Academic Aide - Free Online Math Question Database for Academic Improvement

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Abstract - **Lack of funding is a common problem for many public schools and small private tutoring centers. Some schools have a policy that prevents students from taking textbooks home to study. Sometimes teachers will take money out of their own pocket to let students use existing online services to improve education quality. However, those internet services are not guaranteed to have materials that are best fit for individuals' teaching style. In some cases, the best fit material simply does not exist on the internet, and creating it would take many hours. We have created Academic Aide to combat this exact problem. Academic Aide is a free online database that allow users to generate and share content in a well organized manner. We allow users to create problems that fit their needs and upload it to the website. People from around the world can access to these problems at no cost. If the type of problem is not available on the website, the user can simply create their own. We believe that Academic Aide will be a place for people to learn from each other, create their own content and share it with people around the world. Academic Aide is the result of a project-based learning approach for undergraduate computer science students.**

Index Terms – Project-Based Learning, Computer Science Education, Educational Aides, Online Math Worksheet Creation

INTRODUCTION

We describe a project-based learning initiative undertaken by two undergraduate computer science students. The undergraduate authors have worked as afterschool and private tutors in the past. We understand that teachers are always looking for better ways to convey information to their students. Methods have ranged from writing their own worksheets, to experiment with other teachers' teaching materials, or utilizing online technology. One author has had experience in writing his own lesson plans according to school outlines and creating teaching material for a summer school geared towards getting students ready for a new semester; this process has proven to be very time consuming. It is true that a lot of new teachers would consider borrowing lesson plans from colleague; however that means the new teacher is learning from a very limited pool of people, and the new teacher might not have a similar teaching style at all. In cases when public school teachers want to implement online services, like WebAssign, they are often forced to pay out of pocket as they are not given a budget to implement such services. In this particular example, each student would need to pay twenty dollars for one access key, each class would have an average of twenty-five students, and each teacher would teach four classes each year. That would come to a total of two-thousand dollars either out of the students' or the teacher's pocket. Paying such a large amount for such services is an unrealistic expectation on students and teachers.

Balancing quality of education, financial budgeting, and time are always on the mind of educators. This project's goal included learning about a variety of computer science techniques in the context of a project designed to help address these larger educational issues. Through much diligent studying and applying our old and newfound skills, we attempted to tackle the issues of quality, budgeting, and time.

We have addressed these issues through two methods. The first is permitting users to easily create problem types through the web application which uses several algorithms to generate variations of the problem. This is done through recalling operations used in the problem and switching out certain constants, creating a nearly infinite number of variations. The quality of these questions will be as good as the base question submitted by the user. The second method is the fact that we save the base question into a database giving users the option to choose existing problems created by other users. This saves a lot of time since only one question is actually required to be written for each type of question. With the addition of a comment and rating system, users will be able to socialize and create an online community to ensure the database will grow to become even better over time.

In order to reduce the financial burden of running the website, we have created the web application so that most of the computing is done on the user's computers. This in turn allows the server to run with minimal system requirements as the server will simply be storing the uploaded questions. As a result, the webserver should be able to continue to run with minimal donations from satisfied users post its initial investment.

We have produced a system which will allow users to create materials that are best fit for their education styles. They will be able to share amongst a community of educators who are in need of good teaching materials, learning from each other to create an environment where users and their materials will be constantly improving.

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This project is part of a culminating undergraduate experience at Clark University as part of the LEEP learning model. LEEP stands for Liberal Education and Effective Practice and contains five learning outcomes. The first four are tenants of liberal arts educations: knowledge of the natural world and human cultures and societies, intellectual and practical skills, personal and social responsibility, and ability to integrate knowledge and skills. Clark University's defining contribution is the 5th learning outcome: capacities of effective practice – "creativity and imagination, self-directedness, resilience and persistence, and the abilities to collaborate with others across differences and to manage complexity and uncertainty. *These will be demonstrated by application of knowledge and skills to issues of consequence and by emerging membership in larger communities of scholarship or practice."*

As part of a LEEP Fellowship, this project was created in the context of realizing that 5th learning outcome.

Project-Based Learning

The LEEP program funds student driven programs aimed at making a difference in the community, be it global or local. In order to receive funding, we had to outline our project in such a way which appealed to their demeanor and clearly outlined what our goals were as well as how we intended to accomplish them.

We began by attempting to conceptualize what it was we wanted to do and how it should be presented to our users. This consisted of writing down a list of all the functions that should be available to users, e.g., like adding a question, and what kind of webpage we wanted to use. Due to the fact that neither students on the project had any experience with web development meant that all of our planning was being done without taking into account how to implement it. As we moved forward, we ended up making some adjustments to our plans.

Though we did not have any experience with web development, we had done research as to what languages to use. There was the obvious HTML/CSS and JavaScript to use for the front-end. We then intended on using Ruby, Ruby on Rails and MySQL for the back-end. We spent the first two weeks of the project learning the front-end languages and creating templates for our main pages, like the homepage [1][2].

The next step was to begin work on a prototype for a parser which calculated equations in LaTeX format. LaTeX would allow equations to be stored in plain text format but then display them as complex symbolic math equations. This proved to be a very difficult endeavor as we did not anticipate the difficulties that came with factoring in all possible mathematical concepts. Luckily, our research led us to the free licensed library *math.js* which opened the doors for us to the world of open source software. This allowed us to greatly increase the speed and quality of our website since we now only need to develop components that are not preexisting.

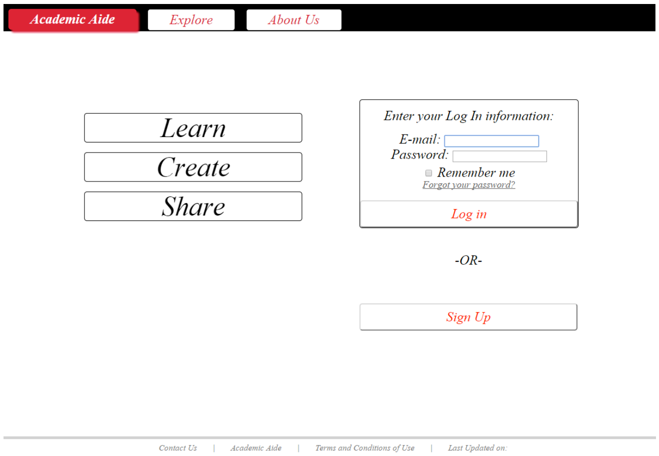

FIGURE 1
WE MADE IT CLEAR IN OUR FRONT PAGE THAT THIS WEBSITE IS FOR LEARNING, CREATING, AND SHARING.

Learning at Development Time

We ultimately decided upon the *Agile* development method since our prior knowledge with web development was very limited. *Agile* is a software engineering development lifecycle approach that focuses on quickly developing working software. We hoped that by using the Agile approach, we could have a short development cycle, allowing us to easily break up the project into several manageable assignments. As the project developed, we were able to learn new technologies and implement them right away before moving on to the next step. With the goal of having a working product at the end of each assignment, we always began by learning the skills we thought would be necessary to complete each one. As we worked on each task, we attempted to have the prototype ready within a week's time so that by the weekend we could discuss what all we had individually accomplished as well as how we should proceed; at these weekly meetings, we would also consult with Professor Magee to see if he had any input and discuss how to accomplish our goals in a better or more appropriate manner. Due to this adopted system, we were constantly polishing and preparing at every stage of development.

There are a few things we have learned that were of great help during the development of the application.

I. Open Source/Free Licensed Software

One of the greatest lessons learned in this project is "do not make it unless you cannot find an open source version".

At the beginning of the project, the team worked on a parser which used javascript to process math equations written in LaTeX. Fast forward three weeks, our parser was still fairly unpolished and lacking quite a few features. We then discovered math.js, a javascript math library that is better than our script in terms of both optimization and functionality.

In addition to the parser, we also attempted to write our own authentication for the user account system, however, we found *devise*, a gem in Ruby on Rails, which installed a

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secured account system [3]. This gem was not optimized for the web application so we customized it.

Another challenge we faced was how to display all of our math problems in LaTeX format automatically on the web page. With the discovery of math.js, we also learned about the javascript package MathJax which highly simplified the process [4][5]. Any equation can be marked in the online system and MathJax will automatically convert the equations into LaTeX for display.

Math.js, *devise* and MathJax are just three of the many software we used to help us in developing our web application.

II. Software Development Practices

Though our overall software development method is agile, we still utilized other development practices to ensure the quality of our project:

- **Prototyping[6]**: Due to our inexperience with the various programming languages and libraries, we used this technique heavily in the learning process. In order to have a good understanding of the methods we are utilizing, all features of the website have been tested before implementing. For example, prior to us implementing *Ruby on Rails* and devising a *gem*, the team spent over three weeks doing research for the best configuration, testing various ideas until finally creating the skeleton on which the current website is based. Another example is MathJax, whose implementation took less than a day.
- **Version control with Github [7]**: The roll back and merge functions were the main functionalities of Github that we utilized to ensure that we always have a functional version of the project and so that members of the team could work on different parts of the project simultaneously. This was ideal as members often had different times that they could work and as a result could simply use Github as a way to quickly synchronize the project. This is beneficial as any time one of the members has issues, they can simply contact the other member, synch their project, and share their screen in skype to discuss the issue. This allows for a "remote hot seat" style of programing in cases where one member is more familiar with the code being worked on can show the less experienced member what to do without physically being there.
- **Development Environment**: For the first half of the project, the team focused on the front-end of development and wrote most of the HTML/CSS and javascript code in notepad++, a relatively simple text editor. Moving onto back-end, we began to sample different Integrated Development Environments (IDEs) including sublime text, JetBrain for Rails and Net Beans for Rails; however we ended up using Aptana Studio 3. We made this decision as its layout is very similar to Eclipse, which is the most commonly used IDE in our school and it feels like an IDE designed for web development. Therefore Aptana does not feel like a brand new IDE and has some useful functions such as autocomplete for HTML and a debugger.
- **Don't Repeat Yourself (DRY) [6]**: This is a programming practice that one of the members has become familiar with in software engineering class, as well as repeatedly hearing about it on programmer podcasts as being one of the most overlooked bad programming practices in the field. As result, DRY becomes one of the first things we do when it comes to optimizing the project. This ultimately lead to deleting repeat CSS code, greatly reducing the amount of code in the CSS files, making them much more organized. We intend to continue applying such programming practices in algorithm development for other components of this project.

III. Documentation, Online Tutorials and Google

The learning methodology for everything in this project can fall into two categories: online tutorials or reading documentations, and googling the problem and testing every solution we can find until there is one that is most suitable for us.

The main tutorials that we utilized were on the sites codacademy.com [1], railstutorial.org [8], railsforzombies.org [9], and w3schools.com [2]. Each of the members spent anywhere from ten to forty hours learning on these websites; we additionally spent hundreds of hours on tutorials and lessons on YouTube to pieces useful information. After learning basics of each language, we found that the best website for furthering our learning at development time is our beloved search engine, google.com; but most often, the best answers came from the community on stackoverflow.com [10] and digitalocean.com/community [11].

We quickly realized that it is one thing to simply find a tutorial, but it is completely different to find a thorough and easy to understand one. As the project progresses we find ourselves spending less and less time watching tutorials as we slowly become people who know where to find the answers we are searching for, people who are familiar with the skills and tools we acquired just a few months ago. This is project based learning in action.

STATE OF THE PROJECT

I . Current Capabilities

At the time that this paper was writing, our offline version of the web application has the following functionalities:

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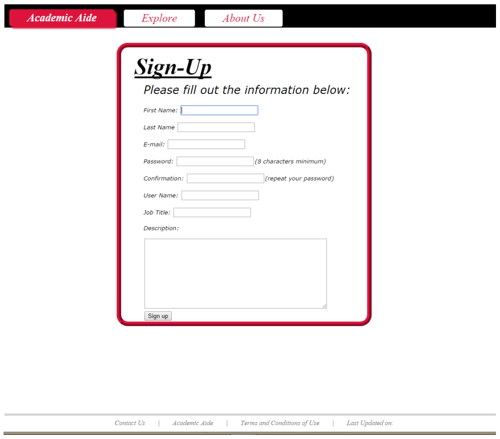
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About Us
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Sign-Up

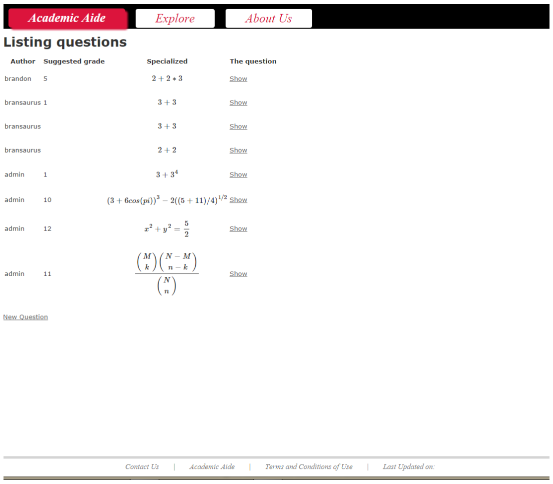
Please fill out the information below:

First Name:
Last Name
E-mail:
Password: (8 characters minimum)
Confirmation: (repeat your password)
User Name:
Job Title:
Description:

FIGURE 1

USER CREATING A PROFILE WITH A MODIFIED VERSION OF DEVISE

- **User System**: This is done with a modified version of the open source Ruby gem – *devise* [3]. Devise handles the users' registration authentication, login and logout. Extra fields are added to the table to store other user profile information that was not provided with *devise*.
- **Database for individual questions**: Questions are stored using SQLite database. It keeps track of information such as the question, author, suggested grade for the question, creator comments for the question, creator's answer to the question and a table of variables that help categorize the question. The table will be used when we implement a proper search function.
- **Display Questions in LaTeX**: This is done with MathJax gem for Ruby [5].
- **Browse created questions**: Currently, the questions can be shown in two categories: all questions and questions created by the current user who is logged into the computer.


Academic Aide
Explore
About Us
New Question
Contact Us | Academic Aide | Terms and Conditions of Use | Last Updated on:

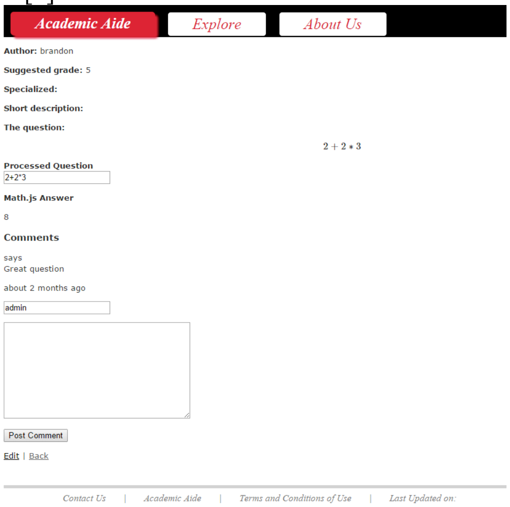
Listing questions

Author	Suggested grade	Specialized	The question
brandon	5	$2+2*3$	Show
bransaurus	1	$3+3$	Show
bransaurus		$3+3$	Show
bransaurus		$2+2$	Show
admin	1	$3+3^4$	Show
admin	10	$(3+6cos(pi))^3-2((5+11)/4)^{1/2}$	Show
admin	12	$x^2+y^2=\frac{5}{2}$	Show
admin	11	$\frac{\binom{M}{k}\binom{N-M}{n-k}}{\binom{N}{n}}$	Show

FIGURE 2

REGISTERED USER BROWSING EXITING QUESTIONS

- **Comment System on individual questions**: As the user browses through individual questions, more detail of the question will be shown and the option of leaving a comment on any question is given. This is done with the model function in Rails. We hope this option will help the creative process of users, as they can learn from the comments on the questions. On each comment, the author of the comment and time which the comment was written will be displayed. The user does not have the ability to delete or edit past comments. We are looking into ways such that system administrators and the question creator will be able to delete inappropriate comments. A screening script will be written to censor profanity and direct answer of the question [8].


Academic Aide
Explore
About Us
Post Comment
Edit | Back
Contact Us | Academic Aide | Terms and Conditions of Use | Last Updated on:

Author: brandon

Suggested grade: 5

Specialized:

Short description:

The question:

$$2+2*3$$

Processed Question

2+2*3

Math.js Answer

8

Comments

says
Great question

about 2 months ago

admin

FIGURE 3

BROWSING THROUGH INDIVIDUAL QUESTION, MATH.JS AND COMMENT SYSTEM AT WORK

- **Computer Generated Answers**: This function is done with math.js. At the moment, this only works on simple questions as we are still working on a parser to translate LaTeX into the equation format used in math.js.

II. Current Development Plans

We are currently working on the following four main topics:

- **Deployment**: We tried to deploy the website during the summer when we did not fully understand the difference between a web host and a virtual private server. We are now working on deploying the application using Digital Ocean, one of the cheapest and well received virtual private servers hosting services around. In this process, one of the most important things we learned is to be flexible on what we are using. We started the deployment process using Nginx, and the Unicorn gem [12] [13], but after a month of reading, attempting to deploy and fixing bugs with the rails app template, we ended up taking a completely different approach. We ended up setting up Phusion Passenger [14] and combining it with Nginx on a Ubuntu server. This has proven to be a much more promising way to set up as the process to do so is much more well documented on the internet [15]. As of recently, the project is running on the IP

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Address: 104.236.4.133, and we will point the domain academicaide.com to that IP Address once more functions are added.

- **Question Generating Algorithm**: This should take the user submitted question as the base structure and generate similar questions according to it. This algorithm has been in the brainstorming phase for the longest time and it has shown to be more complicated than we had initially intended. We are retackling this problem as we are now at least three months wiser.
- **Answer Checking Script**: This script allows the user to check the answer of a question after translating it from LaTeX into the math.js format. Our parser script does a similar task however there is a chance that we will start over writing this script from scratch as its current state is incomplete and poorly documented.
- **PDF output**: Recently we found an open source library called PDF.js which will help us to output questions and worksheets in .pdf format. We have been discussing writing and working on a prototype as this will be a vital part of the project [16].

III. Future of the project

We envision the final product of this project to be a website that can be used as an aide in teaching and tutoring mathematical concepts. This aide will be a database organized by topics ranging from order of operations to early concepts in calculus that are seen in grades 5-12. Each concept will hold a variety of problem types, for each of which the user can generate an infinite amount of unique examples with the push of a button. Our goal is that after thorough testing, the website will be open to the public for usage, assisting teachers in their endeavors. But currently the state of the project can only say to be pre-alpha stage as it is not ready to be tested due to the lack of necessary functionalities that are required for this website to be called an educational tool.

- **Creating Worksheets**: Our storage system for worksheets will work similar to ours for storing individual questions, except it will store the list of IDs of each question on each worksheet. The team has not looked into this part extensively yet, however we know it can be done. A comment system will also be created for each worksheet as well.
- **Creating Classes**: This will be very similar to how the worksheets are created however, instead of storing the ID of question, it will store the IDs of worksheets and have creator comments for each worksheet. The main difference of Classes and worksheet will be the way we display it. When a worksheet that is created by other users and is used in a specific class, the author of said worksheet will be credited. A comment system will also be created for each Class as well.
- **Class system**: Different from creating classes, a class system allows users to join classes, do work for said classes, and allows their work to be graded as specified by the class creator. Note that classes work on an invitation bases, therefore unless the creator invites a user to join, only the description of the class will be shown.

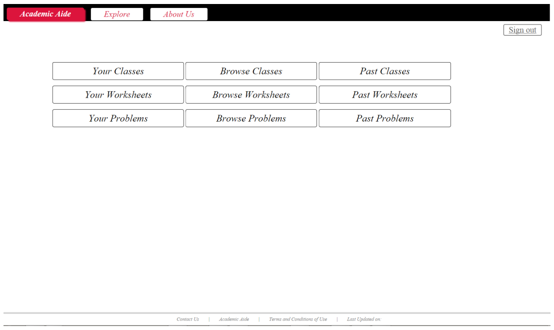

FIGURE 4

CLEAN INTERFACE INTRODUCE USER TO COMPONENTS OF THE SITE

- **Grading System**: This will be written as part of the class system. Still brainstorming as to how to make it such that it is very customizable.
- **User Work Record**: We would want a section that is private to each user which stores the record of each user's past work including classes taken, grades from each class, on each question, one each worksheet and all classes created by user, etc.

After these functions have been completed, we will post the source code on Github and maintain the application on a volunteer bases and sustain the server through donations from users.

CONCLUSION

We started with the idea of creating a free platform for educators to create, share and learn. As part of Clark University's LEEP program and guidance from the project mentor, we built the entire application from the ground up. Learning bits and pieces along the way, we set off as junior developers to be assigned tasks learned to finish these assignments on our own. During the development of this application we were both: the people who assigned the task and the ones who did the research to solve them. Being on both sides of the creation process has allowed us to become more knowledgeable about learning through development and project-based learning as an education methodology. It is indeed a different learning method from the project purpose which is learning with guidance and use Academic Aide as a teaching assistant.

The ultimate goal of our project is not only creating an education platform, but also giving its community the ability to sustain it. The project is still fairly far away from achieving that goal, yet on its way nonetheless. We have tried our best to mold the website into a set of simple tools. However, we can expect that as the application matures we

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will have a platform where customized teaching materials can be shared across nations; thus, allowing nations of different education systems and financial levels to share materials for free, creating a community where educators across the globe will be able to work together to improve the quality of education around the world.

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ACKNOWLEDGMENT

The developers of this project would like to thank Professors and colleagues for giving assistance during the development of the application. The project also owns its success to all the open source and free licensed software, frameworks and libraries such as MathJax, math.js, devise, and many more in the future. Last but not least, without the Liberal Education and Effective Practice (LEEP) program at Clark University, this project would not have existed.

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