Global Undergraduate Research Landscape Analysis and Its Effect on 4th Industrial Revolution

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Abstract Undergraduate level research engagements can aid the students in learning about the current ongoing innovations and shape them to become an efficient workforce for the future. However, it is poorly managed globally, including in Bangladesh, because it is difficult to track due to the scattered nature of this information. InNeed Intelligent Cloud, along with the University of North Carolina Chapel Hill and National Science Foundation(NSF) of USA, aims to tackle this issue through the BLUMER research project. Based on the researchers' research study, we created a searchable database with a web-based search interface that searches through the awarded projects data of the National Science Foundation (NSF) website, which is stored in the AWS cloud database. It also provides an analytical overview of the undergraduate research data through an analytical dashboard that provides numerical insights into the current research landscape around the USA. The aim of the system is to guide the students, researchers, and supervisors in their desired research interests. By establishing an evaluation metric for understanding undergraduate level research production, in the future, we can build upon this and focus on the commercialization of this project which would enable global outreach and connection. This will help create an iterative process that would promote undergraduate research among students at an early stage and build a technologically enabled and industry-focused workforce. So, it can aid in students' theoretical and applied skills development and create an efficient workforce that can lead the 4th industrial revolution in various fields such as Artificial Intelligence, Robotics and Automation, IoT and Smart Agriculture, Data Analytics, Cloud Computing, etc.

Keywords Education · Research · Cloud computing · Data analysis · Behavioral analysis · 4th industrial revolution · Workforce development

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1 Introduction

Every year, millions of research products are produced throughout the world. Research outputs including publications, conference presentations, and patents do not commonly contain information that would help undergraduate students to get affiliated with them, which can later be used as a launching pad to help them build a career in that research field. In the context of the USA, in recent researches, it was shown that the undergraduate research opportunities are limited to a single site [2], participants of NSF REU that are specially selected [6], lastly structured research opportunities in the first year of study are very rare [1]. In a country like Bangladesh, where the socio-economical situation is very dynamic, it is very important that we give a platform to the various categories of students that exist, to help them go beyond typical academic work and actual research work that would aid them in gaining higher studies opportunities, and also cater to specific student's needs. This iterative process will create a sustainable and scalable workforce for the various industries within the country. By understanding the undergraduate research outcomes, especially the goal of developing the knowledge mine that would aid in developing "Digital Bangladesh", we can create a cycle that would help future students in the decision-making process.

1.1 Problem Statement

There is a lack of a proper system that can track, analyze, and consolidate scattered research project data that can enable students to search for research projects and create an international network with other fellow researchers across the world. Students need to search in a very scattered and time-consuming way through google or other platforms. Institutions also don't have a tool to track their undergraduates' research output, the current comparative studies are comparatively labor, resource, and time-intensive due to the use of longitudinal survey data [4]. All of these lead to a workforce that is not well adapted to the current technologies that would accelerate the 4th industrial revolution in our country. The universities can benefit by having a portal where they can post project opportunities for the student thus creating a collaboration platform for everyone to use. The administrators can track student engagements and determine the strategy to influence more students' interest in research participation and understand their career trajectories. The students themselves can find a single source of information that aggregates research projects from different sources and find opportunities for research work based on their own interests. A combination of all of these can provide a national platform that can generate a technologically efficient workforce capable of bringing changes to various industries.

1.2 Literature Review

We tried to find research ideas that dealt with how research can bring innovation to the industry and if there are any tools that empower students to get affiliated with their desired research projects.

After reading through the Institute of Entrepreneurship and Innovation's multi-year study on research participation of graduate and undergraduate students, we found that these respective students had contributed greatly to the industry. This further enforced our original idea, as reading further, we found that students who participated in research grants that enabled work between a third-party organization already in the industry had further pushed the industry path and contribution of said students [3].

We came across another study conducted by The University of Tennessee regarding the extent to which perceived learning gains from undergraduate research affected degree (and consequently industry) aspirations. The study found it statistically significant that a student involved in undergraduate research would be more inclined to continue education in a graduate degree, and consequently, the contributions to the industry he/she specialized in, in an industrial application [5].

Another article we followed was conducted by the Milwaukee School of Engineering, which also focused on tracking the influence of undergraduate research programs on a student's future career path, either graduate school pursuit or industry-related. Though mainly focused on higher education, there was a particularly interesting statistic that suggested almost 71% of the sourced students would continue education and further contribute to the industry standard. This makes it essential that providing these open opportunities to participate in research grants is great in furthering industry development [7].

2 The BLUMER Project

To tackle the aforementioned need for such a tool, InNeed Intelligent Cloud partnered with the researchers of the University of North Carolina at Chapel Hill and the National Science Foundation of USA to create a web application that facilitates the BLUMER vision. It is a web application that promotes the following:

- Establishing an evaluation metric for understanding undergraduate research production.
- Creating an initial database of undergraduate research products.
- Developing, refining, and validating the tool to be scalable to understand the impact of undergraduate research experiences on the nation's scientific workforce.
- Using the evaluation metrics to contribute to the science of science and innovation policy within the country.

- Allowing institutions that do not currently track undergraduate research work a repository which can, in turn, be a collaborative workspace for the students and other professors.
- Creating an iterative process that ensures the creation of a research-minded and technologically advanced workforce that sustains industrial advancements within the country.

By incorporating institutional awarded projects as our data source, we provide a single source of information for the users.

3 The Model Of BLUMER System

Our work on BLUMER started from the EAGER proposal that was done by the team in the Carolina Health-Informatics Program(CHIP) at the University of North Carolina at Chapel hill. Our team in InNeed Intelligent Cloud worked with the researchers at UNC to define the scope of our technical foundation. Based on the requirements we got, we decided that the architecture of the BLUMER system will contain the following modules:

- A web-based search engine that can search through thousands of awarded research projects based on topics chosen by the user
- Email search capabilities through which users can also query the database.
- Admin capability to add newly awarded projects inside the database that can later be searched
- An analytical dashboard that allows the admins of the web application to see the state of the awarded projects throughout the country through various graphs, that would allow them to make informed decisions.

3.1 Process of Creating The Architecture

Based on the proposal we had from the University of North Carolina at Chapel Hill, we based our architecture on the following action items:

1. Data Modeling and DB design: We analyzed and designed data models for the undergrad research database. This database stores structured data on undergraduate research which will be accessed by the undergraduate students through an Omni-channel search interface. This will be established as the central datastore of the system.
2. Development of Basic Web Search Front-End/UI: Our next set of action plans involved creating a search application that allowed searching the database and retrieving project information. The application features both simple and advanced

search features and was designed with cloud-native technology. The technology is serverless, thus it is flexible and scalable to the user number.

3. Basic Email Front-End Query and Retrieval System: To establish the omnichannel system, we implemented the search to be done through basic email clients like Gmail or yahoo, which give users access to the database through an email interface.
4. Basic Admin Panel: The universities that adopt our application would require an admin panel that would give them the ability to put newly awarded projects and other related information in our database. So, We developed a database data entry, update, and maintenance system for BLUMER system administrators for the universities.
5. Data Loading: We added National Science Foundation or NSF's awarded project data to our database.
6. Testing: To test the usability and scalability of the system, we did extensive testing which involved black and white box testing to understand the unit capabilities of the application. We also had a sample group from the University of North Carolina at Chapel Hill, which acted as the user to test out the web application from a user perspective.

The whole architecture of the system is given below (Fig. 1).

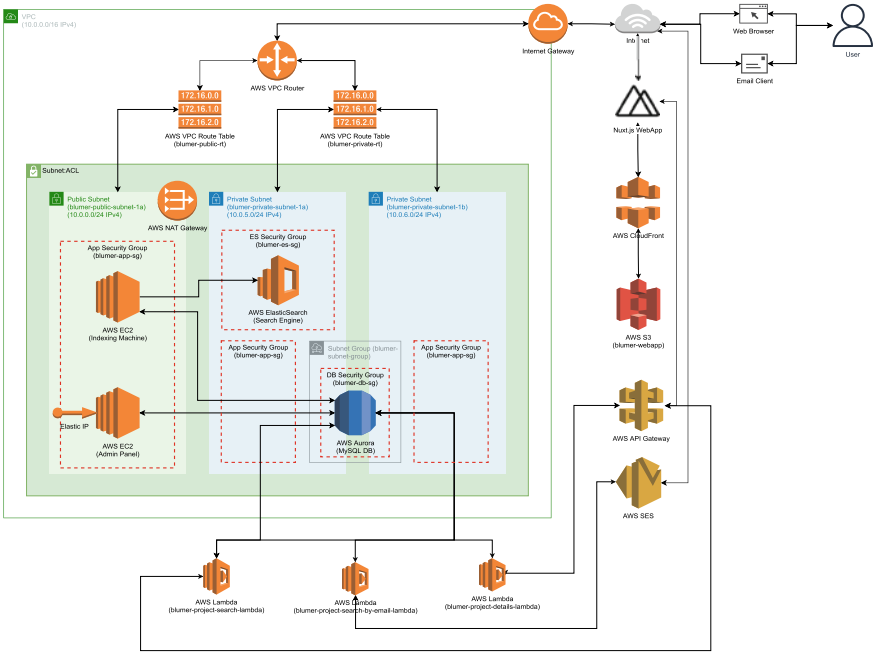

Fig. 1 The AWS architecture of the BLUMER application

We had built the whole architecture of the system in the Amazon cloud environment. For computing, we had used AWS lambdas, which would interact with the RDS Database we had used to store the data. We used API gateway to capture the user request from the front-end web application that also interacted with AWS Simple Email service or SES to provide the search capability through the email client. The admin web app that we have built is created through a Django framework and it is run on an EC2 machine. The whole infrastructure is secure through AWS VPC with the databases in private subnets and user-facing components on public subnets.

3.2 Data Collection

From the initial proposal of the University of North Carolina Chapel Hill, we ingested the database with National Science Foundation's awarded projects. The whole data flow pipeline diagram is given below.

The award was given out to various universities in the United States of America. The individual Data consisted of various fields such as start time, principal Investigators, University, University states, abstract, etc. We scrapped the data from their website and ingested it within our own database. We extracted the data from 2021 to 1990 to give the database a considerable amount of data to start on. The application performed considerably well by retrieving the data in 3 s from the database we had. By having the database in the cloud, we were able to be this efficient, also the serverless compute tool we used, AWS lambda, scaled up based on the request.

As seen from Fig. 2, we can see that after we had ingested the data into our database, we also indexed the data to Elasticsearch to provide the admins a dashboard that would allow them to see the state of awarded projects from a high level throughout the nation.

As previously mentioned, we modified the data we got from the NSF website in such a way that it adheres to the data model we had created. For the database, we had used the aurora database which is also serverless, thus it is able to scale really well. Below is the ERD Diagram we had to build for the system (Fig. 3).

4 Results and Output

4.1 The Web Application

The main portion of the system is the web application that will allow users to search through the awarded projects and get details of an individual project, that one might get by searching the web application. We can see the workings of the web application through Figs. 4, 5, and 6.

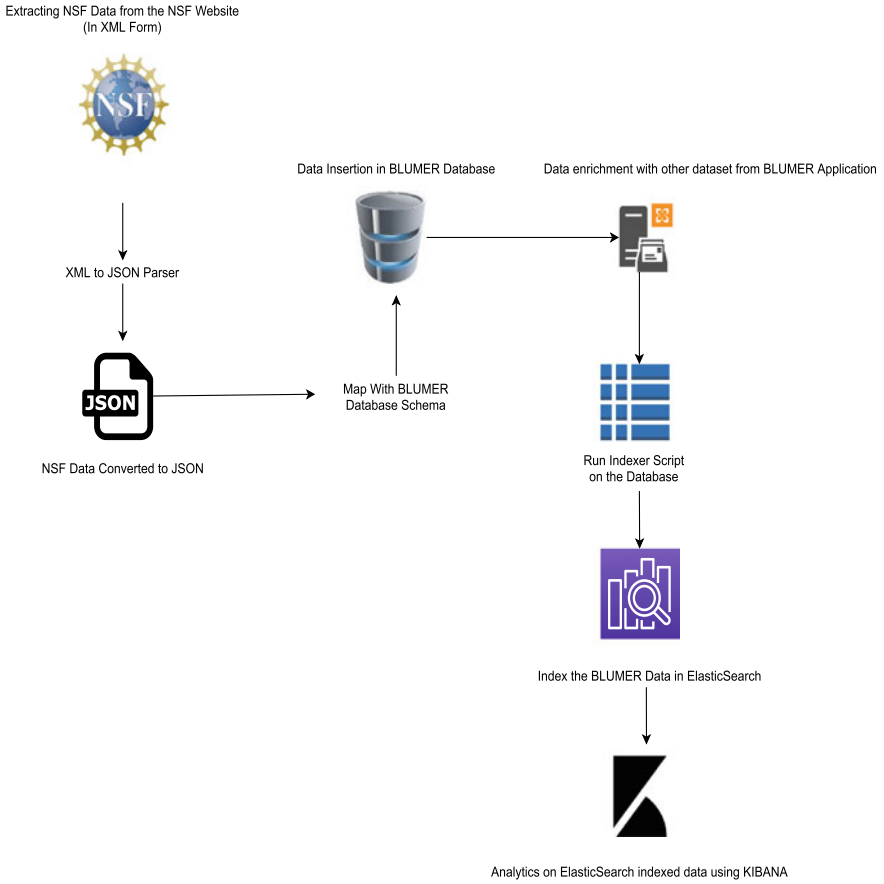

Fig. 2 The data pipeline of BLUMER

The working process of navigating the web application is given below:

- The user uses the search bar to write down desired keywords and choose related fields such as computer science, chemical science, etc.
- The resulting page gives the results based on the search criteria a user provides.
- The results can be further filtered using university name, university states, supervisor, and date.
- The user can click on a particular project to get the details regarding the project such as project description, start date, related researchers, project duration, the type of project, etc.

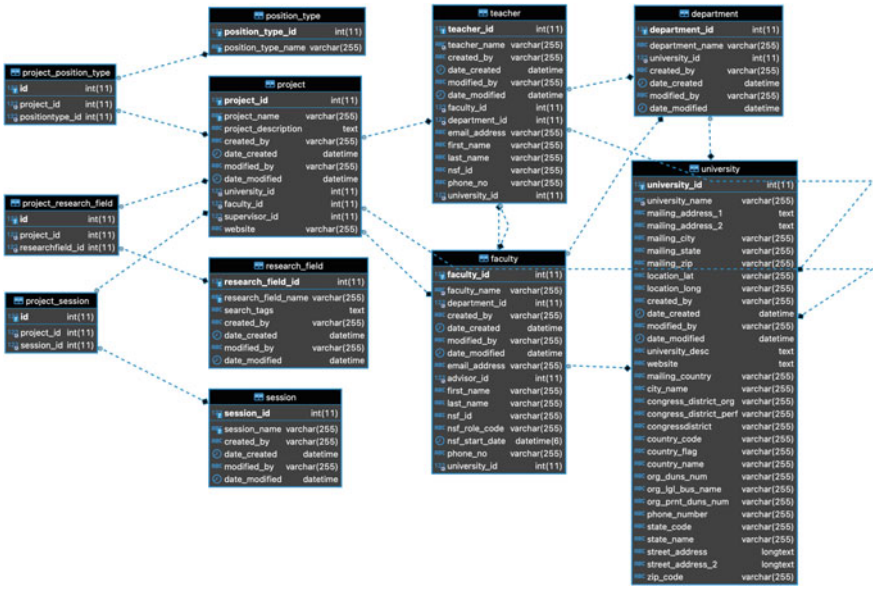

Fig. 3 The ERD of BLUMER

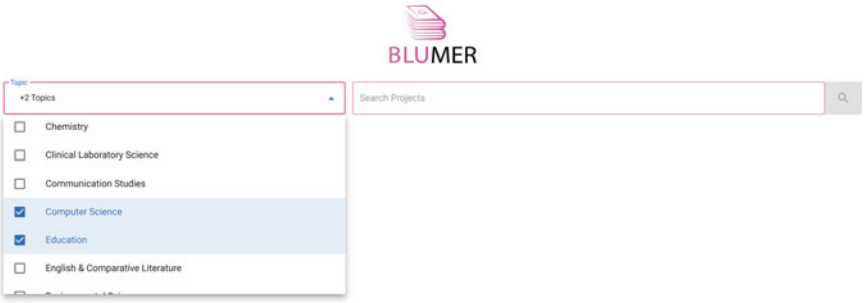

Fig. 4 The frontpage of the web application

4.2 The Admin Panel

The admin panel allows the proper authority within a university to add their own data to the database by adding newly awarded projects. They can also add information such as Faculty, Research type/position type, Research Fields, and The sessions needed for the research (Fall/spring/summer). Under those topics, there is an extensive array of information that can be entered to further enhance this knowledge mine. The topics that an admin user can change or add inside the BLUMER admin dashboards are—Faculty, Teacher, Research Type/Position Type, Projects, Research Fields, Sessions

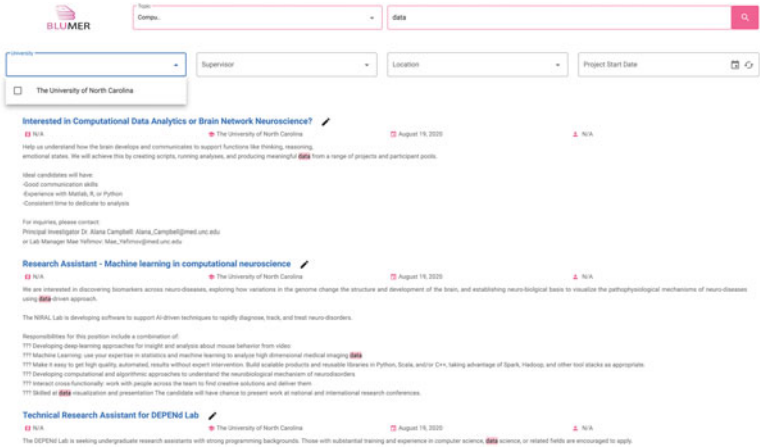

Fig. 5 The result page of the web application

(Fall/Spring/Summer), University User (A root admin user can enter other users), and Group (Similar users can be placed inside a group).

The following Fig. 7 shows the admin pages of the web application.

4.3 The BLUMER Dashboard

The BLUMER dashboard consists of the analytical dashboard that gives the administrators of the universities a look into the state of the awarded research projects throughout the country. It gives the admins a view into how the projects are distributed throughout different areas, what are the fields where most awards are given, and the type of projects that are typically available. Our goal is that the admins can use this dashboard to provide useful information to the students as advisors such that students can get informed advice regarding their future intentions. Below we can see the view of the dashboard (Fig. 8).

5 Conclusion and Future goals

In conclusion, Bangladesh is a country with a lot of potential to make the youth into a research-oriented outcome-based workforce. With the advent of technology and with the vision of "Digital Bangladesh" looming, our focus on creating and making BLUMER accessible to Bangladesh will fulfill that vision. The outcome of

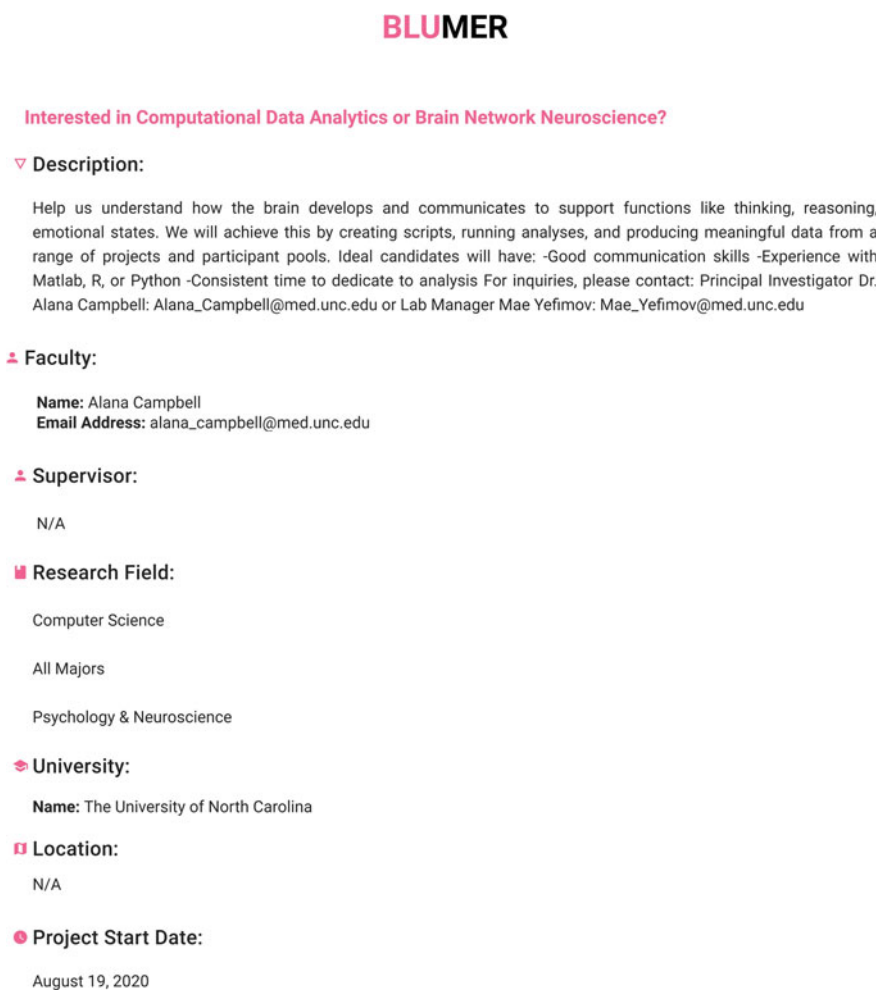

Fig. 6 The description page of a project

our current system facilitates this by enabling the students to start research work at a very early stage. In the future, we plan to use machine learning that will also show the administrator and industry leader's future career projections of the students using our application. It will help us to collect data and do trend analysis and behavioral analysis through machine learning that would allow us to observe student behavior on a mass scale. We are also open to collaborating with universities in Bangladesh and their researchers to run localized BLUMER pilot research on undergraduate research data, outcomes, and future careers in industry and academia. Through the commercialization of BLUMER, we can connect researchers, students, and industry experts on a national and international level. It can provide a collaborative workspace

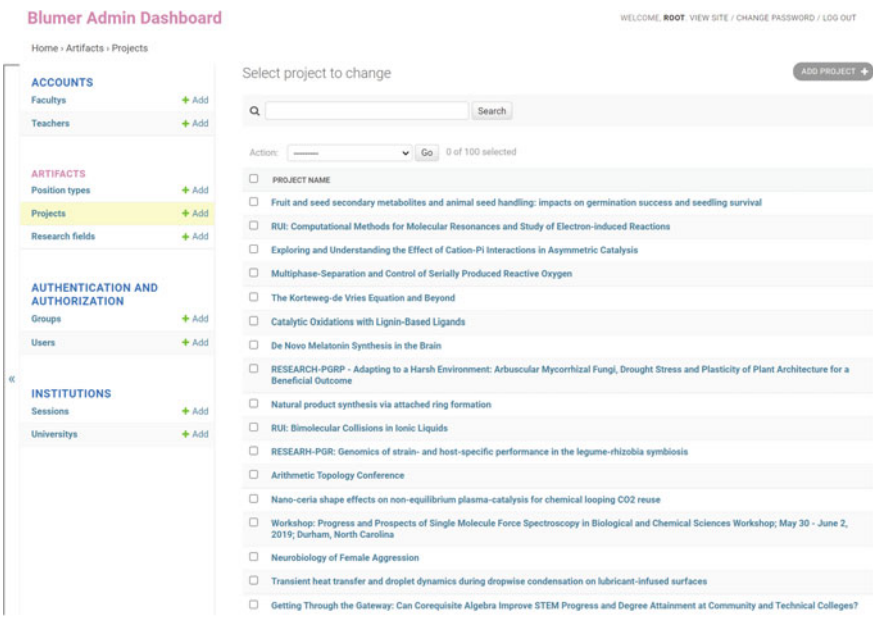

Fig. 7 The admin panel result

Fig. 8 The BLUMER dashboard

for the professors and students of various universities in Bangladesh and outside of Bangladesh. This can be a revolutionary platform that would help students be a better workforce for the 4th Industrial Revolution and beyond.

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