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Mycelium

Browser-based IDE for interactive and proactive teaching

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Bucharest 2021

**Statement regarding the content’s originality and accountability**

Everything that is presentment in this document is the result of my own efforts and it’s entirely original. The only exceptions are instances where I either refer the works of other authors. Any such material from other sources (books, articles, websites or GitHub pages) are clearly stated in the bibliographic references list.

# **Introduction**

Since the global pandemic hit the world and brought teaching in the online medium many of its shortcomings became apparent. During physical classes, it was already hard for the professor to track every student’s performance and his rate of assimilation regarding the subject. Students were usually reluctant to ask for help and the professor could only guess if they have a problem or not based on their facial expression. Now that classes moved online this problem has became even bigger. Most students don’t ever signal that they did not understand something or that they have a compiler error. The professor can’t even see their expressions so he can only assume that everything is in order when in reality he knows that there are at least a couple of students who have problems. Hitherto, there is a huge lack of feedback going between the professor and the student that leads to situations where the student fails to grasp certain concepts that will lead to him having even greater problems down the line.

In a situation like that described above the logical solution is to encourage the student too seek help when he needs it. However, this solution is unreliable so the next best solution is to enforce the student-professor feedback loop through the creative use of software solutions. That is exactly what I tried to archive with Mycelium. When it comes to coding there is one really simple way of seeing whether or not the student understood the concept that was just taught to him: Compiling and running his code. Most often than not students will get compilers errors and will simply give up without communication their problem with the professor. With Mycelium that is not a problem as the teacher is able to see the last output of every student and whether or not his code has errors.

Mycelium aims to solve the professor-student feedback problem while also providing features such as secure accounts, data encryption, a secure backend with built-in resistance to most attacks and clear separation between account types (student/professor), each with its own permissions and restrictions enforced both on the front-end and the back-end. The goal of the application is to feel safe and easy to use while also streamlining the teaching process.

A great advantage of using this app is that the professor knows exactly which student has problems and the exact problem he is having. This will greatly speed up the teaching process and will increase its effectiveness as the professor always knows haw the students are performing without the need for them to signal that they have a problem. Another advantage is the fact that Monaco [1] is used as the text editor which offers the same code writing experience as Visual Studio Code.

As I mentioned before this idea came as a direct result of the current global situation. When we were forced to interact using only microphones, we lost an entire dimension of the teaching process and it all became linear and non-interactive. In this current context the app that I created will help alleviate this problem. Students will be unable to just join the zoom and pay no attention to the ongoing class as the professor will see their code outputs and is also able to view the code in its entirety. So, the students will not be able to hide the fact that they could not follow along and will be encouraged to seek help when they need it thus ensuring the professor-student communication. Moreover, the application is not only useful when it comes to remote teaching. Its features could also help streamline the physical teaching process as the teacher will not have to rely on guessing whether students understood the concept or where able to implement a certain task. They will be assisted by a tool which tells them exactly who and what problem they have. Hitherto, the usability of Mycelium is not relevant only in the context of remote teaching but also for on-site teaching.

[TO DO DESCRIPTION OF CHAPTERS]

# **Remote teaching**

With the global pandemic and the introduction of the general quarantine, teaching was moved in the online medium. This proved to be a challenge both for students and professors alike. Remote teaching can take many forms, each with its own variations. The method of teaching had to be chosen to fit the subject as some subjects require more dedicated live teaching while others can be taught with minimum interaction, if necessary, resources are provided. The most common type of teaching, at least in computer science universities, is the meeting on Zoom, Microsoft Teams, Discord and so on. During such a mating, the teacher shares his screen for all students to see while using his microphone to explain in further detail. In the ideal case the students would also ask questions and interact with the professor. When it comes to coding classes, many shortcomings of remote teaching become more apparent. In this case, the device used to connect and teach for both professors and students begin to matter and make a huge difference in how well the students will be able to follow the class. For example, if a student has a two-monitor setup, he will be able to watch the professor’s stream and write his code at the same time. Meanwhile, someone who only has one monitor will have to split his screen. His situation can be made even harder if the resolution (or size) of his screen is smaller. Moreover, students tend not to communicate with the teacher out of commodity, anxiety or other such conditions. Hitherto, when it comes to teaching code in the online environment there are many other factors that get in the way such as the student’s display size and quality, the performance of his machine or even his willingness to follow along and write code at the same pace as the professor.

Everyone can agree that the teaching process does not really go as smoothly in the online medium. It is also important to mention the fact that I will be mostly referring to coding and the process of teaching code. Even though programmers were amongst the least affected by the current pandemic [2] and the process of teaching software development didn’t have to change that much, it is still an extremely important field of study that would benefit from improvements that would make it more accessible and easier to teach. Comparing online teaching with physical teaching we can draw some simple conclusions about how to process goes and how efficient it is. Firstly, we can take a look at interaction between students and the professor. During on-site teaching the teacher can freely go up to a student and ask him how he is handling the subject or get and instant feedback from the entire classroom by just glancing around, looking at what the students are doing, their facial expressions and so on. Moreover, students are more inclined to ask questions when the only thing they have to do is look at the professor and speak. In contrast to this, during online teaching, students are way more likely to either not pay attention to the class or to be unable to follow and not signal this fact. Interacting with the teacher is more complicated as anxiety problems (from everyone being able to hear each other perfectly), internet problems, lack of interest, or bad microphone quality really get in the way of the student-professor interaction. Thus, it requires a greater motivation to actively participate in the course. Following the professor during the class might also be a barrier that needs to be overcame by some students as they need to both watch the professor’s stream and write their own code. This is extremely hard for someone with only one monitor especially if it a small, low-resolution one like the monitor of an average laptop. So, students are likely to fall behind or not properly understand what is being taught and not signal this fact. To add on all this, we have to take in consideration the fact that the only means of interaction between the teacher and students are the webcam and the microphone. (The webcam is rarely required so I will only be referring to the microphone) If the student does not turn his microphone one to interact with the professor, this leads to the professor being in a situation where he or she has no means of getting a feel on what the students were able to understand and what was too hard to grasp and needs further explaining.

There are also other gaps that need feeling in order to come up with a good online teaching solution. Those who have built online programs over the years will attest that effective online learning aims to be a learning community and supports learners not just instructionally but with co-curricular engagement and other social supports. Consider how much infrastructure exists around face-to-face education that supports student success: library resources, housing, career services, health services, and so on. Face-to-face education isn't successful because lecturing is good. Lectures are one instructional aspect of an overall ecosystem specifically designed to support learners with formal, informal, and social resources. Ultimately, effective online education requires an investment in an ecosystem of learner supports, which take time to identify and build. Relative to other options, simple online content delivery can be quick and inexpensive, but confusing that with robust online education is akin to confusing lectures with the totality of residential education. [3]

In order to solve this problem (more specifically the lack of student-professor feedback going around during the class) I tried to come up with a software solution that can be useful both in remote teaching situations and physical classes. What parked the idea in the first place was re repeating pattern I kept observing at all coding subjects. Almost always there were people complaining in private that they couldn’t follow the code or did not understand the lesson. The professor has no way of knowing this and has to keep going on with teaching as if everyone followed perfectly. So, the best way to approach this issue is to create a real time way for the professor to see how the students are handling the subject and if they are following along or not. Furthermore, the solution must be secure and trustworthy.

To expand on the security side of things, from past events I’ve notice a great lack of trust regarding solutions developed by the university and as personal data becomes increasingly more valuable, solutions, especially those who handle the data of students who are compelled to use the solutions should be properly secured. The students tend to be distrustful to applications that ask for too many permissions, trigger the antivirus or seem easy to hack. Thus, I decided that the solution I develop should be secured to the best of my abilities.

As I mentioned before, in the context of the global pandemic and with classes moving into the online medium, it is extremely important to create the proper environment for students. This should include both access to resources and more accent placed on individual work, as well as better interaction between students and the professor. Encouraging students to ask questions and seek out help should be one of the main priorities of an educational institution. Thus, there is need for a software solution that could help solve this problem through a simple and secure approach. If there is nothing to encourage and even force the student to ask questions and interact with the professor, he or she will most likely choose the comfort of sating muted the entire session and possibly not even paying attention to what is being taught. The approach through which this positive outcome should be achieved should be as simple and non-intrusive as possible. If the student knows that he is likely to make a mistake because he did not understand the lesson and that the professor will be able to see the way he or she is performing, they will be more likely to seek help beforehand and will not end up in situations where they failed to understand a concept and fell behind while the professor has no idea of this. Ultimately, such an approach will lead to less cases when the professor only finds out how well the students understood the subject at the exam and will be able to follow their progress much closer.

# **Used Technologies**

The application has three major components. Those being the frontend AngularJS webpage, the backend NodeJS REST API and the MongoDB database. All those parts can work fully independent from each other and can be tested as such.

## **Frontend**

The website page was developed using the AngularJS [4] framework and was written using TypeScript [5], HTML5 and CSS3. Additionally, Bootstrap [6] has been used in a few instances for a quick to build, standard and pretty visual interface. For the code editor, the Monaco Editor has been used. Angular was also enhanced through the use of RxJS [7].

Angular has been chosen for a couple of reasons. Mainly for its “holistic” software development approach. It is entirely self-sufficient and works without the need for additional libraries. It is also a full-fledged JS framework unlike React which is a library for UI development. It also works for both web and mobile (if integrated with Ionic or NativeScript) and has great potential for future improvement as it is used by large companies such as Apple, Adobe or Microsoft. It is especially useful in my context as it gives access to the model, the component and the view and is optimized with change detection as opposed to the virtual DOM approach of React. With the help of Angular CLI you can further refine the experience as it allows you to quickly perform actions from the command line. In addition to all the already built-in features, Angular supports dependency injection and can be improved with RxJS or NgRx. Data binding, component-based routing, project generation, form validation, and dependency injection – can be implemented with the means of Angular package. The only downside of using Angular in the project is the fact that Angular itself is a huge library, and learning all the concepts associated with it will take much more time than in the case of React. Angular is more complex to understand, there is a lot of unnecessary syntax, and component management is intricate. Some complicated features are embedded into the framework core, which means that the developer cannot avoid learning and using them. Moreover, there are a lot of ways of solving a single issue. Although TypeScript closely resembles JavaScript, it also takes some time to learn. Since the framework is constantly updated, the developer needs to put some extra learning effort. [8]

Bootstrap is a front-end framework used to quickly design responsive sites. It is extremely useful in situations where you need to quickly create an interface that will work well both on mobile a desktop web browser. Bootstrap includes user interface components, layouts and JS tools along with the framework for implementation. “In the physical world, a bootstrap is a small strap or loop at the back of a leather boot that enables you to pull the entire boot on and in general usage, bootstrapping is the leveraging of a small initial effort into something larger and more significant. There is also a common expression, "pulling yourself up by your own bootstraps," meaning to leverage yourself to success from a small beginning.” [9]

TypeScript is an open-source which builds upon JavaScript. The main difference between it and JavaScript is the fact that TypeScript is a strict syntactical superset of JavaScript and adds optional static typing to the language. It ultimately transcompiles to JavaScript via the TypeScript compiler or Babel. I decided to go with TypeScript because of how enforcing types on variables helps develop complex apps. It increases testability and speeds up debug times as many errors can be caught ahead of compile time in the editor. It also has great long-term support as it is developed and maintained by Microsoft.

HTML stands for HyperText Markup Language and is the standard markup language for documents designed to be displayed in a web browser. It offers many options for structuring content in a webpage and it consists of a series of elements, which you use to enclose, or wrap, different parts of the content to make it appear a certain way, or act a certain way. The enclosing tags can make a word or image hyperlink to somewhere else, can italicize words, can make the font bigger or smaller, and so on. [10] HTML can be further enhanced by adding styling through the use of CSS or Cascading Style Sheets and scripting languages such as JavaScript.

CSS stands for Cascading Style Sheets and it is a style sheet language used for describing the presentation of a document written in a markup language such as HTML. [11] Through its many features such as selectors, declaration blocks, sources, positioning and so on, CSS offers incredible flexibility when separating and styling the presentation of content. This improves the accessibility of the webpage and enables reusability as the code can be applied to any HTML document thus creating the possibility of reusing the same CSS for many different documents.

The Monaco Editor is the code editor the powers Visual Studio Code. It is an open-source editor that is designed for high productivity. When used together with programming language services, it gives you the power of an IDE and the speed of a text editor [12] and makes it ideal to be used in a browser environment. For the project I decided to use an open-source project named “ngx-monaco-editor” [13]. It is an implementation of the Monaco Editor as an Angular component. This allows easy and seamless integration of Monaco inside any Angular project. It can simply be added to angular as any regular dependency by using the Node Package Manager or npm.

RxJS or Reactive Extensions Library for JavaScript is a library for composing asynchronous and event-based programs by using observable sequences. It provides one core type, the Observable, satellite types (Observer, Schedulers, Subjects) and operators inspired by Array#extras (map, filter, reduce, every, etc) to allow handling asynchronous events as collections. [14]

## **Backend**

The REST API has been developed using NodeJS [15] and additional modules or “middleware”. Those middleware components provide functionality from security to colored strings in the console for improved readability. For security purposeless bdcrypt.js, cookie-parser, cors, express-mongo-sanitize, helmet, hpp and xss-clean were used. Additional middleware such as detenv, node-jsonwebtoken, mongoose, morgan, nodemailer, nodemon, slugify and colors were used either to make the development process easier or to provide ease of use for the user. It was created as the core of the application and any frontend application can communicate with it and use it in a simple and streamlined manner as long as it knows the rules. The entire code is simple and robust and satisfies all principles of clean code in order to be easy to understand by anyone willing to use it. It can be further expanded and features can be turned on or off by simply commenting a single line of code. The added functionalities of the third-party middleware and the reason for their use are the following:

* It uses the dotenv package in order to access and use a set of environment variables that are constant and can be easily changed. Such as the database connection link or settings for the security middleware.
* For database communication the mongoose package was used as it is simple to use, expertly powerful, feature rich and well maintained. Even though the database is nonrelational, mongoose provides great querying ability as well as clean table schema creation and management.
* For logging purposes morgan was used in conjunction with colors.js.
* As changing something in the node app requires a restart of the server, I used nodemon solely for the development environment. This package will automatically restart the server when it detects changes to the files.
* As logging in is an important process because it serves as the user’s gateway into the app, it was designed to be as simple and secure as possible. The bcrypt.js package was used in order to hash and encrypt the password.
* node-jsonwebtoken was used to generate web tokens that will be sent to the client and stored as cookies. They are also the key to the application as almost all routes are protected and require authorization. That is why any request has to have the required headers with the java web token bearer token to serve as the authentication key in order to determine if it belongs to an actual user and figure out the user’s role (student/professor).
* For password resetting (in case of a forgotten password), nodemailer was used for sending email with the link containing the token for password reset.
* Security is an extremely important part of the backend. Many middleware solutions were used for the single purpose of eliminating risks of attacks such as XSS and DDOS. Firstly, cors was introduced for adding security headers for the CORS protocol.
* express-mongo-sanitize was used to sanitize the incoming data and prevent malicious code from being executed on the server. It acts as a barrier against sql/nosql injection.
* Http secure headers were added with helmet.
* Against HTTP parameter pollution, the hpp package was added.
* The express-rate-limit package is used to limit the number of allowed requests from a single source, good for protection against DDOS attacks.
* xxs-clean was used to prevent cross site scripting attacks.

Representational State Transfer or REST is a software architectural style which uses a subset of HTTP. It is commonly used to create interactive applications that use Web services. A Web service that follows these guidelines is called RESTful. Such a Web service must provide its Web resources in a textual representation and allow them to be read and modified with a stateless protocol and a predefined set of operations. This approach allows interoperability between the computer systems on the Internet that provide these services. REST is an alternative to, for example, SOAP as way to access a Web service. [16]

## **Database**

The database of the application has been implemented using MongoDB [17]. The main advantage of MongoDB is that it is a document database so data is stored in JSON-like documents. This offers a more natural way of thinking about data for a programmer as opposed to the traditional row/column model. MongoDB also boasts a powerful query language which are themselves JSON so are easily composable, unlike the concatenation of strings required in order to dynamically generate SQL queries. Moreover, non-relational databases are way faster when it comes to accessing data thus fits better for the case of this application.

MongoDB also has a big advantage in the fact that it is based in the cloud. MongoDB Atlas is the multi-cloud database service for MongoDB available on AWS, Google Cloud, and Azure. Best-in-class automation and built-in proven practices provide continuous availability, elastic scalability, and support with regulatory compliance.

For visualizing the contents of the database MongoDB Compass [18] was used during the entire development process. It is an application that allows the user to search, visualize, and work with your data through an intuitive GUI and manipulate your data with a powerful visual editing tool.

# **Solution Architecture**

The application as a whole is made of two big components. One is the webpage and the other is the API. Another third smaller component is integrated with the API, the database. The two components are designed to work together but can also be used independent pf each other.

## **The webpage**

It is made out of three main components, all connected to the base one, the “app” component. Those three are: The log-in/sign-up page, the dashboard and the working environment.

### The log-in/sign-up page

Is the page a non-authenticated user is taken upon trying to access the app. Here the user can log-in or sign-up if he doesn’t already have an account.

### The dashboard

This is the component where the user is able to visualize all the classes he is was added to. The professor has a different interface. Apart from being able to see the classes he is also able to add users to a class and create ne ones and also start the class so students can enter the working environment of that class.

The dashboard is comprised of several components. First is the navbar from where the user can log out or return to the home screen depending on the button he clicks. Another component is the list of classes. Here all the classes the user is part of are displayed. Each entry in the list is another component generated based on a list retrieved from the API. Those smaller components are used to display some brief data about the class they represent. In the list of classes component there is also a button displayed only for a professor which will load the component with the class creation. The third and last main component of the dashboard is the statistics component where data about the selected class from the list component is displayed. If the professor clicked the add class button on this component the class adding component is loaded. Moreover, this is the component from where, when a class is selected, the user can join a launched class and the professor can launch the class, add participants or close the class.

See [Appendix 1] for the component diagram.

### The working environment

The working environment has four components. The first and the largest one is the Monaco Editor. This is where the user writes the code that is later sent to the server to be compiled and ran. The other component is the file tree where the code files can be created and selected. The last component is the list of connected users.

## **The API**

The API has one main component, the server. Inside the server are integrated all other components, controllers, middleware. The API routes are integrated through the controllers. There is one module class for each module from the frontend in order to maintain everything clean and easy to understand. Each controller has an associated routes module where the methods of each related API call is implemented. The routes use the models for managing objects and interacting with the database. The compiler class handles all the compilation tasks and return the results that will be sent as a response.

See [Appendix 2] for the class diagram of the backend.

## **The database**

The database is not relational and the tables are only linked by the backend logic by using lists of ID’s. This is used for creating ownership.

See [Appendix 3] for the database diagram.

## **Usage**

The user interacts only with the frontend part which talks with the backend which, in turn, talks with the database. The user creates an account then logs in. A professor has to add him to an existing class and when the class is started, the student can join the ongoing working environment. There he can write code and run it. The professor can see all connected users and the output they had on the code they last ran. (See [Appendix 5-11] for the UI of the application)

# **Solution Implementation**

[TO DO]

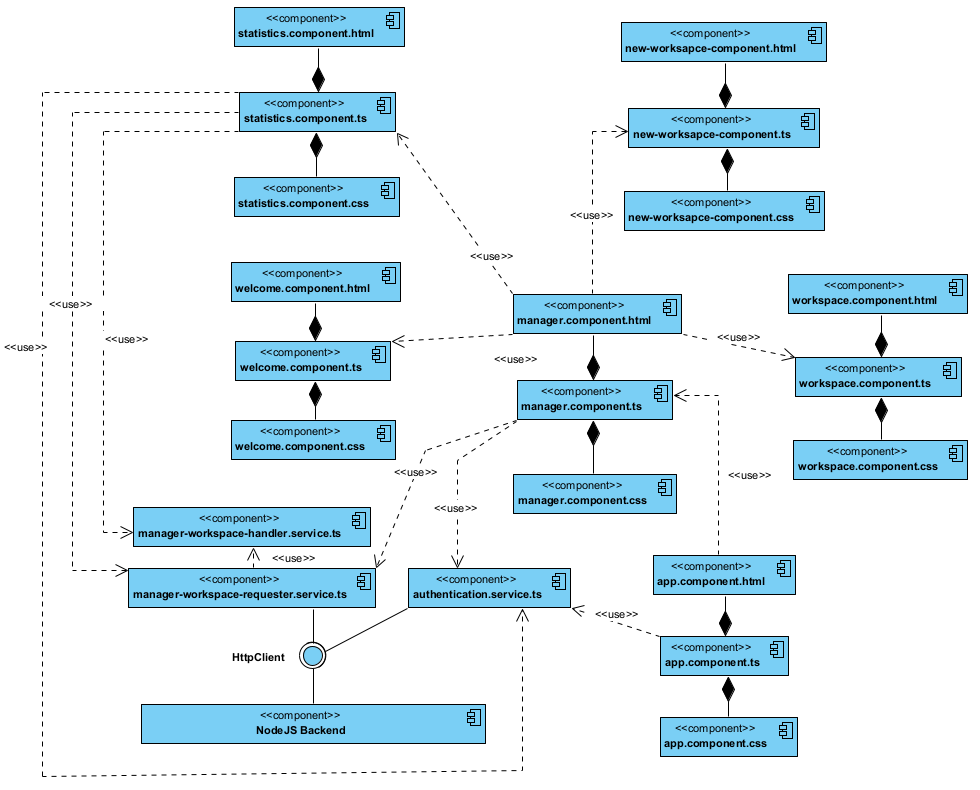
The combination of NodeJS and MongoDB has some vulnerabilities that could lead to the entire integrity of the application to be compromised. The biggest one is the way MongoDB fetches data based on the received parameters. Through a technique much simpler than SQL Injection this can be achieved. Considering the next line of code, the user can authenticate from anywhere in the app:

SELECT \* FROM users WHERE username = '$username' AND password = '$password'

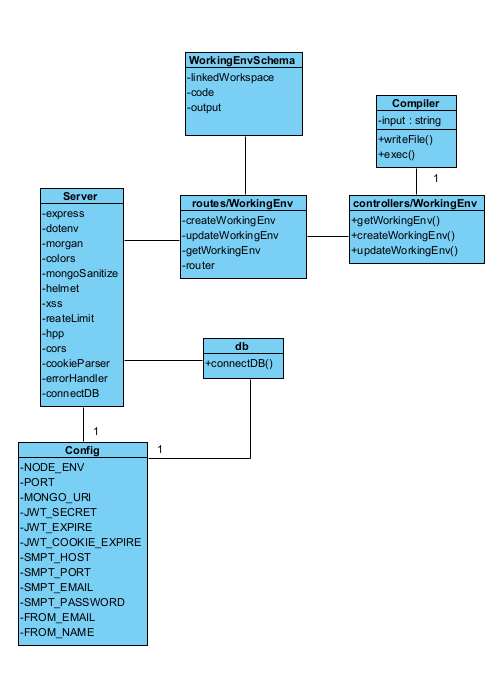
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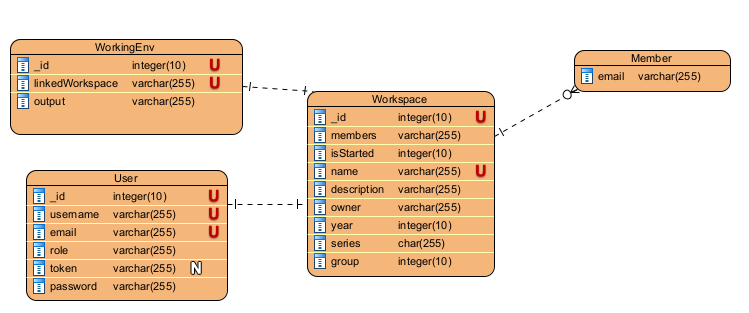
# **Appendix**



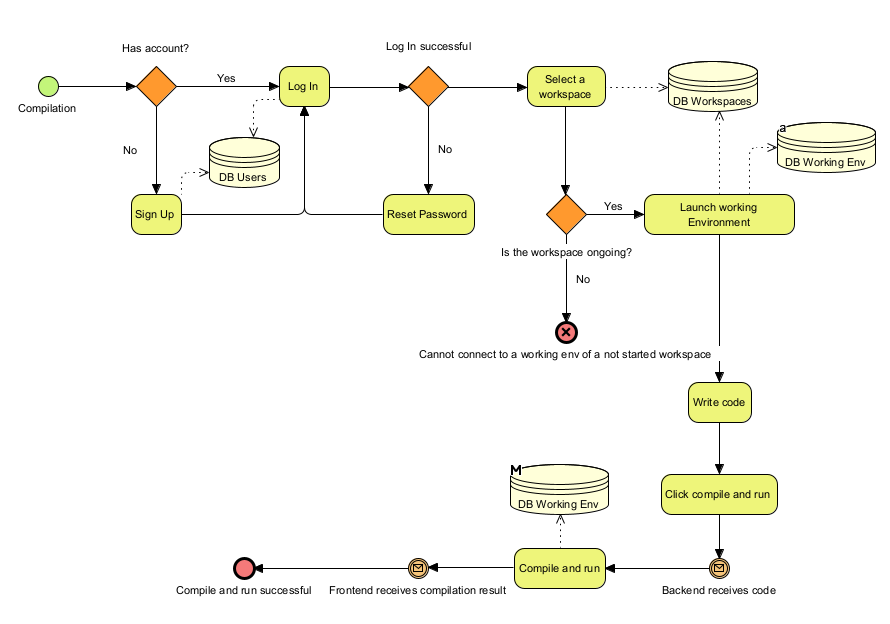
Appendix 1 – Component Diagram for the Dashboard component.



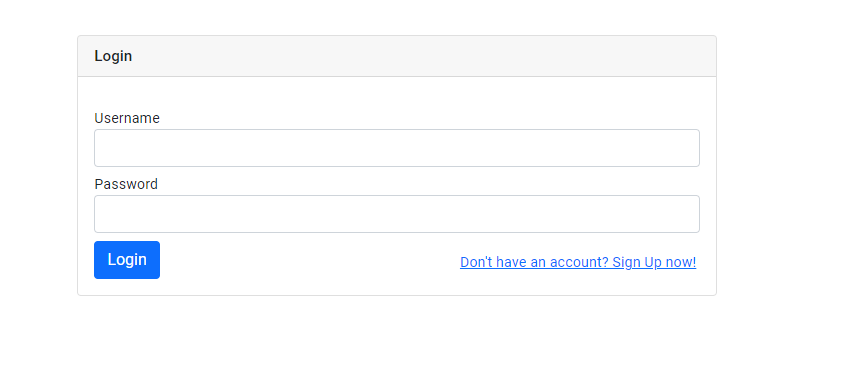
Appendix 2 – Class diagram of the backend.



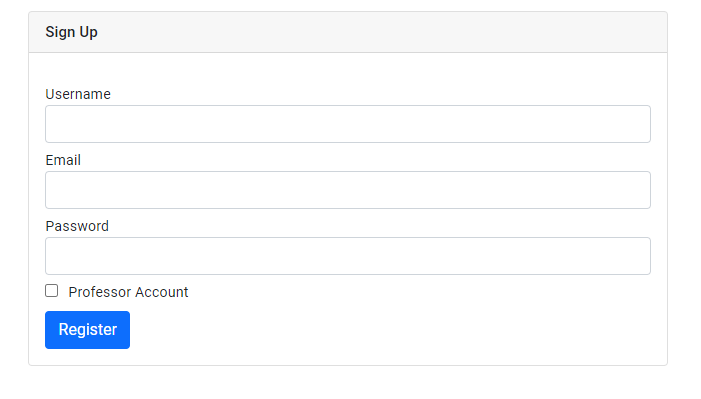
Appendix 3 – Database diagram.



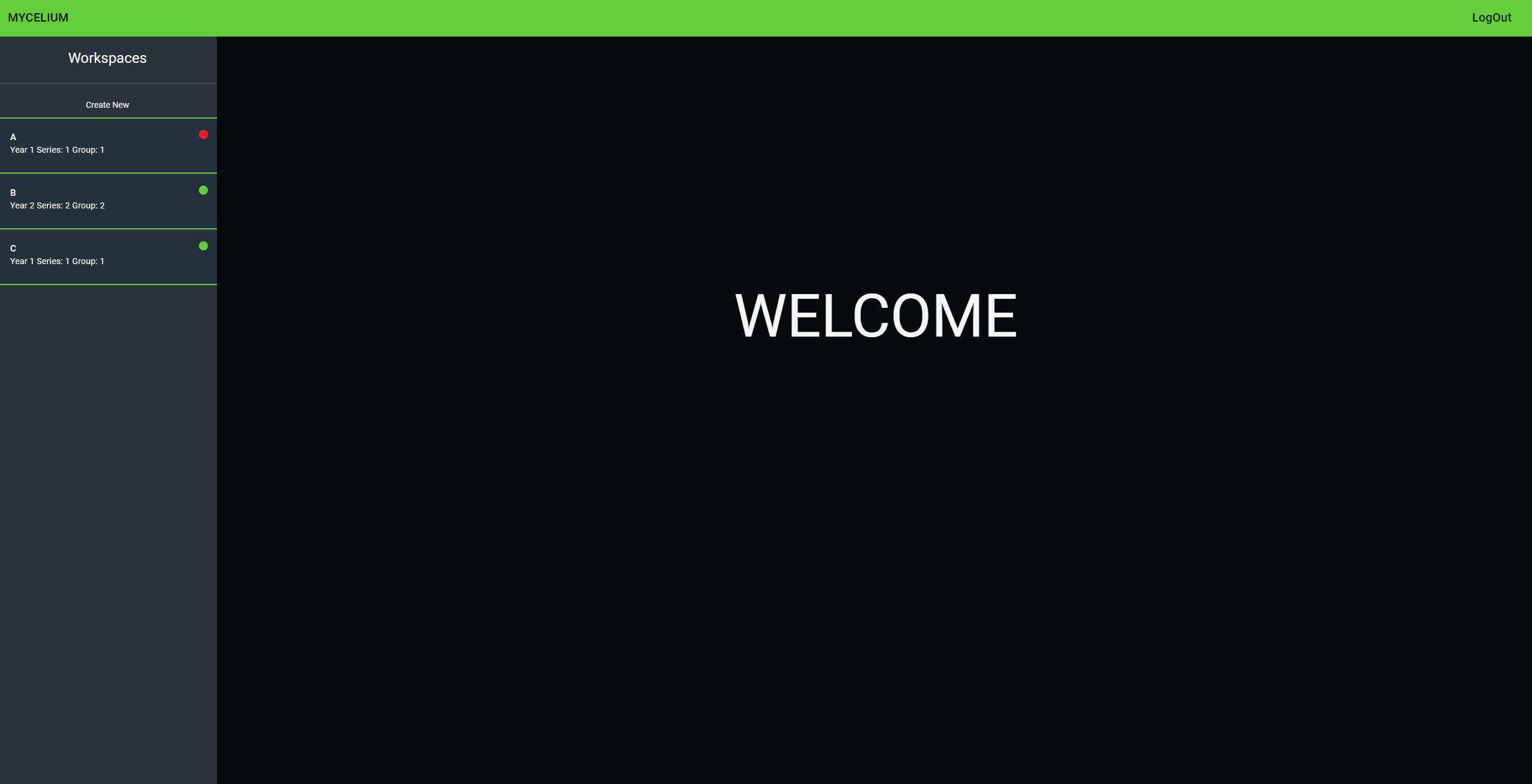
Appendix 4 – Usage flow diagram



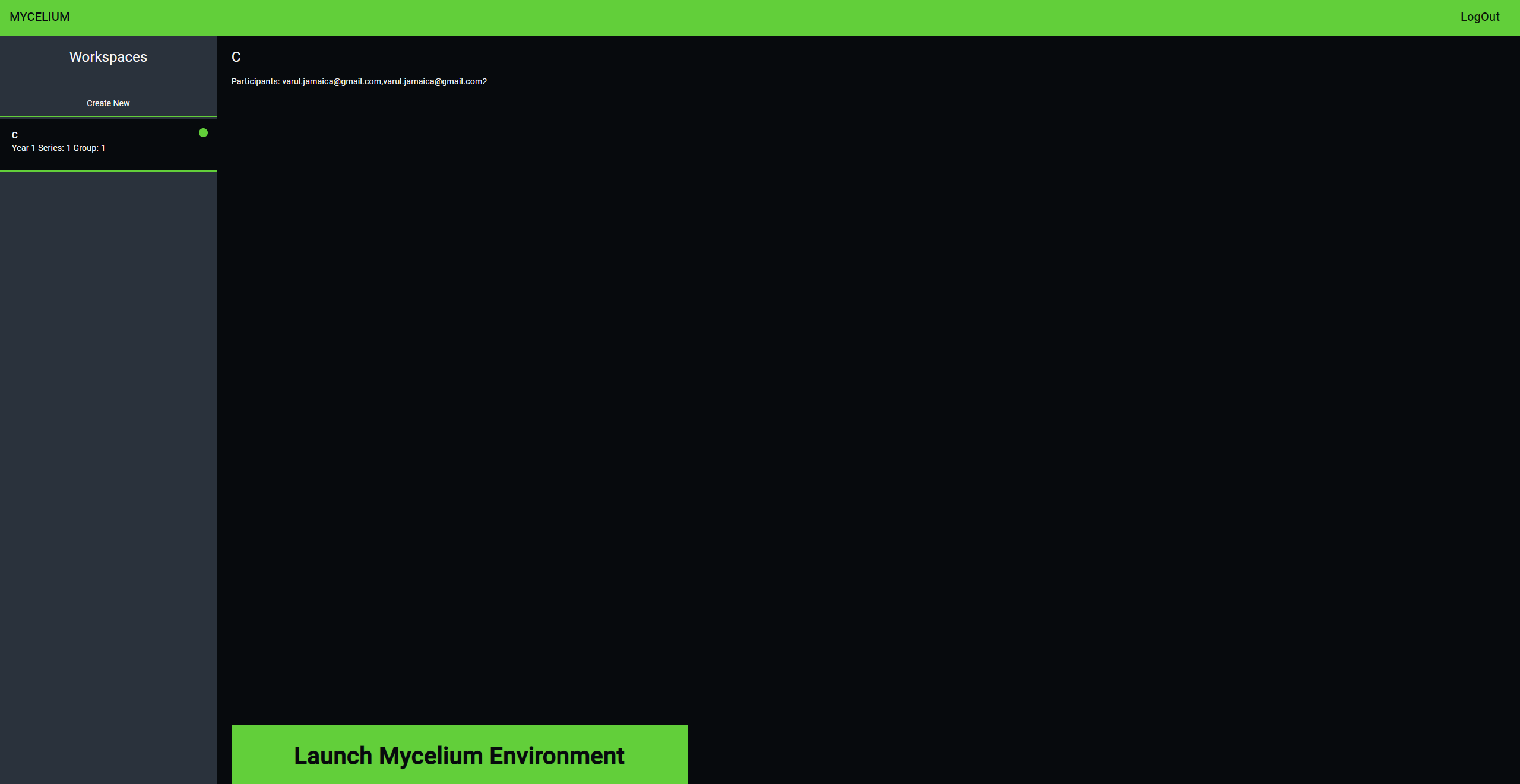
Appendix 5 – Login page



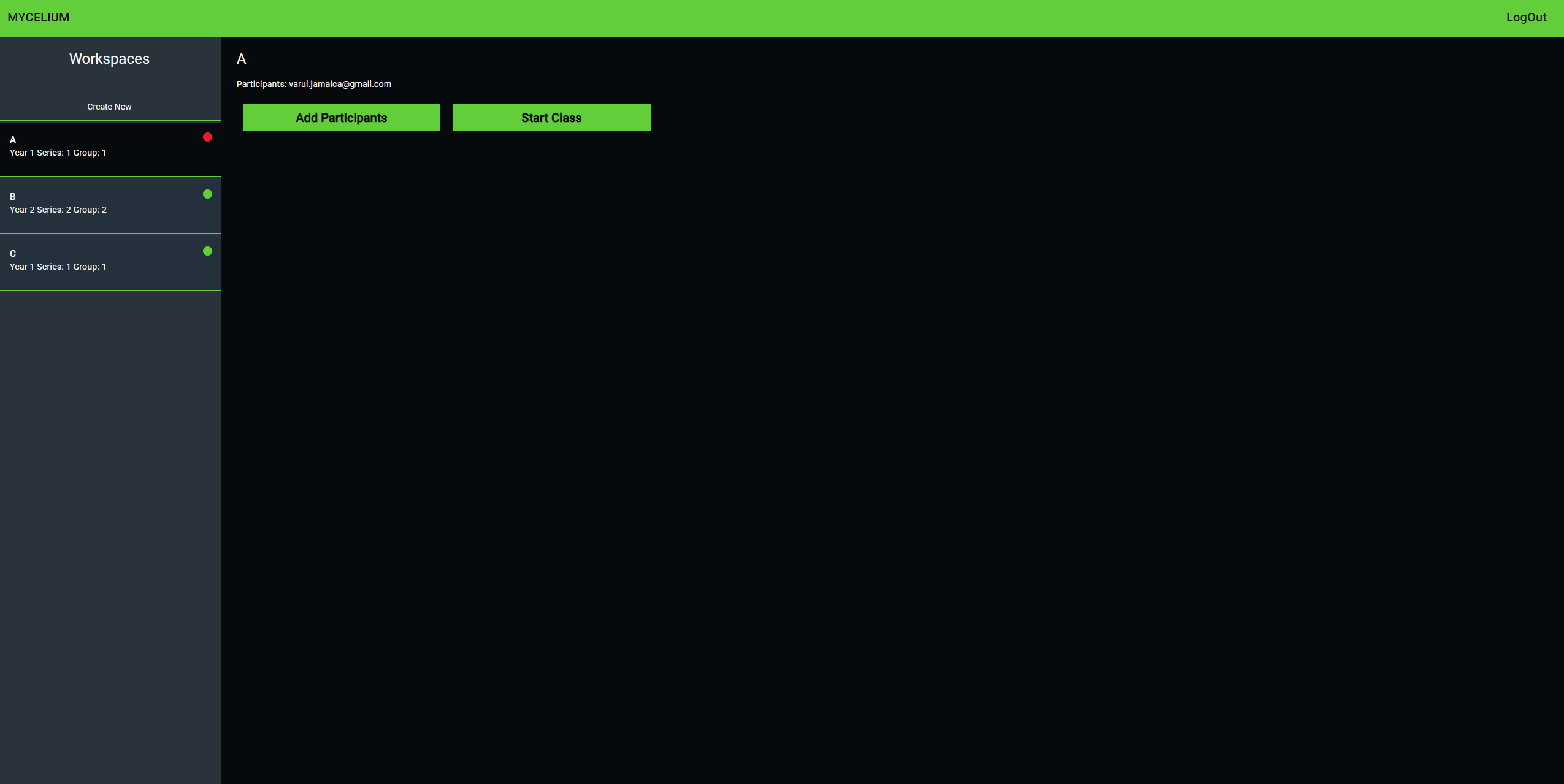
Appendix 6 – Sign up page



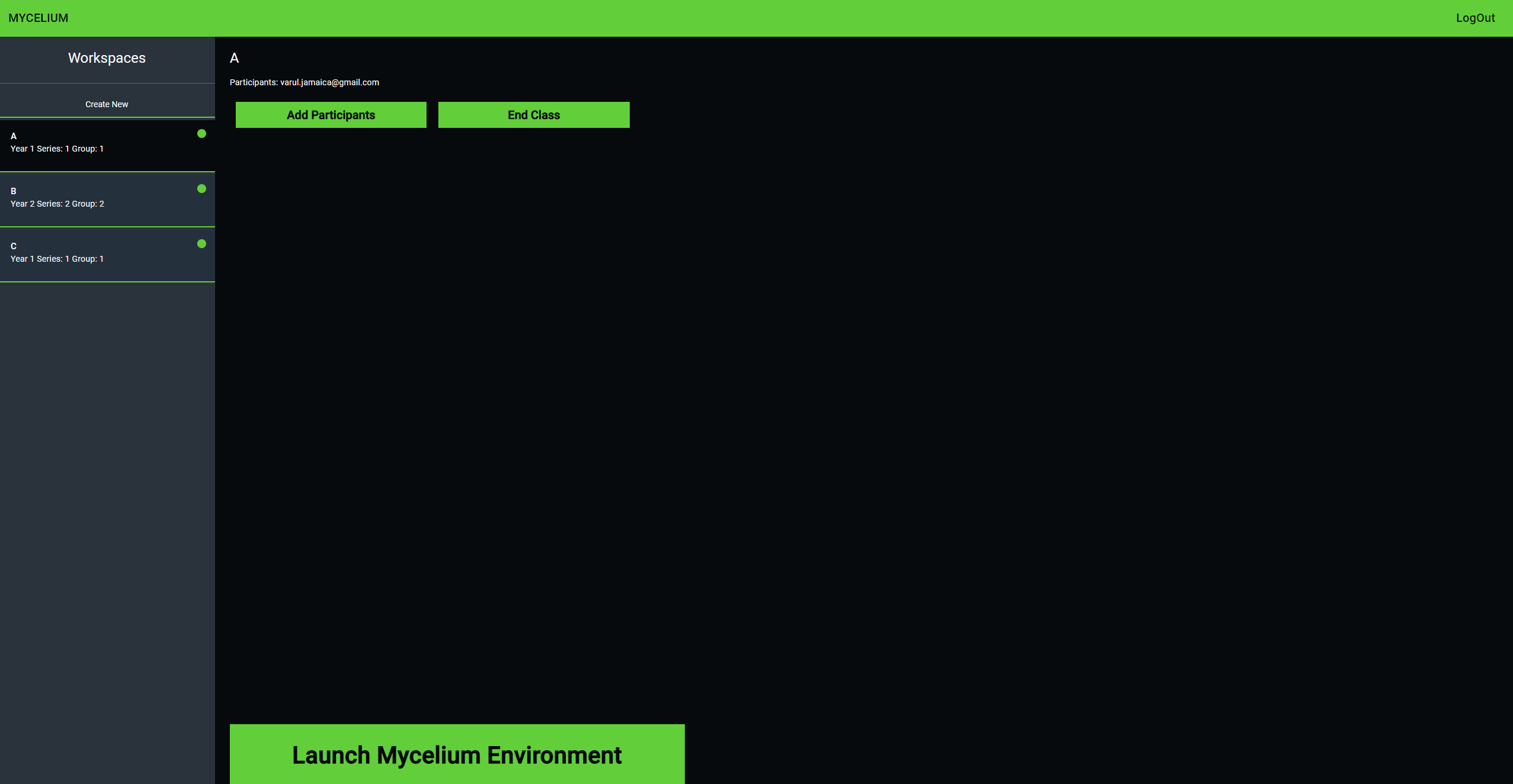
Appendix 7 – Logged in as professor



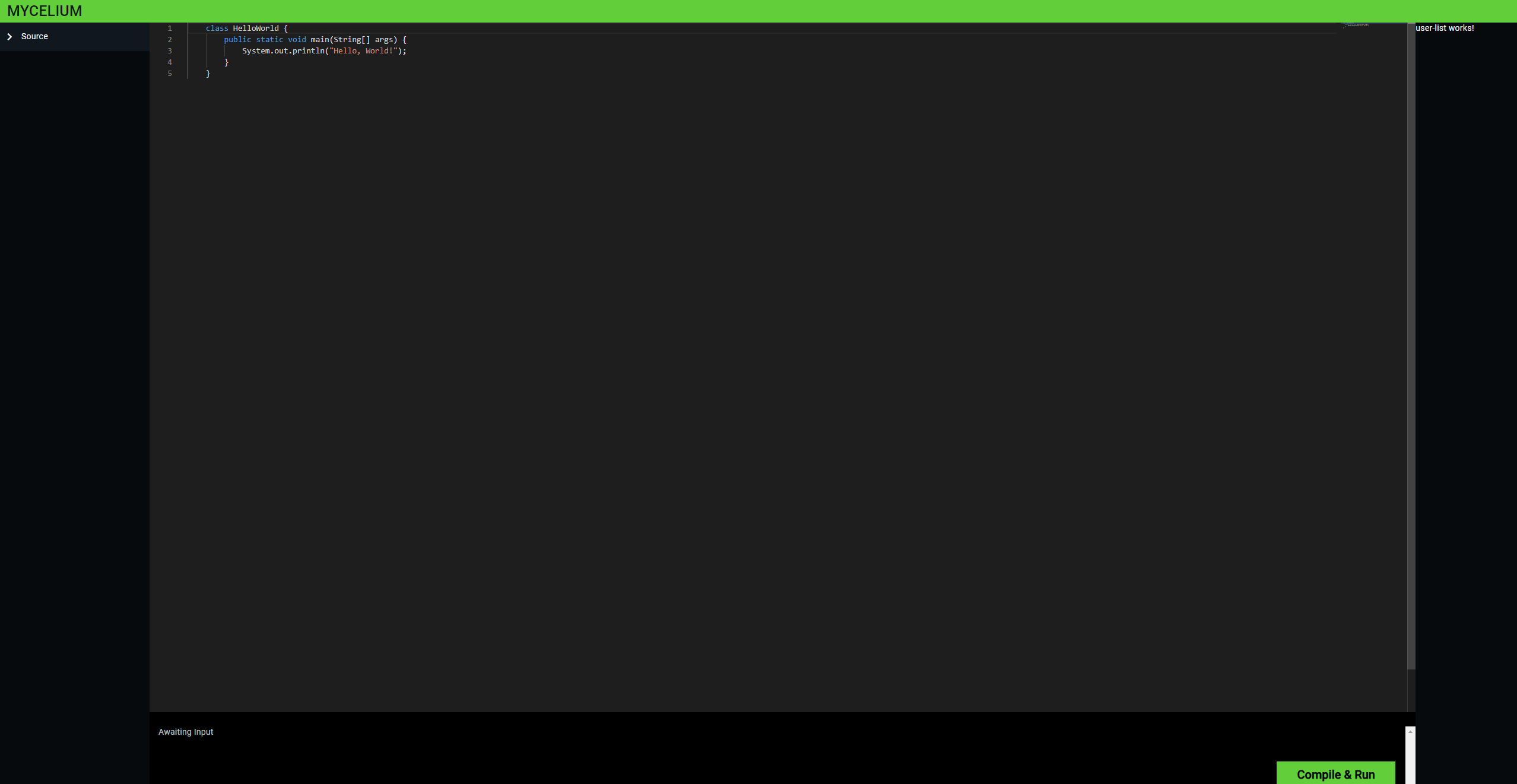
Appendix 8 – Logged in as student



Appendix 9 – Selecting a workspace



Appendix 10 – Launched workspace



Appendix 11 – Working environment