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Free online homework platform gives instructors control of their content

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Free Online Homework Platform Gives Instructors Control of Their Content

Abstract

A free, flexible, on-line homework platform has been developed which allows instructors to create their own custom homework assignments through a simple programming interface.

Engineering classes generally require many homework problems to give students an opportunity to exercise the skills presented in lectures. The textbooks contain problems for this purpose; however, students often have access to solution manuals, which reduces the effectiveness of the assignments. Handwritten homework and the effort required to manually grade it makes it difficult to assign large problem sets. Additionally, homework done on paper provides no immediate feedback as to the correctness of the responses, and therefore the students are forced to submit work in which they typically have little confidence.

Online, automatically graded homework is a potential solution for all of these issues. By allowing students to do their work online, the instructor is no longer burdened with the task of grading, and students receive immediate feedback so that they know exactly what they do and do not understand and therefore can seek the instructor's help before submitting their final work. Since most of the problems are mathematical in nature, it is possible to present each student with a numerically unique problem so that students cannot simply transcribe each other's answers.

Online platforms of this nature already exist; however, they have several limitations. Since they are associated with a textbook, they are based on the solutions manual and therefore, although the numbers in the problems can be changed, the solutions are well known online. These platforms are also inflexible for the instructors: they are unable to modify the problems and can only select from a limited problem set and for a limited selection of courses. These online platforms are also subscription services that are available at substantial cost to the student.

A free online platform that serves this purpose was developed through an Open Educational Resources grant and has been deployed in five engineering courses over three years. This platform allows the instructor to develop questions using a simple Python programming interface and allows the instructor to leverage all of the Python math and science libraries to formulate the solutions. It supports two types of questions: analysis and design. While the current online platforms focus mainly on analysis problems, this platform also allows engineering design problems where a set of parameters and design criteria are given and the student must provide values which satisfy the given specifications which is much more applicable to real world problems. The addition of the design problems and the power of the Python libraries makes this

platform highly flexible and applicable to mathematically complex topics such as circuit analysis, signals and controls.

In this paper we will describe the platform, its programming interface and show its application to the courses in which it has been used.

Introduction

Engineering classes in general, and Circuit Analysis and Microelectronics in particular, require many homework problems in order to give the students an opportunity to exercise the skills presented in the lectures. More advanced classes such as signal processing, Controls and Power Systems may require fewer assignments, but the problems are mathematically complex and difficult to formulate and grade. The textbooks contain many homework problems for this purpose; however, the students have access to the solutions manuals, which reduces the effectiveness of the assignments. This forces the instructor to either create their own problems or to find problems from other sources, which is time consuming and error prone. In either case, the large effort of manually grading the homework makes it difficult to assign large problem sets. Of course, the copying of answers among students is also common if all of the students are given the exact same problems to work on.

Online, automatically graded homework is a potential solution for all of these issues. By using an on-line platform that is not generated from the textbook, the solutions are less likely to be publicly accessible. By allowing the students to do their work online, the instructor is no longer burdened with the task of grading the work and the students receive immediate feedback so that they know exactly what they do and do not understand and therefore can seek the instructor's assistance before submitting their work. Since most of the problems are mathematical in nature, it is possible to present each student with a numerically unique problem so that students cannot simply transcribe each other's answers. If the online platform is flexible enough that the instructor can create or modify the questions, then they can tailor the questions to their specific style or needs.

We have noticed an additional need for design problems rather than analysis problems. Most textbook and online platforms problems are analysis problems. For example in Circuit Analysis the student is given a circuit and component values and must calculate the voltage or current or another parameter. While this is a necessary skill, it does not translate to real world problem solving ability. With a design question, the student is instead given a circuit and some criteria and then required to find component values which satisfy those criteria. Such problems are very difficult to create and grade by hand. For example, in Microelectronics, a student is given a transistor circuit with biasing resistors and is required to specify values which meet a specified gain and input and output resistance value. There are possibly infinite combinations of values which can solve such a design. By using Python to calculate the criteria that result from the student's responses, the response can be automatically graded and provide the student with feedback.

Online platforms of this nature already exist and more are coming online every year. However, they have several limitations. Since they are associated with the textbook companies, they are based on the homework in the books and therefore, although the numbers in the problems can be

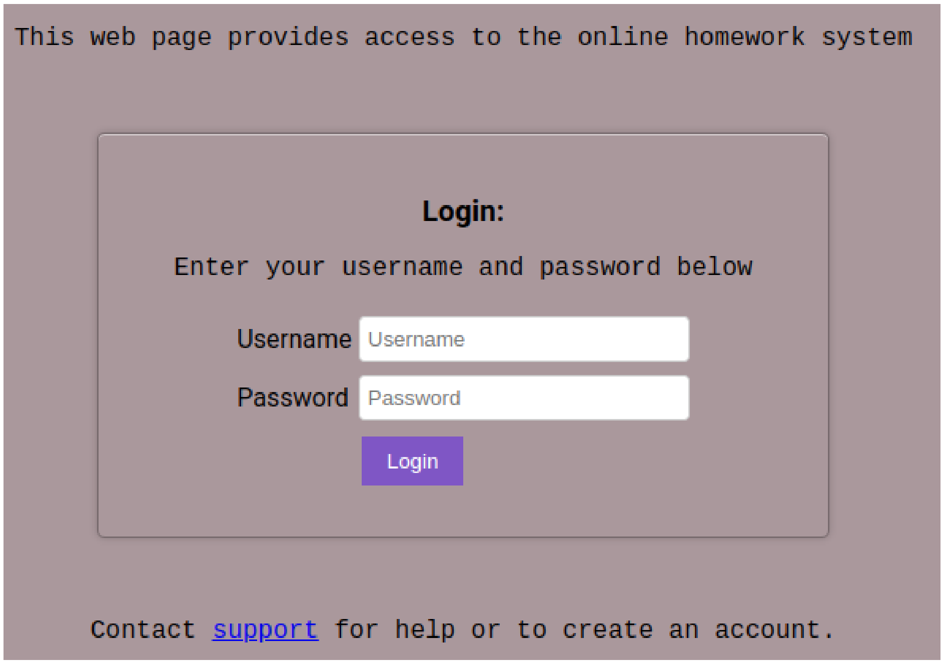


Figure 1: Login

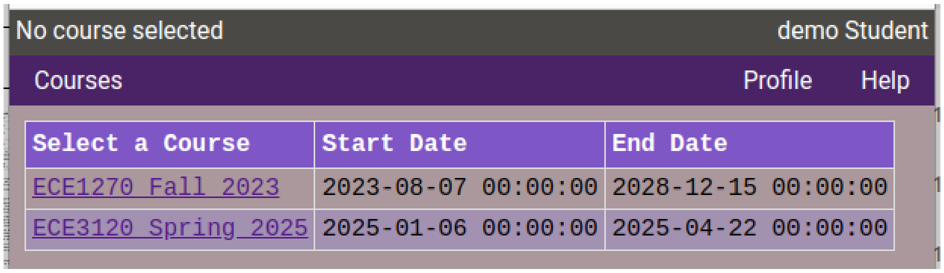
changed, the solutions are well known online. The students simply follow the solution manual formulas and swap in their random values. These platforms are also inflexible for the instructors, they are unable to modify the problems, only select which are to be used. Finally, and perhaps most importantly, they are very expensive. A subscription to one of these services usually costs more than $100 per semester per student which can be prohibitive, especially if several classes are using them in the same semester. The current trend in education is toward Open Educational Resources (OER) to make education affordable for everyone. This homework platform and an accompanying OER Microelectronics textbook allows our students to study Microelectronics 1 and 2 with no materials cost.

This paper will give a brief overview of the platform, first from the student's perspective and then from the instructor's view of creating the content.

Student Experience: Accounts and Login

The decision was made to keep the login and accounts separate from the University Canvas system to keep it independent and self contained, although in the future it may be desired to provide that capability. Each student is given an account and creates a password and logs in through a secure page as shown in Figure 1.

Once in the system the student is presented with a list of Courses in which they are enrolled and within those Courses are lists of Lessons and Questions as shown in Figures 2, 3 and 4. Each Course can have multiple sections with different due dates for the lessons. Once a lesson has expired, it becomes read only and the correct answers are shown so that the student can use them to solve any questions that were missed and to study for exams.

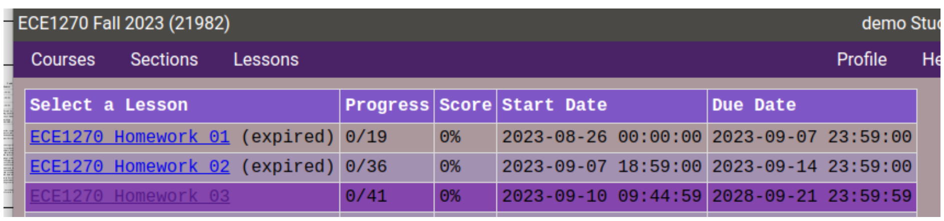


No course selected demo Student

Courses Profile Help

Select a Course	Start Date	End Date
ECE1270 Fall 2023	2023-08-07 00:00:00	2028-12-15 00:00:00
ECE3120 Spring 2025	2025-01-06 00:00:00	2025-04-22 00:00:00

Figure 2: List of courses and their dates

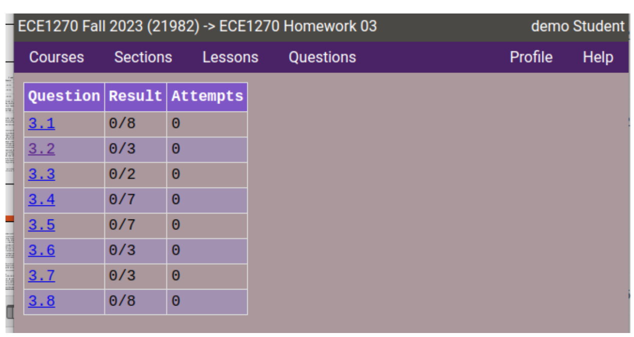


ECE1270 Fall 2023 (21982) demo Stu

Courses Sections Lessons Profile He

Select a Lesson	Progress	Score	Start Date	Due Date
ECE1270 Homework 01 (expired)	0/19	0%	2023-08-26 00:00:00	2023-09-07 23:59:00
ECE1270 Homework 02 (expired)	0/36	0%	2023-09-07 18:59:00	2023-09-14 23:59:00
ECE1270 Homework 03	0/41	0%	2023-09-10 09:44:59	2028-09-21 23:59:59

Figure 3: List of lessons with progress and due dates



ECE1270 Fall 2023 (21982) -> ECE1270 Homework 03 demo Student

Courses Sections Lessons Questions Profile Help

Question	Result	Attempts
3.1	0/8	0
3.2	0/3	0
3.3	0/2	0
3.4	0/7	0
3.5	0/7	0
3.6	0/3	0
3.7	0/3	0
3.8	0/8	0

Figure 4: List of questions and progress on each

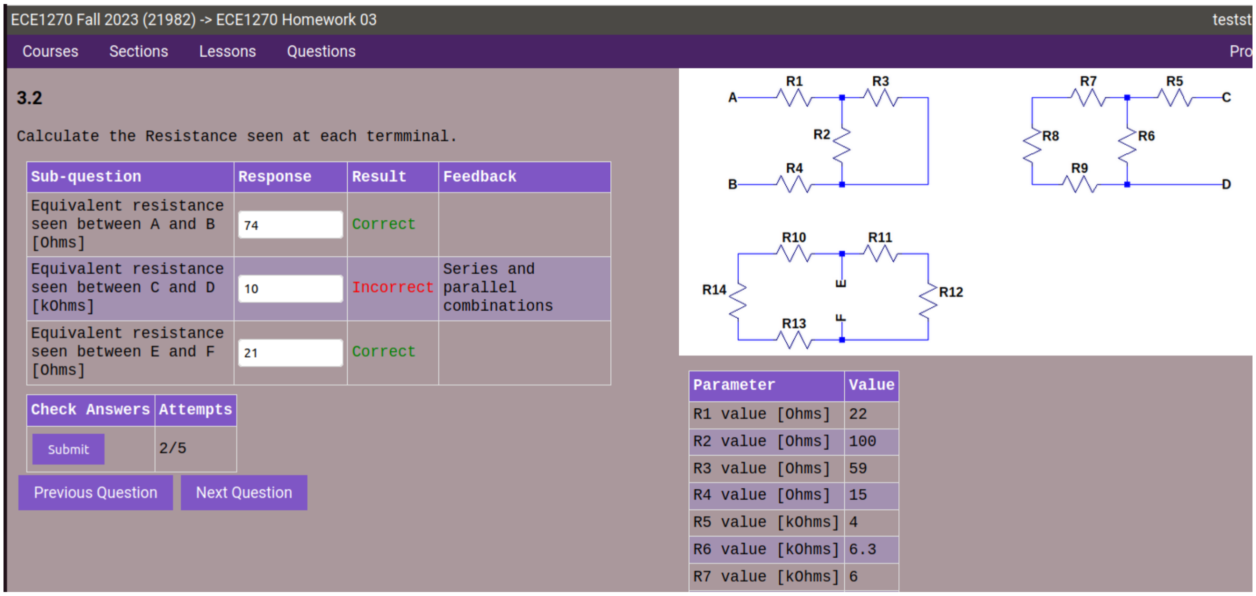


Figure 5: Simple Circuit analysis problem

Student Experience: Analysis Problems

To date, this homework platform has been used in Circuit Analysis 1 and 2, Microelectronics 1 and 2, Controls and Power Systems courses. Figure 5 shows a simple circuit analysis problem. Each student is given a random set of resistor values and must calculate the equivalent values of various series and parallel combinations. The student has three entry boxes into which they can type any value that can be correctly interpreted as a number by Python. They are given a number of attempts (5 in this case) and they are told which answers are correct and if not, they are provided with some feedback. Since the instructor is in complete control of the question design, they can choose to provide any feedback in the form of book section references, general guidance or even numerical calculations to help guide the student to the right answer. The instructor can also specify any tolerance on the numerical values.

Student Experience: Design Problems

The design problems are where this platform distinguishes itself from the others. Analysis problems help students understand the basic calculations, but until they are required to actually select their own values, they cannot actually design anything in the real world. This has been very evident in our lab experiences where the students excel at the homework and the exams, but when asked to design something as simple as a transistor amplifier, they often do not know where to begin. A simple example of a design problem is shown in Figure 6.

In this example, the students must select values for the resistors to meet the design criteria given. The students can have randomly generated parameters (VCC in this case) and they are given their own set of randomly generated criteria. Once they have selected their values, they submit the design and the feedback shows if they met each requirement and the value that their circuit produced for each criteria. This allows them to see where they are wrong and by how much so

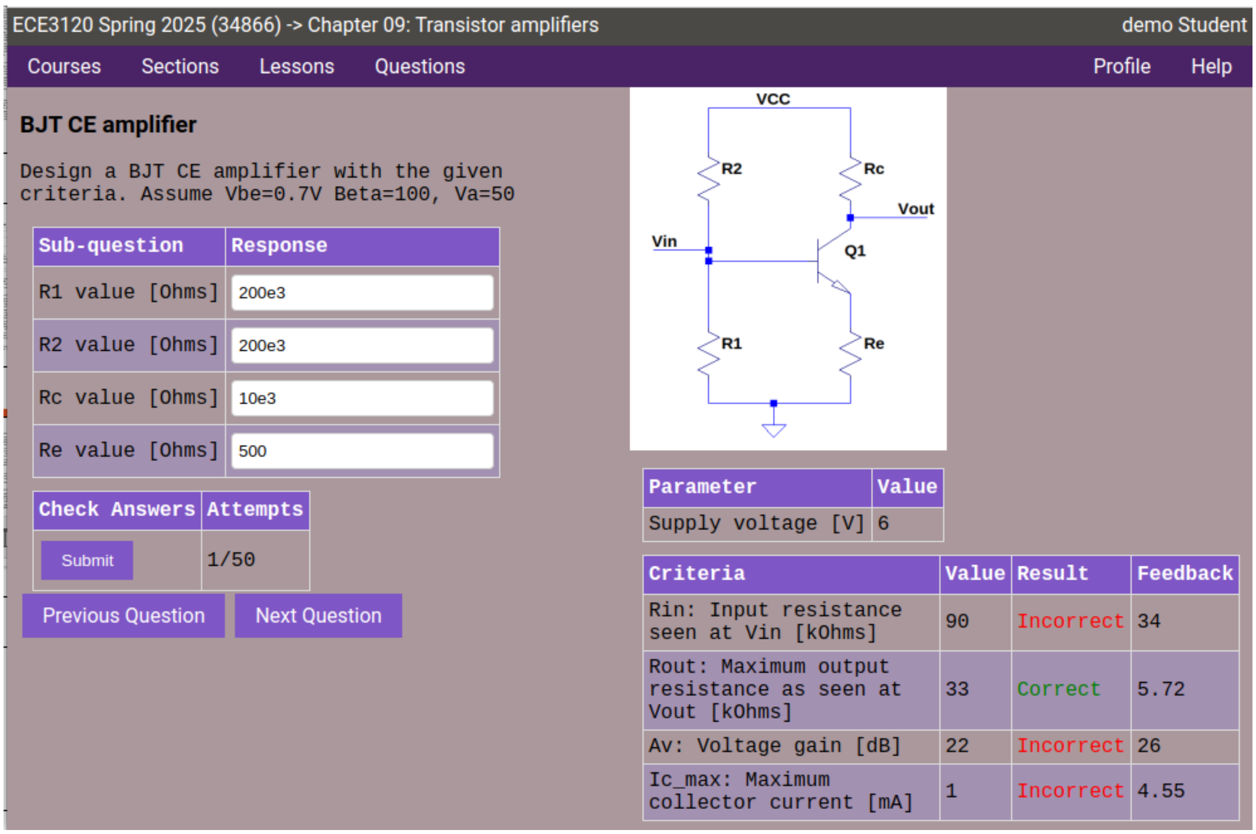


Figure 6: Simple circuit design problem

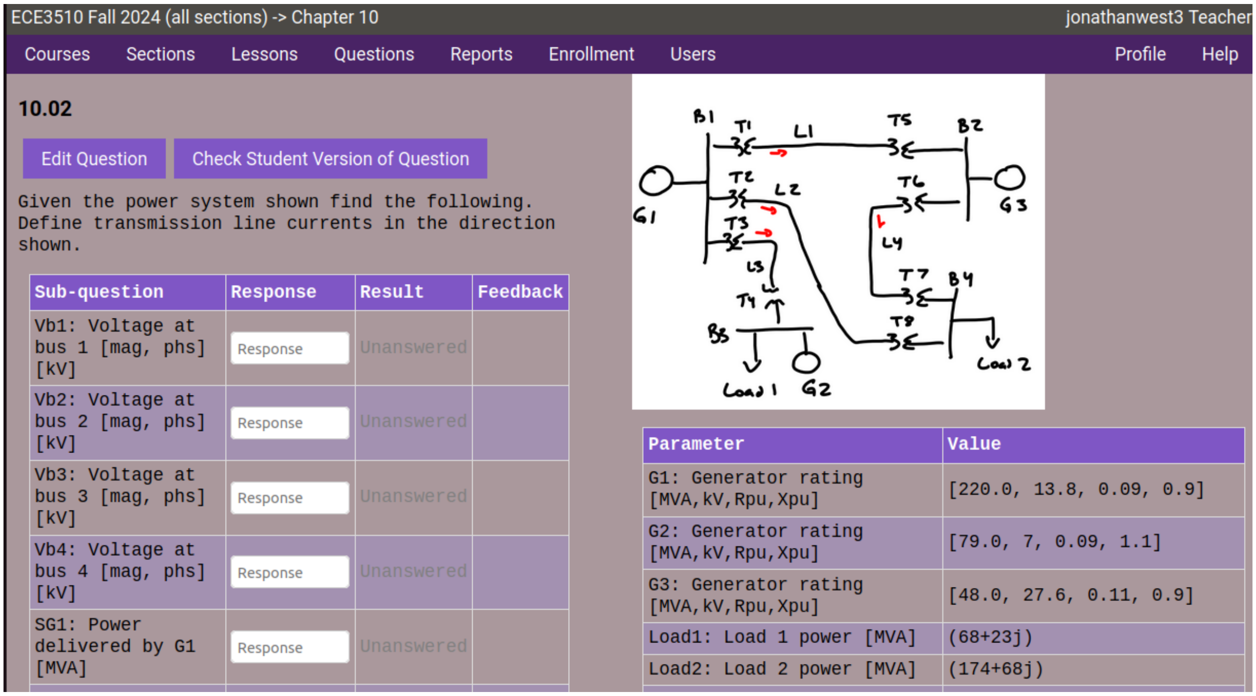


Figure 7: Complex power system problem

that they can adjust the design accordingly.

In our class, we then go to the lab and build the design and verify it in simulation and in real hardware. We have found that although they find it much more difficult at first, they find it very rewarding to experience the entire process of design, simulate, build and test.

The platform is also not limited to relatively simple calculations. Figure 7 shows part of problem from a Power Systems course where the students must enter a bus admittance matrix and the solution requires an extensive simulation in Python to solve. By using Python and its libraries (scipy, numpy, etc) the possibilities are unlimited. The questions can be formulated for the students to enter virtually anything in the boxes and as long and the instructor can write Python to interpret it they can be strings, numbers, vectors, dictionaries, matrices, complex values, etc.

Instructor Experience

Adding, removing and enrolling students are basic operations which we will not cover here. Each user is assigned a role of admin, teacher or student which limits their access as appropriate.

The courses, sections, lessons and questions are all created thorough simple menus and the opening and closing dates and times are entered as desired.

The main interfaces for the instructor are the question editing screens. Figure 8 shows the main editing screen on which the instructor can name the question, set the number of attempts, edit the Python script and check the resulting structure of the question. All of the question design is done

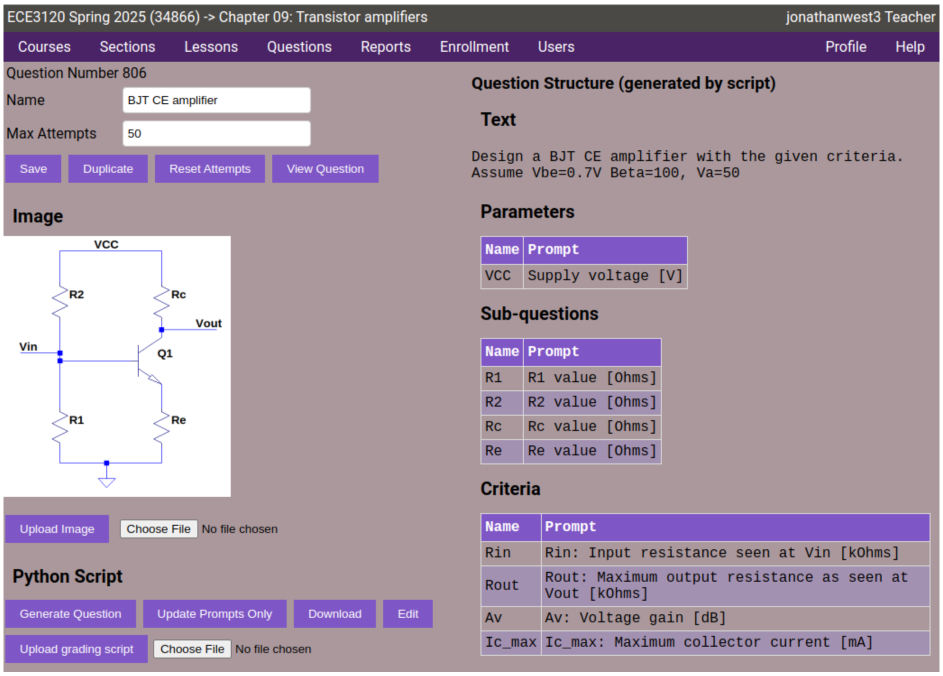


Figure 8: Question design screen

in the Python code which can be uploaded or edited online as seen in Figure 9.

To create a question from scratch, the instructor must simply give the question a name, upload an image and write four Python functions:

1. generateQuestion: Create Python dictionaries for the question text, the prompts for the parameters and criteria and sub-questions which the students much answer (Figure 9)
2. generateValues: Create Python dictionaries of the randomly generated values for each parameter and criteria for each student (Figure 9)
3. calculateAnswers: Take the dictionaries of parameters, criteria and student responses and calculate dictionaries of all of the sub-questions and criteria as appropriate (Figure 10)
4. grade: Grade the student responses against the calculated answers and provide feedback (Figure 11)

Although this may look a bit intimidating at first, there are helper functions and templates to create skeleton files which the instructor can then simply fill in. The complexity of the problems can range anywhere from a simple voltage divider taking a few lines of straightforward code to a complex analysis of a control system equation which imports numerous libraries. The possibilities are limited only by the programming ability and creativity of the creator.

System Requirements

The homework platform requires only a standard Linux Apache MySQL PHP (LAMP) server. The implementation demonstrated here is hosted on a tg4.small EC2 instance on Amazon Web

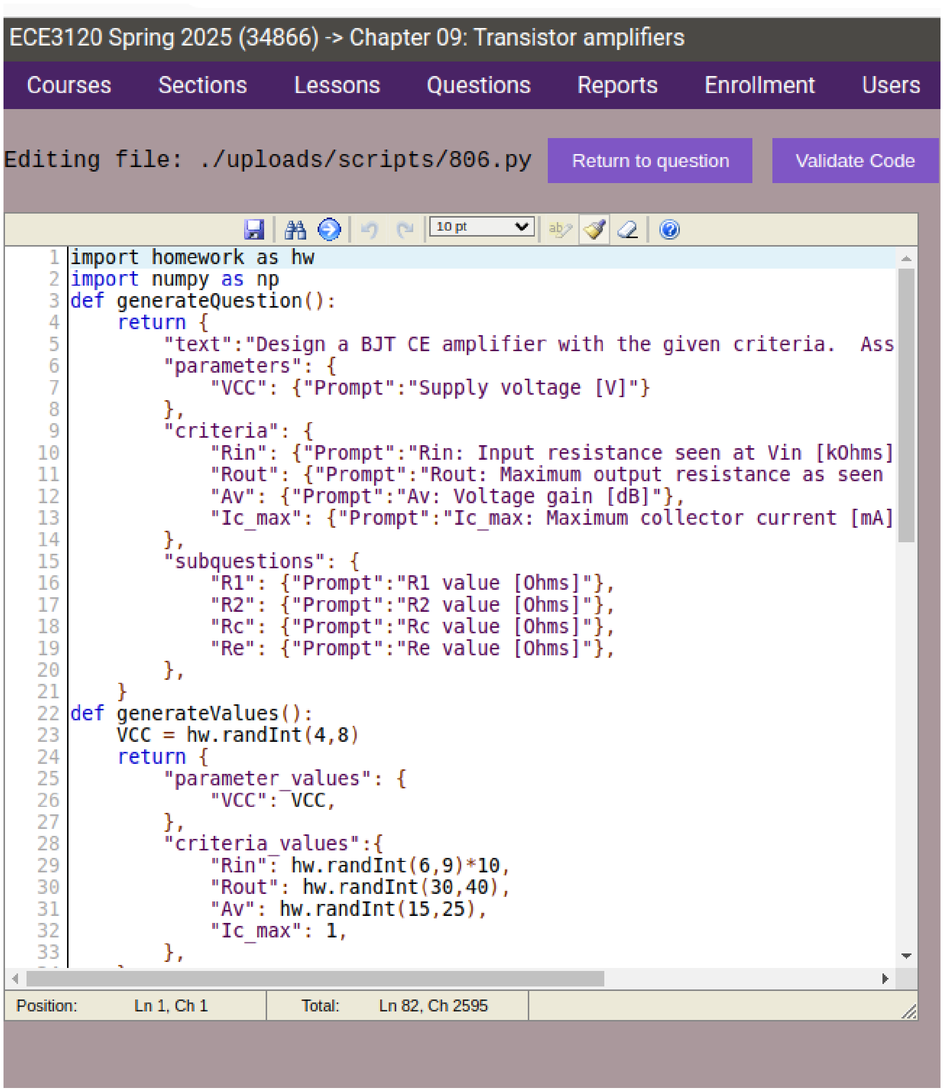


Figure 9: Code editor screen with generateQuestion and generateValues

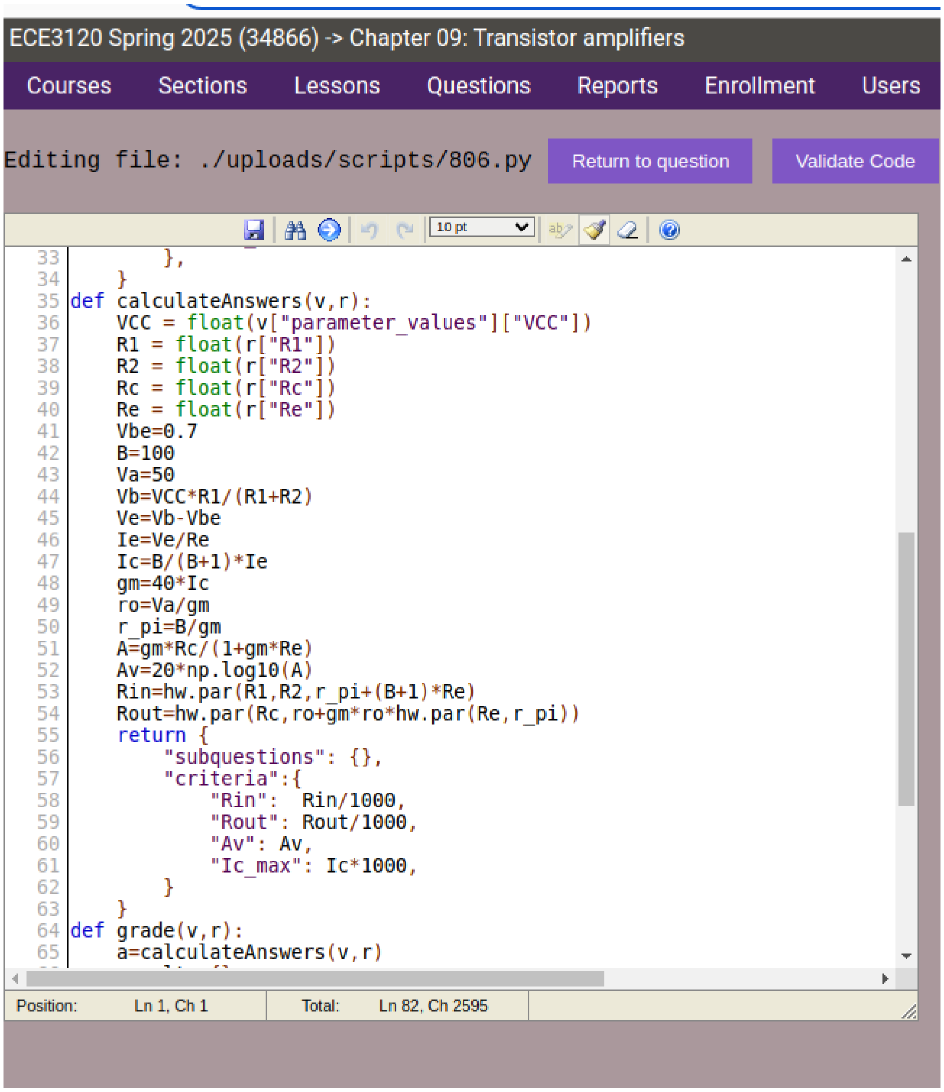


Figure 10: Code editor screen with calculateAnswers function

Figure 11: Code editor screen with grade function

Services running Amazon Linux 2 at a total cost of about $5 per month. The installation is standard, simple, automatically backed up and requires no maintenance.

We are currently writing a revision to improve the user experience on mobile devices by converting the web interface to the Bootstrap application framework.

Discussion

Assessing the effectiveness of a system like this is difficult due to a lack of a control group for reference. We have taught Circuit Analysis and Microelectronics courses for many years both with and without online homework and can at least observe some differences. One instructor who had been assigning paper assignments for Circuit Analysis was frustrated that she spent great amounts of time grading homework submissions that were clearly copies of the solutions manual. The students scored perfectly on the homework, but then performed poorly on similar problems on the exams. After switching to this online homework she found that while her workload grading papers was reduced, her office hours were attended much more frequently which is a positive sign, but after only one semester no significant improvement on overall exams scores or grades was noted. In the Microelectronics class, this online homework with the emphasis on design problems was introduced at the same time as a switch to the OER textbook and a rewrite of the labs to correspond to the design problems of the homework. Therefore isolating the effects of the homework platform itself is difficult.

As it is more widely adopted over a longer period, we expect to be able to look back and assess if it corresponds to an improving trend. Regardless of the statistics as measured by grades, all of the instructors who have used it agree that it streamlines the operation of the course, and even if the grades do not improve, the quality and difficulty of the problems that are assigned have increased.

The effectiveness of online learning has been researched extensively[1,2,3,4] and there is little doubt that it is superior in many aspects to traditional paper submission and that it is going to dominate the educational systems for the foreseeable future. The textbook companies are continually improving their products through interactive books and adaptive assignments. However, this homework platform maintains a distinct advantage in that it is powerful, flexible, free and can be used and modified by instructors to suit their teaching style and focus.

The flexibility of the system does come with a cost of complexity which will likely limit its adoption in non-technical fields. Although the Python programming interface is straightforward, it does require basic programming skills which may be a barrier to some. The templates and examples that are provided help overcome this, but this still may not be attractive to many. However, as this platform was developed specifically to address the needs of engineering courses, it is assumed that most instructors who use it will be familiar with at least basic programming principles and will therefore be able to utilize it without great difficulty.

In its present version, the platform is intended for a relatively small distribution. At our institution we have served approximately 200 students enrolled in 15 courses over three years with four instructors. The administration of the platform has been done by the faculty without integration with campus IT and the platform is hosted on an Amazon Web Service cloud computer. If the platform were to be integrated into the campus IT and especially if it were to be incorporated into a Learning Management System such as Canvas or Blackboard, many improvements would be required, specifically the area of security. The additional complexities of large scale deployment will require significant development which, while technically feasible, is beyond the scope of this project.

References

[1] Alan Jones. Evaluation of canvas-based online homework for engineering. In *2017 ASEE Annual Conference & Exposition*, number 10.18260/1-2–28307, Columbus, Ohio, June 2017. ASEE Conferences. https://peer.asee.org/28307.

[2] David Beevers and Qi Dunsworth. Work in progress: Homework in the digital age: The implementation ,effects, and perception of randomly generated custom digital assignments. In *2021 ASEE Virtual Annual Conference Content Access*, number 10.18260/1-2–38166, Virtual Conference, July 2021. ASEE Conferences. https://peer.asee.org/38166.

[3] Efthymia Kazakou Nikitha Sambamurthy and Yasaman Adibi. Student usage of auto-graded activities in a web-based circuit analysis textbook. In *2021 ASEE Virtual Annual Conference Content Access*, number 10.18260/1-2–37764, Virtual Conference, July 2021. ASEE Conferences. https://peer.asee.org/37764.

[4] Yamuna Rajasekhar Roman Lysecky Efthymia Kazakou, Alex Daniel Edgcomb and Frank Vahid. Randomized, structured, auto-graded homework: Design philosophy and engineering examples. In *2021 ASEE Virtual Annual Conference Content Access*, number 10.18260/1-2–37636, Virtual Conference, July 2021. ASEE Conferences. https://peer.asee.org/37636.