Investigating the Design and Implementation of Web-based Learning for Programming

Ross Kohler
University of Cape Town
+27761684133
khlros003@myuct.ac.za

ABSTRACT

Students who begin introductory courses at such in computer science usually struggled with grasping the basic concepts surrounding programming. There are numerous computer languages that beginner programmers are introduced to, one of the most popular being Python. Python is a language that is designed to be prioritise the human element of programming rather than just pure computation. In addition to this it is also optimised to reduce development time and powerful enough to implement solutions regardless of context. Even with a language like Python students still struggle with course content and understanding the fundamental concepts. This problem can be solved by providing a more interactive experience to the student, where a student learns small pieces of the course material and then verifies what he has learnt through immediate feedback [1]. Such an experience could be implemented in a web based platform. A web-based environment

1. INTRODUCTION

In modern society programming has become an essential skill in everyday life. Technology has evolved to such a point that almost every electronic device is running a program in order to complete its task. This programming and computer science has been taught at tertiary institutions for a number of years and as programming becomes more valuable it is slowly making its way down to secondary level education. There is however a difficulty for beginner programmers to grasp some of the basic ideas of programming. Python is a common choice for introducing learners to computer science. It is widely regarded as a good choice due to it being powerful and user friendly. However, the traditional classroom approach of teaching Python does not always lead to the best results for students. E-learning and the Internet could be the solution to this problem. Web-based learning environments have been shown to be more effective at teaching complex subjects such a programming [2].

In the sections to follow we'll first explore what are aspects that make Python a good beginning language for novice programmers then we'll move onto education platforms and what makes them effective in achieving their teaching methods. Finally we'll explore a few of the existing implementations that have built in this context.

2. TEACHING PYTHON AS A FIRST LANGUAGE

For new students interested in the disciplines of programming and Computer Science, learning how to program can appear to be a daunting task. There are numerous factors that an instructor must consider before choosing one of the many languages available for teaching the fundamental programming concepts. In modern day secondary and tertiary education not all teachers have mastered a single language and as a consequence revert to pseudocode throughout the curriculum. In an intellectual sense this may build problem solving and deduction skills however, without experience in an existing language, the practical utility of programming within the context of an application such as mathematics or science is lost on the student [3].

2.1 FAVOURABLE TRAITS FOR A TEACHING LANGUAGE

Factors that make up the ideal programming language for teaching are ones that prioritize the human element of coding. Such factors could include how easy it is to grasp the fundamentals of the language (at least for teenagers), how practical it is to use the language to solve real world problems, its ability to encourage problem solving and not obstruct the process as well as the language's versatility in the context of problems it can solve [3].

There are conditions that are widely considered necessary for learning a new computer language, they are as follows:

- A simple notational machine where the meaning of constructs can be easily understood.
- An interactive system that allows the users to query and inspect the process.
- All commentary found in the language (error messages, API documentation etc.) should be written at a level that can be understood by novices.
- Some of the processes of the environment should be visible to the user. [3]

The language should also ideally be scripted as this allows for the user to construct a rapid solution to a problem when the need arises. Execution time of a scripting language is roughly double that of a compiled language however this is counter balanced by the fact that a solution is formulated in half the time [3].

2.2 BENEFITS OF TEACHING PYTHON

Python is a clean and intuitive scripting language. Aspects that make the language favourable for novices:

- Small and intuitive syntax compared to other languages such as Java, C++ etc.
- Python is dynamically typed and thus reduces the syntax required for working code even further.
- Python's basic data types are extremely powerful and can be easily manipulated for the context of the application.
- Python is an interpreted language and as such provides immediate and interactive feedback at runtime of the program.
- The language enforces proper programming practice through indentation and structure.
- Python is an open-source language widely used in many applications this has resulted in a large resource pool in the form of libraries, exercises, documentation etc. that users can draw from [4] .

The most commonly used programming model in the real world is the imperative model. Thus this model is typically found being taught in classrooms. Other programming paradigms such as Object Orientated and Functional programming are gaining more traction in the world of computer science thus shouldn't be neglected [5]. Python is a good substitute for learning all three paradigms as the language has the mind-set of object-orientation with inherited features from imperative and extensions from functional [3]. In modern computer science more needs are arising that require knowledge from all three paradigms.

2.3 OBJECTIONS TO TEACHING PYTHON

Scripting languages are often rejected due to certain aspects of their operation. Some educators object to dynamic languages as they lack compile-time checking whose job is to catch as many errors in the code before it is run [6]. This provides the student with the concept that code must be tested before it is run thus encouraging proper programming practice through thoroughness.

Another problem point is the fact that scripting languages are generally considered inefficient when compared to their compiled counterparts. In production code they can be shown to be at least a factor of 10 slower when considering execution time [6]. However, modern day scripting languages are efficient enough to be used in deploying major applications.

Students cannot graduate in computer science until they have had exposure to and experience with at least one system language [6]. These system languages include C, C++, C# or Java. Scripting languages should never be considered as substitutes to these system languages, rather, they should act as support [7]. The argument is that students should start gaining experience with one (or all) of these system languages as soon as possible. They are generally more complicated and thus require more time to learn.

Some difficulty in trying to teach Python as an introduction language is the general lack of textbook support [6]. There have been numerous educators who have written textbooks for Java and C however very few who are supporting Python. Due Python's growing popularity this may very well change in the future.

3. WEB-BASED TEACHING

In the past decade there has been a trend in using the Internet as an aid for learning and creating a learning environment through which students can learn complex subjects such a computer programming. The student typically uses these learning resources in solitude where the platform should be sufficiently well designed so as to guide the user through the learning process. The web-based teaching platforms will never replace the traditional instructor-led learning [8]. There are many cases where classroom learning and face-to-face interactions with an instructor are preferable and are required for an effective learning experience [8]. This web-based form of learning does require us to ask some fundamental questions on how to best deliver the content to the student. For example how can the platform be used to best customize the learning to the individual and how can the learners performance be measured and the material tailored to suit the users specific needs. Modern web technologies allow for innovations to be made in this medium of teaching thus improving the overall goal of education.

3.1 PLATFORM ARCHITECTURE

From a technical point of view building a web-based education platform is in theory fairly simple. The difficult part is how to design, organize and implement the contents (i.e. learning materials, tutorials, feedback channels) of the learning environment. The following sections will discuss some of the hardships that are encountered when developing a new education platform.

3.1.1 Learning Complexity

The process through which humans absorb information and learn new ideas is extremely complex. There are many factors that play a role in how easily an individual can acquire new knowledge and skills. The process usually relies on previously acquired knowledge to prove and verify new cognitions [9]. Discussions are used to transfer knowledge between individuals while examples and exercises are used improve and solidify newly acquired knowledge [9]. In addition to these mediums that knowledge is manipulated there is also the existence of different learning styles. Examples include learners who learn better through audible communications, visualizations or when an instructor is guiding them. The learning ability of a student also depends on additional set-up aspects like health, emotional state, ability to concentrate, how rested the student is etc. [9] Modern education does not take many of the aspects into account and the student is simply provided with the information he is required to learn.

3.1.2 Platform and Student Interaction

Interaction between student and instructor has always been an important aspect in teaching. In the web-based education it is important that we address this aspect and ensure that students can communicate with the education platform. Modern web technologies allow for a variety of possibilities in communicating with the user. It is important to make the most out of these possibilities. A few of the most important interaction mediums are as follows:

- The ability for users to make notes and annotate the material so that they can highlight sections that they deem important.
- The ability to ask questions or perform tasks and automatically receive answers or feedback to verify their understanding on the subject.
- Electronic discussion or forums where students can discuss what they've learnt and also improve on their own understanding.

3.1.3 Student Individuality

A classroom environment has the disadvantage of a lack of individuality when it comes to the interaction between the student and instructor. A web-based teaching system has the opportunity of correcting this by tailoring the learning experience to the student. This concept of individuality is clearly important however it is seldom implemented in a web-based teaching environment [9]. The reason being that developing an environment that is responsive to the student's needs is not trivial.

3.1.4 Teaching Activities

The delivery of information to the student is only part of the learning experience. A student should also be able to review completed examples, modify or improve solutions and be able to test and validate their knowledge by attempting exercises

themselves. A web-based teaching platform should also have an equivalent or improvement to the traditional teaching methods of education [9]. Thus an implementation of these in a web-based environment is essential.

3.2 DEVELOPING EFFECTIVE WEB-BASED LEARNING

There are guidelines to follow when it comes to developing an effective platform for web-based learning. Following these guidelines helps to create a more succinct learning environment and ultimately improve the user experience. The following subsections will be divided into two parts; steps that should be taken before the design of the website and factors that need to be considered during the design of the website.

3.2.1 Preparation and Planning

The initial step in planning involves conducting a needs analysis that includes the problem your website is trying to solve, the needs of the learner that your website will be required to satisfy and an assessment of the current teaching environment [10]. A study needs to be conducted on the current performance of the students in the form of their knowledge and skills and in what aspects they are lacking. A needs analysis will clarify what goals should be set for the platform and in what parts of the current learning experience there is room for improvement [11]. The designer needs to decide whether his platform will supplement existing course material or whether it will become the primary method of instruction. Typically class size is unimportant in an online learning platform as an increase in students generally only result in higher traffic and server load however, if the course requires an instructor to facilitate the learning process, then plans need to be in place in the event of high user inflow. A thorough investigation will help to focus the design and function of the website in order to achieve the educational goals.

Effective design requires that there is an understanding of the technical resources and needs of the website and its users. Online education platforms have unique needs when it comes to the interaction with their students. A specification should be created that clarifies the hardware requirements of the system. This includes an analysis of the system architecture and the required network and computer capacity [11]. Periodic maintenance of the hardware should also be factored in to the specification. The technical requirements of the user should also be considered. Factors such as whether they're comfortable using the internet, if they've used an online learning website before, what device do they typically use to browse the web i.e. PC, smartphone, laptop etc. and whether or not they have access to high-speed internet [11].

Preparation for development requires a research on what features are essential for your website and what software already exists that will aid in implementing those features. It is highly recommended that developers make use of what's available instead of attempting to code new software from scratch. It is also very easy for developers to be caught devoting time to features that are non-essential and do not aid in reaching the goals of the platform.

Commitment from all parties involved in development is a must. In the case of an education platform, development will require regular advice and feedback from instructors and specialists in the relevant fields. The design of the web platform should be flexible enough so that feedback can be acted upon so as to better reach the needs of the target user and the goals of the system.

3.2.2 Development

During the development phase of your website there are a few guidelines that should be followed in ensuring an effective learning environment. One of the first important aspects to remember is that the design of the website must go hand in hand with the development of the learning material [11]. A common mistake is to create a website and simply place existing content onto the page without any modification or thought as to how applicable it is in an online context [11]. This is changes the purpose of the website to an interactive learning platform to more of an information repository. Effective e-learning environments usually make full use of the power of modern web technologies through the modification of how the content is presented to the user.

This highlights the next question the website designer should ask himself during development, how best can I use various web components and features to achieve the goal of the website? Multimedia can be used to supplement and provide value to the learning material [11]. This could be through the use of explaining concepts through visuals such as images and animations or a means through which information can be highlighted by changing the font style and colouring. It's important to keep the goal of the website in mind, as too much multimedia can detract from the learning experience. Something else to also consider is copyright of certain materials. Content that allows an individual copies for personal use may not always allow for open distribution on the internet. The licenses of any material placed on the platform needs to be checked in order to ensure that you are permitted to use the content in your context.

The internet allows for various forms of communication. These can include emails, forums, chatrooms, voice calling and instant messaging. Since the ability to interact with people is a big feature of the internet it is definitely essential for any e-learning platform. There are two types of communication that the designer can choose from. Asynchronous communication where there is a delay in receiving a reply e.g. posting on a forum, chatroom or even sending an email. This has the advantage of allowing the student to write down his thoughts, reflecting and perhaps arriving at a solution before even receiving a reply. Synchronous communication where the conversation is real-time e.g. voice chat or instant messaging [12]. This closely follows communication between and instructor and student in traditional communication.

The instruction and feedback has an important role to play in an e-learning environment. The same processes that are typically implemented in traditional teaching should be implemented in a web based program [11]. Instruction is conducted through the use of short focused lectures (using the multimedia such as video or images) and feedback through the communication as discussed in the previous paragraph. Regardless of how the feedback presented and delivered it is important that the student always has the opportunity to interact with an instructor.

3.3 PREVIOUS WORK

In the following sections we'll explore some of the work that has been conducted on the topics that have been discussed in this review.

3.3.1 Web-based Learning Platforms

Here we'll explore some of the implementations of web-based learning platforms in attempt to find what made them successful, aspects they could have improved upon and how they were designed.

3.3.1.1 Online Python Tutor

Online Python Tutor is a web-based program visualization tool for Python that has the purpose of allowing students and teacher to write Python code directly in the web browser. The platform visualizes how the program operates by allowing the user to step through their code. The Online Python Tutor is widely popular boasting over 1.5 million users in as many as 180 countries around the world [13] and used as an instruction tool in the top ranking universities.

Online Python Tutor claims to be one of the only Python program visualization tools that runs on any browser without plugins or third-party software installed. They attribute part of their success to the fact that their platform does not need any setup time on a client's computer and that the webpages load as fast as any other website [13]. Another feature is that Online Python Tutor can be embedded into other webpages through simply adding one line of JavaScript code. The platform is usually embedded alongside electronic textbooks so that students can practice and experiment with the content on the page. Students who interacted with Online Python Tutor were found to score higher on their exams [13].

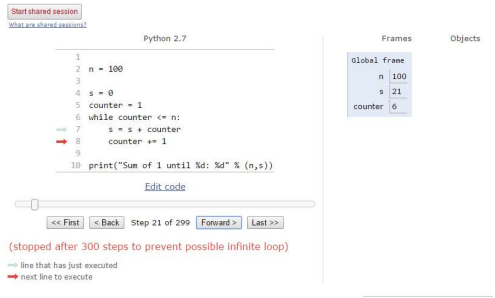

Figure 1: Online Python Tutor (www.pythontutor.com)

The figure above shows how a simple script can be placed as input into the platform and the output is an execution that allows the user to step through the code and visualise the process that the program is following. The inputted source code is displayed in the top left with a hyperlink below it that allows the user to edit his code. The slider and button input controls allow for the user to navigate through the timeline of the execution fluidly and pause at every instant. The object frame on the right shows different attributes of the variables and objects as well as how they are related to one another. The program output box (not seen in the figure) displays the final output of the program.

The backend of the program works by taking the input text submited by the user, executes the text as python source code, generates a stacktrace of the execution and then returns this stacktrace in a defined format [13]. The development team involved started their design by taking common features from existing program visualisation tools and re-working them to be intergrated into a web platform. Their initial design was refined and features were added based on feedback from users [13]. In addtion to users they also received invaluable advice from instructors in the field.

3.3.1.2 Pythia

Pythia is web-based solution grader for programming and algorithm design problems, specifically in the Python language. The platform is described as being a user friendly and accessible way to learn programming [14]. The platform is in development for the purpose of bringing computer science courses to students in Belgium, where there is a need for such courses in high school. The environment is meant to be a more general e-learning website where the platform not only allows users to submit and execute code but also provide a collection of problems and exercises that students can attempt and then compare their results with other students within Pythia. In addition to this Pythia would also allow students to select and follow courses where they would be guided through lessons designed to teach programming concepts [14]. When students complete an exercise they submit the solution to Pythia that then provides feedback on the code. This is also used throughout the coursework where students learn about a new programming concept and then get the chance to test their knowledge on a small example or exercise.

Special attention has also been given to make the framework language-agnostic, meaning as long as there is an interpreter or compiler available within the framework a student may submit any supported code and receive feedback [14]. The Pythia framework is yet to be released however a prototype has been developed. For Pythia's future there are plans for modules that facilitate automatic homework grading, online programming contests and even cheater detection [14].

3.3.1.3 PyThy

Pythy is another web-based, Python-focused programming platform focused on delivering content that would be found in introductory CS courses. Similar to Online Python Tutor, Pythy is also requires no installation or setup and is simply run in the clients browser. This implementation stores the user code to the cloud which provides various benefits in assignment loading and organization [15]. This platform doesn't eliminate the need for an instructor but rather provides an environment where students and teachers can meet online to run the course activities.

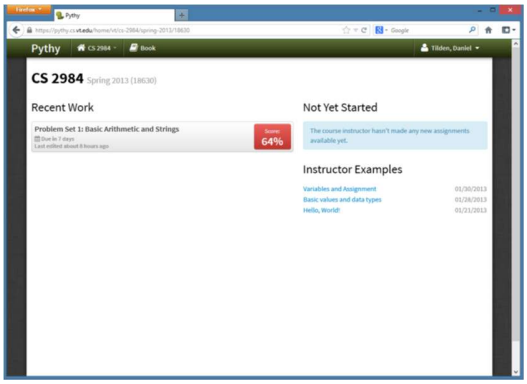

Figure 2: Home page of Pythy (as seen by student) [15]

The above figure shows a little of how the Pythy looks from the perspective of the student. The student enters a course and is thin subjected to a number of assignment and lessons that are assigned by the official instructor of the course.

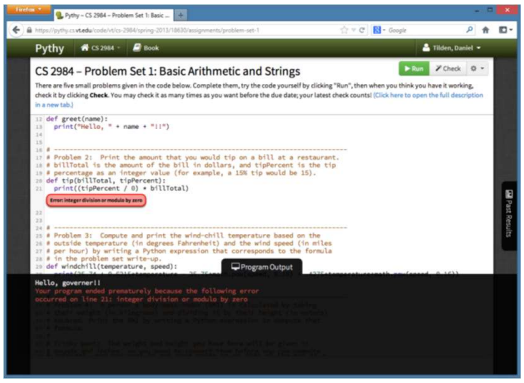

Figure 3: A student working on an assignment [15]

The above figure shows how a student would typically work on an assignment within Pythy. The student writes his code in an editor online. At any point he can click the RUN button at which point the platform will execute his code and provide the output as well as feedback on how the code executed. When completed the user can submit his code to an automatic marker where it will be run and put through a series of test conditions.

An instructor has the ability of making a new assignments using an online creator within PyThy. All that is required is a name, a description and uploading a few test cases that the submitted code will be evaluated against [15]. New examples can also be created and shared among all the registered user through the use of the underlying cloud technology. When a change is made on the instructor's example the change is propagated through the cloud to reflect in all of the students versions of the example.

Pythy hops to improve its service in the future by offering a practice area where students can test their ability without an existing assignment, version control to keep a history of the progression of student code and support for group projects.

CONCLUSIONS

When building a new web-based education platform it's important to keep in mind the final objective; to provide the student with an interactive environment that allows him to build and verify his knowledge on a subject. The Python language provides the student user-friendly and interactive experience. Python's features that are beneficial to beginners need to be considered when designing the e-learning environment. Every feature needs to help the student improve his learning experience.

When reviewing the previous work conducted in this field certain common elements appear. All of the implementations allow the user to submit code and receive feedback on its execution, requires no additional setup to operate the platform and can simply be run in a browser. In Pythy the aesthetics and usability of the platform were obviously a big factor during the design. They also made considerations for users who may wish to use their website on a mobile device as their page is responsive to changes in the screen size. Feedback from your users is also crucial as the platform needs to adapt to fit the needs of the learners.

There is an opportunity for further research to be conducted in the evaluation of how effective teaching programming is through a web-based platform also on how visualisations and other multimedia in a web context could be used to effectvely convey programming concepts to the student.

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