning and sharing their skills through competition and rating systems. SkillSwitch was also intended to provide material that users would want to engage with and not seemingly random content.

Tech Stack

For the front-end the team used React, Next, Tailwind CSS, and MUI. Next simplified page routing, and the overall structure of the front-end. For the back-end the team wanted to use Python, so Django was used. For user authentication, Firebase was used. For the database, Google Cloud SQL was used in combination with Google Cloud Storage Buckets for video storage.

Context

The project was completed as an assignment for CS 3300, Introduction to Software Engineering. The team spent the entire semester working on the project, from initial planning, to project design, to implementation, and finishing up with testing. With the team participating in the course during the summer semester, the time window for the project to be completed was relatively short. The implementation phase was relatively short in comparison to the other parts of the development lifecycle.

Significance

Despite being a class project, SkillSwitch was a significant challenge for the team to take on. The initial objectives for the platform were pretty ambitious, and it would be difficult to implement everything that was initially wanted. However, the team still wanted to create a cool project that would be worth showcasing to others.

Scope

SkillSwitch was intended to be deployed and demoed for the class presentation. It was never intended to be actually released to the public and scaled. This definitely impacted a handful of decisions the team made during development and requirements gathering. There was no sort of content filtration system or user reporting system, as the team knew none of the users would have malicious intent.

Management Approach

The team had initially wanted to use the sprints to all work on each MMF together and split the workload between front-end and back-end so that experience on both front-end and back-end development could be shared across different MMFs. This idea; however, was quickly abandoned due to the structure of the course and the MMFs being expected a lot sooner than had been originally thought. The team then switched to each person managing an MMF to minimize blockers. Ultimately, there were still blockers that prevented development from speeding up to an optimal level due to the backend already being heavily designed from the former management, and the tech stack changing to allow for both local development and deployment. In the end, while experience was shared for both front-end and back-end development, there was still a clear skew in back-end experience and front-end experience.

Related Work

SkillSwitch is similar to YouTube, KhanAcademy, Reddit, and Duolingo, and is directly inspired by the features that these applications provide.

How is SkillSwitch unique?

SkillSwitch is unique in the sense that it combines features from different platforms to utilize an active hands-on learning experience. It is similar to YouTube with how any user is able to upload a lesson, though it differs by including features to directly contact the uploader on the platform. In another sense, it is similar to KhanAcademy and Duolingo, with the newly added feature being that anyone can upload a lesson. It is similar to Reddit, though the userflow is geared toward learning through lessons and active xp-battles rather than just commenting and posting.

Software Technologies (15 points):

Technologies

The team used Firebase for user authentication. The team used Google Cloud SQL for storing SkillSwitch data and Google Cloud Storage Buckets specifically for videos. The back-end was deployed using Google Cloud Platform, but issues arose with lesson uploading.

Frameworks

For the front-end the team used React along with the Next framework. Both frameworks simplified the front-end development process, providing an intuitive, well structured guideline for the project. For styling, the team used Tailwind CSS. Tailwind allowed for a consistent but highly customizable design for every page on SkillSwitch. For the back-end the team used Django. This decision was made early on and it led to some difficulties in implementing features later on. Django was still very easy to use for implementing basic API routes and interacting with the database through its built-in ORM. For back-end testing, the team used the Pytest framework. This made implementing and running tests very simple, and it was easy to gather data on test success rate and coverage.

Libraries

The only crucial library for SkillSwitch was Material UI, which was used in coordination with Tailwind CSS to style the front-end. Material UI provided basic components that were easy to implement requiring minimal additional styling.

AI Tools

There were many different AI tools used across the different phases of the development of SkillSwitch. For design, the team used Mermaid, Gemini, and ChatGPT. For implementation, the team used GitHub Copilot and ChatGPT. For testing, the team used Postbot, ChatGPT, and GitHub Copilot. Overall, the most frequently used tool was ChatGPT, due to its versatility. The team found success using all of these tools.

Requirements (20 Points):

Functional Requirements
SkillSwitch had 10 primary functional requirements set during its planning phase. These are slightly modified versions of each requirement for simplicity and clarity:

1. The system shall use Firebase for user authentication.
2. The system shall support lesson upload, including a video, title, description, and category. The system shall support manual quiz input for each lesson, and the system may AI generated quizzes based on the video transcript.
3. The system shall allow users to select interests to influence their recommended content. This complexity of the recommendation algorithm may be increased down the line using AI.
4. The system shall implement a Karma system which rates users based on their interaction as a teacher. The Karma rating should be influenced by basic interactions including lesson rating and discussion board answers.
5. The system shall implement an XP system which rates users based on their interaction as a student. The XP rating shall be influenced by discussion board interaction and XP battle performance.
6. The system shall implement a discussion board for each lesson. This discussion board should support basic questions and answers. The interactions on the discussion board should influence user Karma and XP.
7. The system shall support direct messaging between students and lesson teachers using WebSockets.
8. The system shall support XP battles, where users are tasked with a quiz based on a specific lesson. The student performing better shall gain XP.
9. The system shall support an analytics page rendering basic user data. This data should give the user a better understanding of their XP and Karma ratings.
10. The system may support an algorithm providing insights on interaction with a user's uploaded lesson.

Non-Functional Requirements
The primary non-functional requirements for SkillSwitch include usability, portability, testability, and reliability. The team intended for SkillSwitch to be easily accessible. For development, the team wanted the codebase to be easily testable to quickly identify any minor bugs. Lastly, it was essential for the system to reliably support video upload and rendering, as it was the backbone of the platform.

MMF 1: Home Page Lesson Recommendation
The first major feature on SkillSwitch was the lesson recommendation algorithm appearing on the home page. This algorithm worked based on the user-selected interests and the category

tags on each video. The content recommendations were also influenced by the Karma ratings of the lesson creators.

MMF 2: Discussion Board

Each lesson on SkillSwitch had an associated discussion board. Here, users could ask questions and provide answers about the lesson’s content. The creator of the lesson was able to endorse questions and answers, and users could mark answers to their question as helpful or unhelpful. These discussion board interactions would influence Karma and XP ratings of the users involved.

MMF 3: Direct Messaging

Another major functionality of SkillSwitch was real-time direct messaging between students and instructors. Conversations would be initiated on the lesson page by students, and a direct messaging tab would support resuming past conversations.

MMF 4: Karma Rating System

The fourth major functionality of SkillSwitch was the Karma system. This system intended to provide a rating that estimated a creator's credibility. It was influenced by lesson ratings and discussion board interaction.

MMF 5: XP Rating System

SkillSwitch’s XP rating system intended to evaluate user performance as a student on the platform. The XP rating would be influenced by discussion board interaction. Users could also compete in XP battles, which involved completing lesson based quizzes. The better performing user would be rewarded with XP.

MMF 6: Analytics Dashboard

The last main feature of SkillSwitch was a dashboard that displayed statistical data based on their engagement as a student and teacher. This would provide a better understanding of the user XP and Karma rating.

AI Tool Implementation Usage

In implementation, the two AI tools used were GitHub Copilot and ChatGPT. Both tools were helpful for producing boilerplate code. They were also used to implement new features and fixing past bugs.

AI Tool Implementation Impact

Using these tools in the implementation phase significantly boosted productivity. Without them, it certainly would not have been possible to produce an application on the scale of SkillSwitch in such a short time frame. These tools also introduced very few bugs relative to the amount of code they produced.

Identifying Requirements

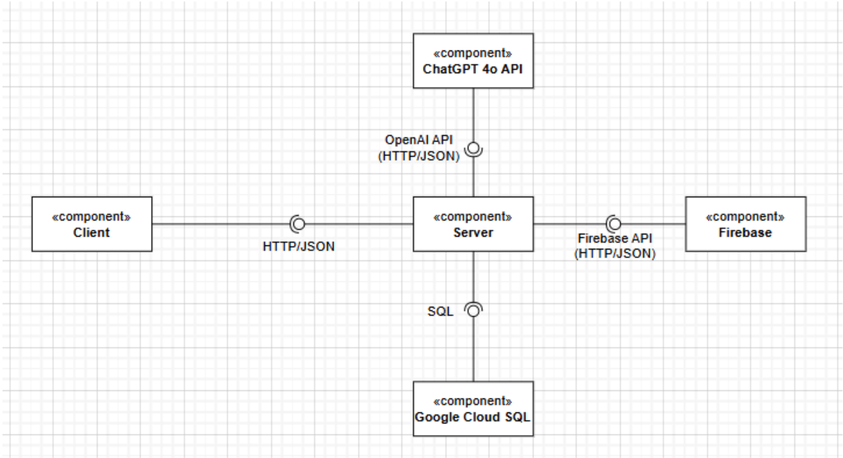
Identifying requirements was difficult, as the original ideas for SkillSwitch were ambitious and vague. The team had to settle on requirements that were realistic and achievable, but still exciting and impressive to develop and showcase in the presentation. The main goal of identifying requirements was to gather requirements that were clear enough that the entire team was on the same page for the implementation phase.

Prioritizing Requirements

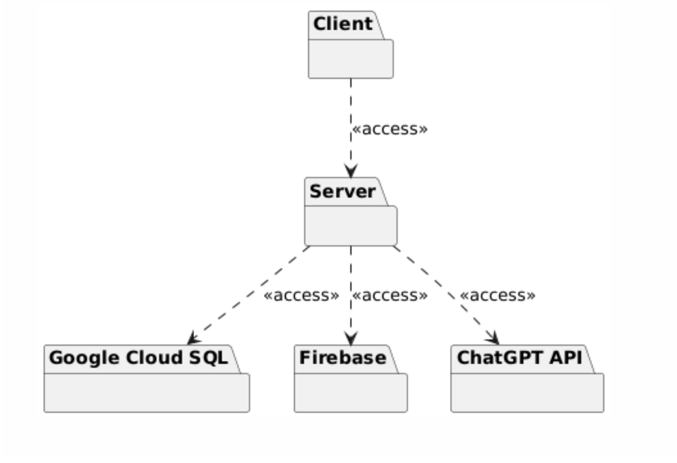
The team prioritized the requirements that were related to the six core MMFs. Requirements that were considered stretch goals were put to the side, as implementing the core features was already taking a significant amount of time. AI integration with the lesson recommendation algorithm and analytics dashboard were two stretch goals listed in the requirements initially that were not prioritized as they were not imperative to the core functionality of SkillSwitch.

Design (30 Points):

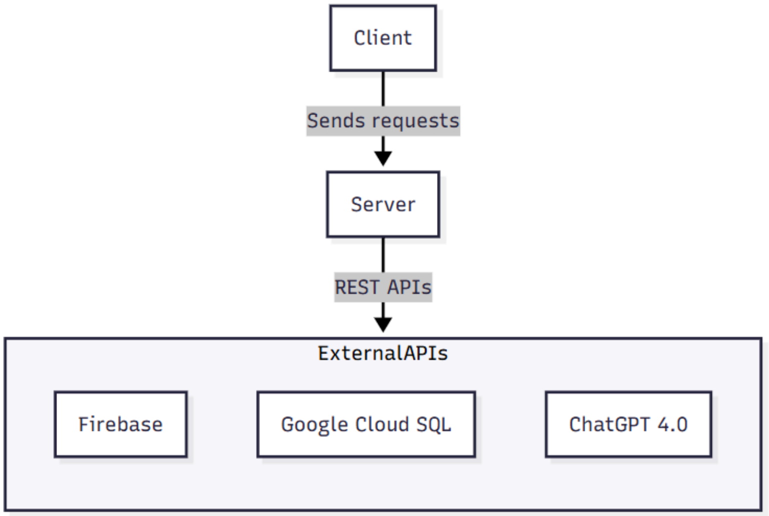
Diagrams



This is the first architectural design diagram. This diagram was created manually using Draw.io.



This is the second architectural design diagram, generated by ChatGPT.



This is the third architectural design diagram, which was created using Mermaid.

Design Decisions

The most difficult decisions made in the design of SkillSwitch involved the class diagram. The team knew it was important to separate all of the classes in a logical, modular, usable format. Early in the development phase, the team had not put much thought into the design. After completing the design document, the code base was refactored to reflect these changes. Other influential design decisions involved the deployment diagram. The team decided the front-end should be hosted on Firebase, with the back-end being hosted on GCP. This seemed to be the easiest way to host SkillSwitch at the time.

Decision Impact

The design decisions involving the class diagram of SkillSwitch had a strong impact on the implementation phase. This led to a refactoring of the code base, separating the Django project into applications for each major functionality. Each separate application stored the most important class models, which had the same relationships defined in the class diagram.

AI Tool Design Usage

For the design phase, the team used ChatGPT and Mermaid to generate diagrams. For UI mockups, the team used Gemini. The team also manually created one version of each diagram. This gave a better idea of the impacts the AI tools had on the design phase.

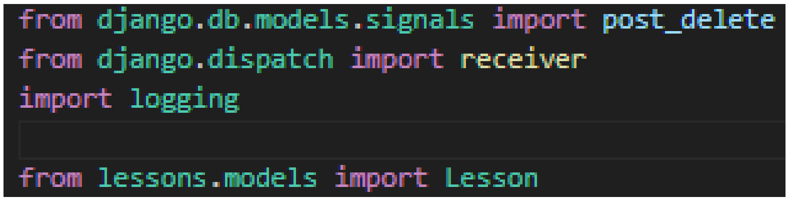
AI Tool Design Impact

Overall, AI tools greatly increased productivity in the design phase. Most diagrams could be completed in half as much time using AI tools than creating them manually. Although the AI tools hallucinated and produced minor errors, they were easy to fix through additional prompting or manual adjustments. Without AI tools, it would have been very difficult to complete the design phase in such a short time window.

Design Patterns Implementation (30 points):

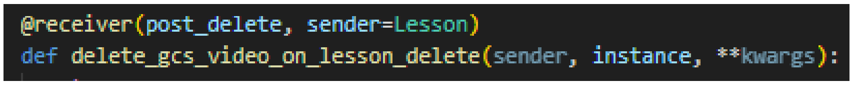
Design Pattern 1: Observer

The first design pattern implemented in SkillSwitch was the Observer pattern. It was implemented in order to decouple the deletion logic of videos from the lesson model. This design pattern promoted a separation of concerns between the functions in our back-end API. It also provided loose coupling and reusable, centralized logic for handling lesson deletion.



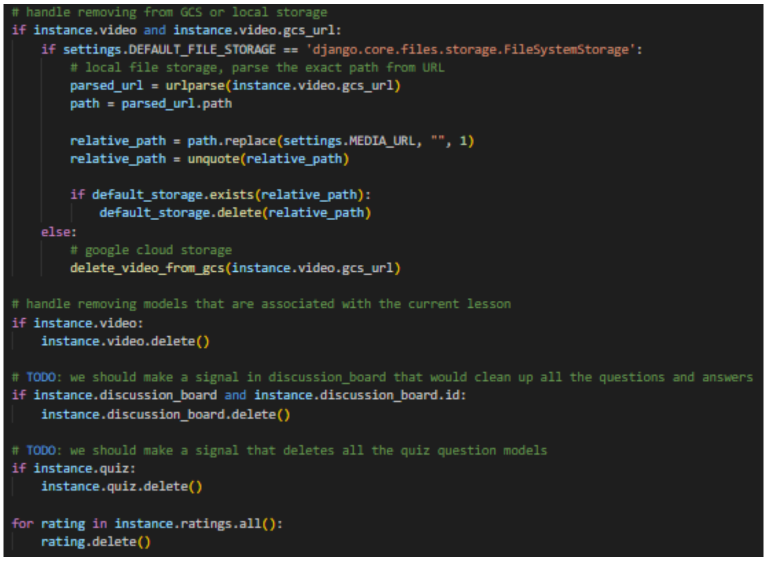
```python
from django.db.models.signals import post_delete
from django.dispatch import receiver
import logging

from lessons.models import Lesson
```

The built-in Django signal observes lesson deletion.



```python
@receiver(post_delete, sender=Lesson)
def delete_gcs_video_on_lesson_delete(sender, instance, **kwargs):
```

This function triggered on lesson deletion due to the signal.

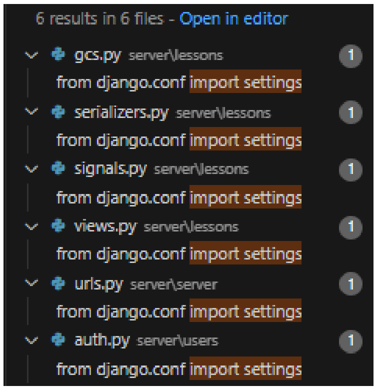


```python
# handle removing from GCS or local storage
if instance.video and instance.video.gcs_url:
    if settings.DEFAULT_FILE_STORAGE == 'django.core.files.storage.FileSystemStorage':
        # local file storage, parse the exact path from URL
        parsed_url = urlparse(instance.video.gcs_url)
        path = parsed_url.path

        relative_path = path.replace(settings.MEDIA_URL, "", 1)
        relative_path = unquote(relative_path)

        if default_storage.exists(relative_path):
            default_storage.delete(relative_path)
    else:
        # google cloud storage
        delete_video_from_gcs(instance.video.gcs_url)

# handle removing models that are associated with the current lesson
if instance.video:
    instance.video.delete()

# TODO: we should make a signal in discussion_board that would clean up all the questions and answers
if instance.discussion_board and instance.discussion_board.id:
    instance.discussion_board.delete()

# TODO: we should make a signal that deletes all the quiz question models
if instance.quiz:
    instance.quiz.delete()

for rating in instance.ratings.all():
    rating.delete()
```

This is the decoupled logic for handling deleted lessons.

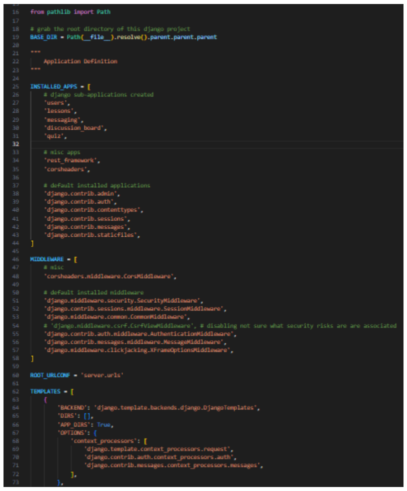
Design Pattern 2: Singleton

The second design pattern implemented in SkillSwitch was Singleton. As a standard practice for the Django framework, the API had a single, consistent instance of project settings across the whole back-end. This reduced the amount of boilerplate code, and provided a consistent, globally accessible settings instance.



```
6 results in 6 files - Open in editor
gcs.py server\lessons  1
    from django.conf import settings
serializers.py server\lessons  1
    from django.conf import settings
signals.py server\lessons  1
    from django.conf import settings
views.py server\lessons  1
    from django.conf import settings
urls.py server\server  1
    from django.conf import settings
auth.py server\users  1
    from django.conf import settings
```

The settings instance was imported across the entire back-end.

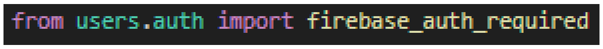


```python
from pathlib import Path

# grab the root directory of this django project
BASE_DIR = Path(__file__).resolve().parent.parent.parent

"""
    Application Definition
"""

INSTALLED_APPS = [
    # django sub-applications created
    'users',
    'lessons',
    'messaging',
    'discussion_board',
    'quiz',

    # misc apps
    'rest_framework',
    'corsheaders',

    # default installed applications
    'django.contrib.admin',
    'django.contrib.auth',
    'django.contrib.contenttypes',
    'django.contrib.sessions',
    'django.contrib.messages',
    'django.contrib.staticfiles',
]

MIDDLEWARE = [
    # misc
    'corsheaders.middleware.CorsMiddleware',

    # default installed middleware
    'django.middleware.security.SecurityMiddleware',
    'django.contrib.sessions.middleware.SessionMiddleware',
    'django.middleware.common.CommonMiddleware',
    # 'django.middleware.csrf.CsrfViewMiddleware', # disabling not sure what security risks are are associated
    'django.contrib.auth.middleware.AuthenticationMiddleware',
    'django.contrib.messages.middleware.MessageMiddleware',
    'django.middleware.clickjacking.XFrameOptionsMiddleware',
]

ROOT_URLCONF = 'server.urls'

TEMPLATES = [
    {
        'BACKEND': 'django.template.backends.django.DjangoTemplates',
        'DIRS': [],
        'APP_DIRS': True,
        'OPTIONS': {
            'context_processors': [
                'django.template.context_processors.request',
                'django.contrib.auth.context_processors.auth',
                'django.contrib.messages.context_processors.messages',
            ],
        },
```

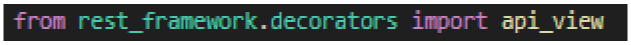
This is a snippet from the settings file.

Design Pattern 3: Decorator

A third design pattern implemented in SkillSwitch is the decorator pattern. Again, this was a standard pattern to implement when using the Django framework. The pattern allowed the team to add special behaviors to functions without having to change their code. The pattern improved code reusability and modularity. It also promoted a separation of concerns between different functions and increased flexibility.

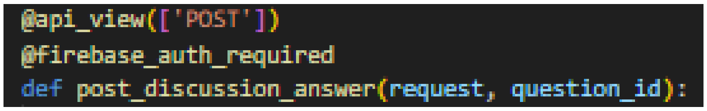


```python
from users.auth import firebase_auth_required
```



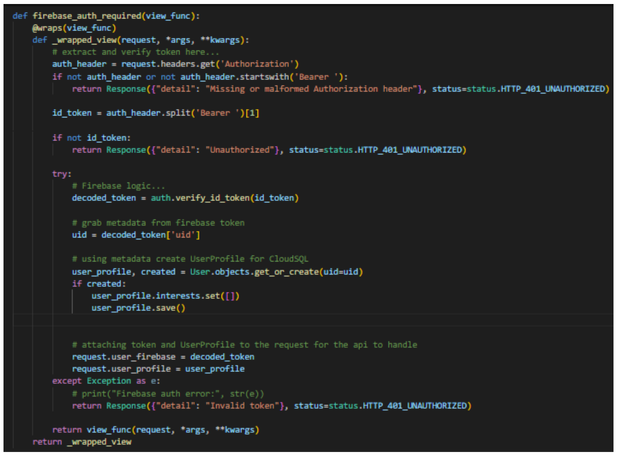
```python
from rest_framework.decorators import api_view
```

These are some of the decorator imports used in the API routes.



```python
@api_view(['POST'])
@firebase_auth_required
def post_discussion_answer(request, question_id):
```

This is an example of how the decorators were used in coordination with a function to handle the route. The decorators above specified the view as a POST request that would require Firebase authentication to run.



```python
def firebase_auth_required(view_func):
    @wraps(view_func)
    def _wrapped_view(request, *args, **kwargs):
        # extract and verify token here...
        auth_header = request.headers.get('Authorization')
        if not auth_header or not auth_header.startswith('Bearer '):
            return Response({"detail": "Missing or malformed Authorization header"}, status=status.HTTP_401_UNAUTHORIZED)

        id_token = auth_header.split('Bearer ')[1]

        if not id_token:
            return Response({"detail": "Unauthorized"}, status=status.HTTP_401_UNAUTHORIZED)

        try:
            # Firebase logic...
            decoded_token = auth.verify_id_token(id_token)

            # grab metadata from firebase token
            uid = decoded_token['uid']

            # using metadata create UserProfile for CloudSQL
            user_profile, created = User.objects.get_or_create(uid=uid)
            if created:
                user_profile.interests.set([])
                user_profile.save()


            # attaching token and UserProfile to the request for the api to handle
            request.user_firebase = decoded_token
            request.user_profile = user_profile
        except Exception as e:
            # print("Firebase auth error:", str(e))
            return Response({"detail": "Invalid token"}, status=status.HTTP_401_UNAUTHORIZED)

        return view_func(request, *args, **kwargs)
    return _wrapped_view
```

This is the Firebase user authentication function the team defined to use as a decorator across nearly every back-end route.

Testing Strategy, Execution, AI tool analysis (60 points):

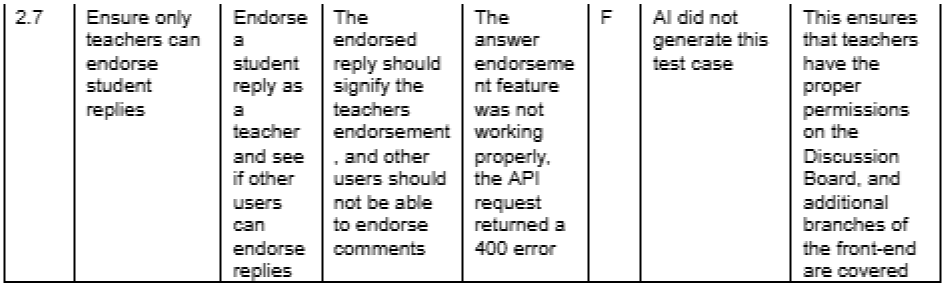
Whitebox Strategy

The general strategy the team followed for whitebox testing was implementing unit tests using the Pytest framework. Whitebox testing was focused solely on the back-end API. The team wanted to have high back-end coverage and a 100% success rate for these tests. This would ensure that there are no bugs with the API, and it can handle any requests that would be initiated by the client.

Blackbox Strategy

For blackbox testing the team worked with both the back-end and front-end. Back-end black box testing involved using Postman to make API requests. For front-end black-box testing, the team manually tested SkillSwitch by running it locally. These tests targeted major functionalities and included common edge cases.

Below are the results of the most important test cases the team worked with during the testing phase.



2.7	Ensure only teachers can endorse student replies	Endorse a student reply as a teacher and see if other users can endorse replies	The endorsed reply should signify the teachers endorsement, and other users should not be able to endorse comments	The answer endorsement feature was not working properly, the API request returned a 400 error	F	AI did not generate this test case	This ensures that teachers have the proper permissions on the Discussion Board, and additional branches of the front-end are covered

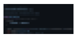
This blackbox test uncovered a minor bug with the discussion board that the team addressed.

3.3	Prevent empty messages from being sent	Open direct message conversation and attempt to send an empty message	The direct message should not be sent without text content	The system did not allow empty messages to be sent	P	This test scenario was generated using ChatGPT 4o	Tests message validation logic on the front-end

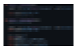
This blackbox test was crucial to the direct messaging feature.

4.1	Ensure site is viewable across different screen sizes	Resize browser	The layout should adapt to smaller screens	The screen does not properly adapt to mobile devices	F	This test scenario was generated using ChatGPT 4o	Tests that the front-end code adapts properly to different media

This blackbox test identified an issue that was addressed later on when the team focused more on developing the front-end and styling for SkillSwitch.

1.5	patch_profile()	Request are sent with a payload which includes modifications to the user's metadata		Returns a json with the user's new metadata that was just saved on the server	JSON response again contains most of the user's metadata (missing interests)	F	Manual creation	Again need to expand project functionality before fully testing this API request

This whitebox test uncovered an issue with profile modification that was addressed when the project functionality was expanded.

2.2	get _all_lessons()	API request to the server to receive all of the published videos that can be viewed by anyone		Returns empty array if no users have uploaded any lessons, or response with an array containing all public videos	Empty array when there are no public videos, an array of 1 element when we populate the server with a single lesson	P	Manual creation	

This whitebox test was central to the early development of SkillSwitch. Before the lesson recommendation algorithm was implemented, a route was implemented to return all the lessons on the platform.

Whitebox AI Tools

For whitebox testing the team used ChatGPT and GitHub Copilot. These tools were used to set up and generate test cases that followed the Pytest framework.

Blackbox AI Tools

For blackbox testing the team used ChatGPT to generate test cases. The team also used Postbot when working with Postman to quickly write test cases.

Whitebox: ChatGPT & GitHub Copilot
For whitebox testing, ChatGPT was used more in the beginning of the process. It was very valuable for setting up the Pytest framework with the Django project. It was able to generate five of the first sixteen tests. The 11 others were manually created. All of the initial tests generated by ChatGPT were passed. Copilot was used later to quickly generate unit tests for the newer features of the project. In total, Copilot generated 36 total tests, for a total of 52 tests. Each test passed and the final branch coverage was 73%. These tools had positive impacts on productivity and quality throughout the testing process. They were able to generate a handful of tests in just minutes of prompting. Manually creating tests is a significantly slower process, requiring writing extensive boilerplate code. After Pytest was working with a handful of tests, it was easy to use GitHub Copilot to add many more tests. The more tests that were present in our codebase provided more context for Copilot, which increased its usability and impact.

Blackbox: ChatGPT & Postbot
For blackbox testing ChatGPT was used to gather test cases for the front-end. This reduced the amount of time necessary to come up with test cases on our own, and ChatGPT was able to provide some interesting test cases. There were 20 total blackbox test cases, four generated by Postbot, 11 generated by ChatGPT, and five created manually. Postbot was used for generating Postman tests for the back-end API. Only three blackbox test cases failed, all relating to the front-end and revealing minor bugs. Two of these test cases were generated by ChatGPT. Overall, ChatGPT and Postsbot were helpful in increasing team productivity during blackbox testing. It reduced the amount of manual work necessary in formatting Postman tests and manual work in identifying proper test cases for the front-end functionality. These test cases were generally high quality and identified a few bugs that were addressed in the future.

Challenges and Innovations (15 points):

Challenges

<u>Video Storage:</u> There was some difficulty with storing and rendering videos. This was solved using Google Cloud SQL and Google CLoud Storage buckets but there was definitely a learning curve.

<u>Developing on different OS:</u> Each team member had completely different OS systems which included Windows, Linux and Mac systems. This meant that the backend work took many hours of meticulous set up, debugging, and adjustments. It also included the creation of a script to completely reset the database.

<u>Google cloud credit usage:</u> Due to the nature of the project it was necessary to have a central video storage and streaming point. However this takes up a lot of our allotted credit VERY quickly, especially considering multiple team members were using it at once.

Innovations:

AI quiz generation: As part of the ever growing usage of AI, we were able to integrate an AI tool into our project. This AI tool can be used to automatically create a quiz based on the lesson the user uploaded. It works by transcribing the audio file into text and prompting the AI to create a few multiple choice questions. This is an optional feature that can be used by users who created a lesson. They can still use the write in feature to create custom questions as well.

Next.js implementation: The implementation of Next.js in this project simplified and improved React front-end structure.

Project Outcomes and Evaluation (10 points):

Final Outputs

In the end, SkillSwitch was a mostly functional, basic platform for learning and collaboration. To scale it beyond a simple class project would be extremely difficult with the resources provided. However, it met our basic expectations and the team is happy to present the outcome. There are some minor bugs with the application, as to be expected, but all of the major functionalities work as intended.

AI Tool Effectiveness

AI tools can be used to speed the initial design phase and to assist in debugging. While AI tools are very knowledgeable and only become smarter as time passes they do not possess the capability to do the work alone. Using AI tools to assist in starting a UML diagram or creating an outline for a system can speedup the process. Additionally a complex project like this can present blindspots for some team members and AI tools can be used to help inform. However in a project like this where file organization, and context is always evolving and is important in coding and debugging AI is not.

Project Outcomes & Initial Objectives

SkillSwitch met the team's initial objectives for the project. All of the high-priority requirements set in the planning phase were implemented. The team found AI tools to be very helpful across each phase of the development process. Although the initial objectives were relatively ambitious, the final product did not disappoint. Clearly, it would have been very difficult to scale beyond a basic class project and actually release the project to the public. This would have required implementing some sort of content filtration system, user reporting system, and taking many more measures to ensure a safe environment for all users. However, for the basic demonstration and minimal testing, SkillSwitch was generally successful.

Future Directions (10 points):

Potential Enhancements:

In the future the battle capabilities and gamification of the platform could be greatly expanded upon. Not only with graphics but with more games and incentives instead of the basic quiz format. Multiplayer games, a minigame where having more karma points can be used to further the game etc. Additionally more learning tools can be integrated. Not only short quizzes but access to lesson plans, built in flashcards, and more than stand alone lessons but an entire course.

AI Tool Usage Improvements

The AI tool usage could be improved through some prompt engineering to fine tune the tools outputs for this project's applications. Additionally the AI tool could be further implemented to create additional study and explanation materials as discussed in potential enhancements.