

The CodingHere Platform for Programming Courses

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Abstract

We designed an online platform called CodingHere for the introductory C programming course. CodingHere is like an online judgment system with additional course teaching functions, making it a helpful tool for programming courses. It automatically checks the codes submitted by students and provides course management functions for teachers. To help beginners in a programming course, CodingHere provides detailed error messages when a submitted code fails. It returns not only a WA message but also a wrong test case with input, student results, and correct answers. This information is helpful for students in finding errors in their code. In addition, CodingHere provides a code format check function, which helps students write codes with suitable coding styles. We have been using CodingHere for four semesters. More than 140,000 codes submitted by 261 students were collected. We analyzed these codes to find out the common mistakes students often made as a reference for our teaching improvement. Based on our experience, we think CodingHere is a handy tool in programming courses.

Keywords: learning management system, programming courses, online judge system, online learning platform

1 Introduction

Massive Open Online Courses (MOOCs) have become popular in recent years. Because MOOCs are free, everyone can use MOOCs to learn. Users only need a device that can access the Internet, and they can take classes anywhere. Users can also arrange their own time for class. Covid-19 accelerates this trend. Because people cannot go out, learning online is the appropriate way. Therefore, more and more people use MOOCs to learn knowledge and skills.

Programming courses have become more critical because technologies such as artificial intelligence (AI), robot control, big data, and cloud services all rely on programs. In Taiwan, programming education starts from elementary school. University professors often need to support programming courses in junior and senior high schools. In some universities, programming courses are even general education courses.

Writing code is essential in programming learning. Usually, the homework of programming

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courses requires students to write programs. The general course platform does not have a mechanism to evaluate the code. Online judgment is a matured tool to judge codes. However, most judge systems are designed for problem-solving or competition, not for online courses.

Our teaching experience gives us some inspiration. We believe that a good coding platform for programming courses should have the judge system part and provide some functions to fit the teaching needs, such as class/students/exam/scores management. Coding style is also essential. It helps students develop good programming skills and is necessary for software development.

We also evaluated or tried some online systems. Those systems did not entirely fit our needs. Hence we decided to design our own. In this paper, we describe our CodingHere platform and its user experiences. In session II, we introduce various online judge systems and compare the features of these systems. Then in Session III, we present the requirements, ideas, and architectural design of the system. After that, Session IV gives an overview of the CodingHere platform. Finally, Sessions V and VI discuss the user experience and conclude the research.

2 Related Work

2.1 Some Tools to Support Programming Courses

An online judge system is a standard method used to check program code automatically. The earliest online judge system may have been developed by Ciriaco García de Celis of Valladolid University in Spain in 1995 [1]. This system was initially used to train contestants in international programming contests and has developed into the well-known UVa online judge system. Since then, more and more online judge systems have appeared on the Internet.

Most online judge systems are designed for programming problems solving or competitions. These systems do not consider the classroom teaching function. For example, most online judge systems do not provide the most basic classroom functions, such as class management and homework management.

For the needs of teaching or research, many experts and scholars have developed some tools or related studies.

T. Staubitz, H. Klement, J. Renz, R. Teusner, and C. Meinel mentioned that the typical MOOCs are not sufficient to support programming education [2]. Real-time feedback is essential for programming learning. Therefore, an automatic judge system is needed to check students' codes and provide immediate feedback. The research also discusses the advantages and disadvantages of some solutions and believes that different users need to match different solutions. Beginners are suitable for using a web-based learning environment since there is no need to set up a development environment. Experienced programming users prefer to use development tools. They can choose and install it by themselves.

Pgtracer is a programming education support tool provided by M. Murata and T. Kakeshita [3]. It provides fill-in-the-blank questions. Each question comprises a pair of program codes and a trace table. The trace table includes code steps and the value of variables. Students must determine how the variables change during program execution to answer correctly. Pgtracer collects students' logs, including answers, spent time, and evaluation results. It also provides some analytical methods for teachers. Teachers can use these tools to grasp the understanding level of the class quickly.

2.2 Error Message

According to our teaching experience, most beginner students need detailed feedback messages. A. Kyrilov's research finds that telling students only “correct” and “incorrect” lead to more students cheating on programming exercises [4] because students keep getting negative feedback and cannot figure out what is wrong. Eventually, students become frustrated and give up their studies. However, most online judge systems focus on problem-solving or competitions and do not provide detailed feedback. For example, when students make errors when submitting a code online, they usually get a WA (wrong answer) as feedback without more information. Most of them do not understand what goes wrong. This confusion can be a daunting challenge for beginners in programming. Finally, some will gradually lose interest in learning programming and finally give up.

We believe that error tips and feedback are constructive for beginners learning a program. The online judge system generally uses fixed test cases to check whether the code is correct. Therefore, most of them do not provide detailed information due to the finite fixed test cases. Once users know the test case input and output, they can use cheating methods to solve the problem. Therefore, the judge system usually does not prompt the user with the test case, nor does it provide a comparison between the wrong result and the correct result.

2.3 Coding Format Style

Most online judge systems do not check the coding format. However, for a good code, both the correctness and the format of the code are significant. According to the research of B. Boehm and V. R. Basili, while developing software, about 70% of the time is spent on program maintenance [5]. Many researchers believe reading the code will take the longest time when maintaining software [6-8]. Aggarwal mentioned that the readability and the related documentation of the code are critical to the software's maintenance [9].

Through these studies, we see that poorly formatted code will increase the reading difficulty and indirectly lead to an increase in software maintenance costs. In addition, poorly formatted code is also prone to many unobvious problems. We often encounter this situation in programming courses when we observe students writing code. Therefore, maintaining a suitable coding format plays a significant role while learning to program.

Nowadays, most software is developed by a team, so it is necessary to read or modify other people's code frequently. A poor format code is challenging to read and understand, and it will reduce software development efficiency. Therefore, many teams will formulate some programming style rules before developing software. Even software developed entirely by individuals may be modified by themselves in the future. Therefore, a good coding style is still an important part.

In our programming class, we often found messy codes. These codes are not easy to understand, and some hidden errors are not easy to find. For example, there is an error in the code shown on the left of figure 1. The student did not notice the error at first. However, after rearranging the code in a suitable format, he immediately noticed the problem - A curly brace was missing at the end of line 6.

```

1 #include <stdio.h>
2 int main()
3 {
4 for(int i=1; i<=9; i++){
5 for(int j=1; j<=9; j++){
6     printf("%d*d= %d ", j, i, j*i);}
7 printf("\n");
8 }
9     return 0;
10 }

```

```

1 #include <stdio.h>
2
3 int main()
4 {
5     for(int i=1; i<=9; i++) {
6         for(int j=1; j<=9; j++)
7             printf("%d*d= %d ", j, i, j*i);
8         }
9     printf("\n");
10 }
11     return 0;
12 }

```

Figure 1: Bad and good code format style examples

3 System Design

We have been teaching C language courses for first-year college students for many years. Most students are beginners to programming languages. Based on our teaching experience and needs, we designed the platform CodingHere. CodingHere is an online judge system that combines classroom teaching functions. This section will introduce the system architecture and functions of CodingHere.

3.1 Helpful Debugging Messages

CodingHere provides functions for online program solving. After a user submits his code, CodingHere automatically judges whether the code is correct and feedback a detailed message to the user. Most online judgment systems provide relatively simple feedback information, such as CE (Compilation Error), AC (Accept), PE (Presentation Error), NA (Not Accept), WA (Wrong Answer), TLE (Time Limit Exceeded), and MLE (Memory Limit Exceeded). For beginners, these messages can hardly help them find the cause of the error. Most beginners may have logical errors in their code, so they get the wrong answer. Only a WA message is not enough for them to solve the problem. Therefore, we designed our platform to provide more feedback information, such as which inputs will lead to the wrong result and what is the correct result. These detailed messages can provide students with more help in finding errors in the code.

3.2 Randomly Generated Test Case

An online judgment system generally uses fixed test cases to examine the submitted code. If the system returns a detailed error message, users could easily cheat. Because when the users test multiple times, they can get all the test cases. Then, they only need to judge the input of each test case and print out the corresponding output to solve the problem without using the correct algorithm. Therefore, it is unsuitable for providing detailed information when using fixed test cases. CodingHere uses randomly generated test inputs and an answer code to check the submitted codes. Although it provides users with detailed error messages, users cannot use this method to cheat since the test inputs are different each time.

CodingHere allows teachers to use Python or C/C++ languages to generate test input data. For example, suppose a program requires two random integers between 1 and 100 as input. We can use

```

print(randint(1,100), randint(1,100))
or
printf("%d %d\n", randint(1,100), randint(1,100));

```

to generate the test input data. CodingHere provides a supporting framework for generating test inputs, so teachers only need to write simple statements. On the other hand, teachers can still use all Python or C/C++ statements to meet complex and challenging data input requirements. Currently, CodingHere provides four modes to generate test input data:

- **Direct Code:** In this mode, simple Python or C++ statements are used to generate test input data directly. The teacher only needs to consider one input test case. The system will repeatedly use the program to generate many input test cases.
- **Data Function:** In this mode, teachers can set multiple test input sets. Each test input set has its passing score. In this mode, teachers can set the way of scoring more flexibly.
- **Raw Function:** In this mode, teachers can set multiple test input sets. The difference from the above is that the teacher only writes the input test data directly instead of code statements. It is easy to establish necessary or fixed test input cases.
- **Mixing Mode:** In this mode, teachers can mix modes 2 and 3 to generate input test data.

3.3 Coding Format Check

CodingHere uses vera++ [11] to check coding format. Vera++ is an open-source project to check the coding format of C/C++. It provides many preset format rules for users and provides a development interface to use Tcl, Lua, or Python to add users' own rules and related messages.

ANSI and K&R are two common styles of C language, as shown in Figure 2; the main difference between the two is the position of the curly braces. In addition to the different positions of the curly braces, the coding style contains more content, such as naming conventions, comment writing methods, the use of spaces and line breaks, and indentation width. Although there are many styles, some formatting principles are consistent. For example, code blocks in branches and loops should be indented, spaces should be added after commas, and there should usually be no extra spaces before semicolons.

CodingHere does not limit the styles that students must use. As long as it meets some basic formats, students can choose their favorite style to write programs. CodingHere also retains some flexibility, allowing teachers to set the styles they want to impose.

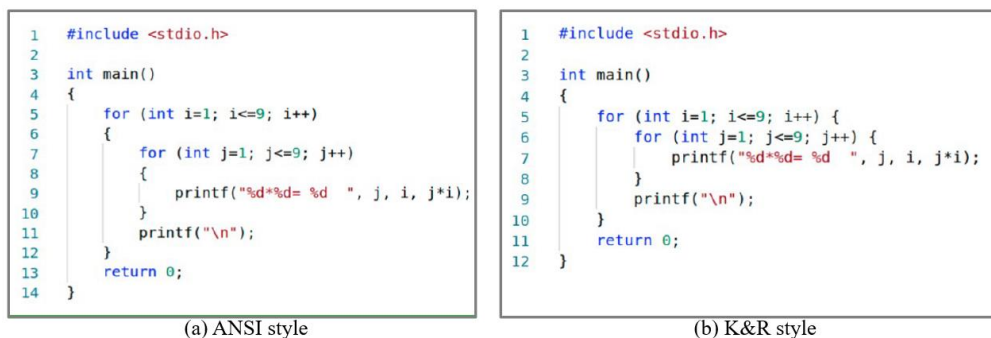


Figure 2: ANSI and K&R coding format style

3.4 Functions for Different Roles

Figure 3 is the system structure of CodingHere. The administrator can set up judge servers, manage courses and problem sets, and export database data for analysis. As for teachers, CodingHere provides some teaching management functions, such as scheduling assignments and exams and viewing students' answer records. The student has a dashboard that lists his/her courses taken, assignments, and problem-solving records. The coding page is mainly for users to write programs and display judgment results.

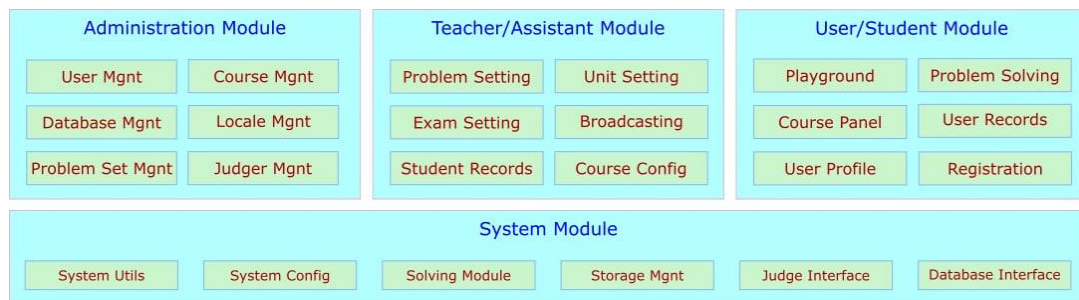


Figure 3: System Structure of CodingHere

3.5 Backend Server and Judge Server

The web backend mainly includes a web server and judge servers. The web server is responsible for coordinating with the frontend to handle various functional modules, such as user management, course management, problem management, homework management, exam management, and database management. In order to build a high-performance server, we choose the Go language for development. Go can easily support web development and parallel processes design. The performance of websites created in the Go language is usually faster than that of websites created in other languages.

The judge server is built using the Go language and C language. In addition to checking whether the submitted code is correct, it must also prevent malicious code from corrupting the system. In addition, many code issues must be considered, such as infinite loops, infinite output, runtime constraints, memory size constraints, and other program issues. We use the seccomp function of the Linux system to restrict system function calls to enhance system security. In addition, the judge server is running in a Docker container. Using Docker to run the judge server can further improve the system's security and ease of use. Multiple judge servers can be executed in different containers simultaneously. CodingHere will choose the server with the lightest load or a random one if they have the same load.

Figure 4 is a block diagram of the judgment process. Students write their code on the website and then submit it to the backend server. The backend server calls the judge server executed in the Docker container. If the submitted code is malware, it will be restricted by kernel seccomp filtering and the container sandbox. This double protection provides higher security for the system. The judge server will also check the code format and return the judgment result to the user.

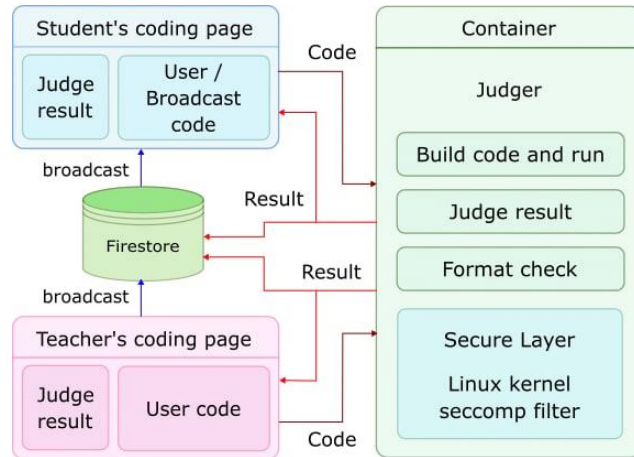


Figure 4: Block diagram of the judgment process

3.6 Data Processing

CodingHere uses Google's Firebase and its authentication function. Firebase is very easy to extend. In addition, it also provides real-time data monitoring functions. When the data changes, it can immediately send the changed data to the server, which is very helpful for the CodingHere platform's development.

Firebase has free and paid versions. The free version limits the number of reads and writes (50,000 reads per day, 20,000 writes per day). Based on our experiences, we generally have two classes with about 60 students in each class. Typically, data access flow per day is far below the limit. However, the day before the midterm and final exams, the usage rate will soar so that it may exceed the traffic of the free version. However, the paid version is still very cheap for our application. The cost of 100,000 reads/writes is less than \$0.24. We rarely need to pay for this. Therefore, we think this is still a good solution.

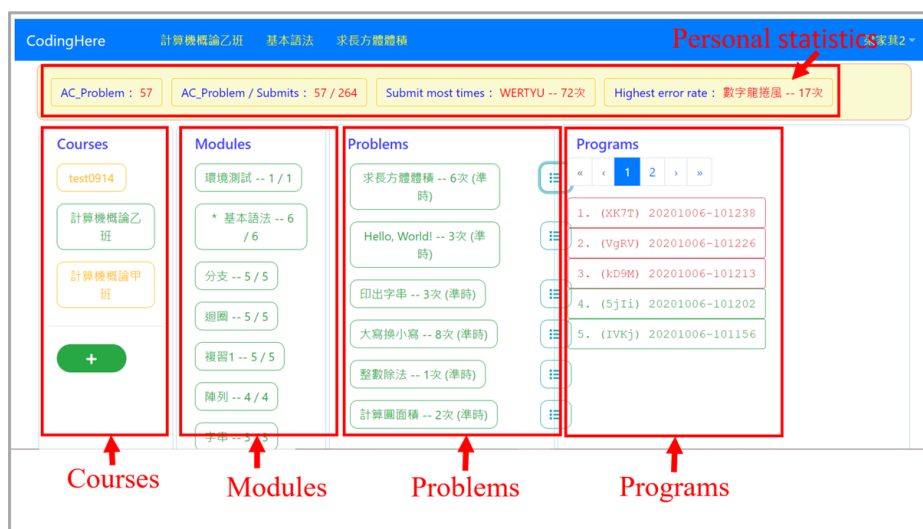


Figure 5: The user dashboard.

4 CodingHere Overview

4.1 Dashboard Page

For students, the most important pages are the user dashboard and the coding page. As shown in Figure 5, the user dashboard lists the student's courses, submission records, and some statistics information. The upper part of the page is the user's statistics information, and the lower part is other information, including selected courses, course modules, module problems, and problem submission records. Different colors are used to identify different status-green means success, red means failure. Students can also click the submitted record to display the code and then click a button to fix the code, as shown in Figure 6. Each submitted record has a unique ID. When students need help, they can tell the teacher the first four characters of the ID. Then, the teacher can search for it to get the submitted code, which is very useful for classroom instruction.



Figure 6: The submitted record

4.2 Coding Page

After selecting the question, the system will enter the coding page, as shown in Figure 7. On the left side of the page is the problem description area. On the right side of the page is the coding area.

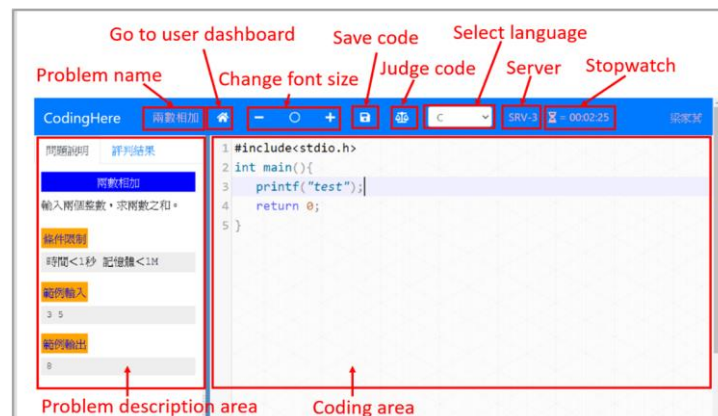


Figure 7: The coding page

In the following, three main features of the coding page will be introduced separately: 1) coding correctness check, 2) coding format check, and 3) software broadcast.

A. Coding Correctness Check

If a user makes a mistake on most online judge systems, he/her may only get a simple response, such as WA, which means the wrong answer. This message is too simple for most programming beginners and does not provide enough information for further debugging. On CodingHere, when a test case fails, it will return a WA message and an incorrect test case to the user to facilitate user debugging. For example, as shown in Figure 7, the problem expects the user to calculate the sum of two input integers, but the submitted code calculates the difference between them. The server shows an error case with input data 3 and 5. The correct output is 8, and the output of the submitted code is -2. Based on this information, students can more easily fix the code.

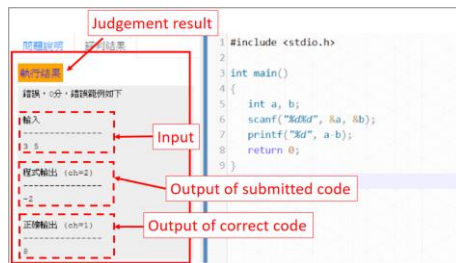


Figure 8: Coding correctness check

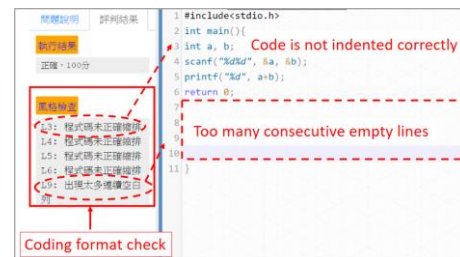


Figure 9: Coding format check

B. Coding Format Check

A good coding style is significant for understanding and maintaining program code. Figure 9 shows a user-submitted poorly formatted code. In this example, lines 3 to 6 are not properly indented, and lines 7 to 10 contain too many consecutive blank lines. After the judge server checks the code format, some warning messages are feedback to the user. The teacher can also use this feedback as scoring criteria to help students develop good coding habits.

C. Software broadcast

CodingHere provides teachers with software broadcasting functions to help classroom teaching. This feature allows some students to watch the teacher's presentation while others write their code. This function increases the flexibility of classroom teaching. Figure 10 shows the teacher's coding page. Compared with the user's coding page, there are two more buttons on the teacher's side. One is used for software broadcasting, and the other is used for code testing. The latter is used to test the code without saving data to the database.

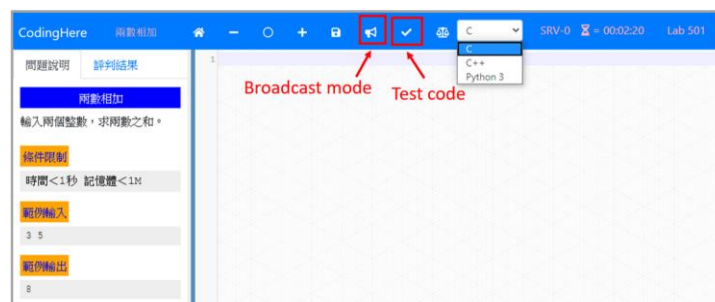


Figure 10: Teacher's coding page.

4.3 Reference Documents

CodingHere allows teachers to upload reference documents. As shown in Figure 11, users can read the language cheat sheet in CodingHere. The reference documents are written in Markdown language, allowing teachers to edit quickly.

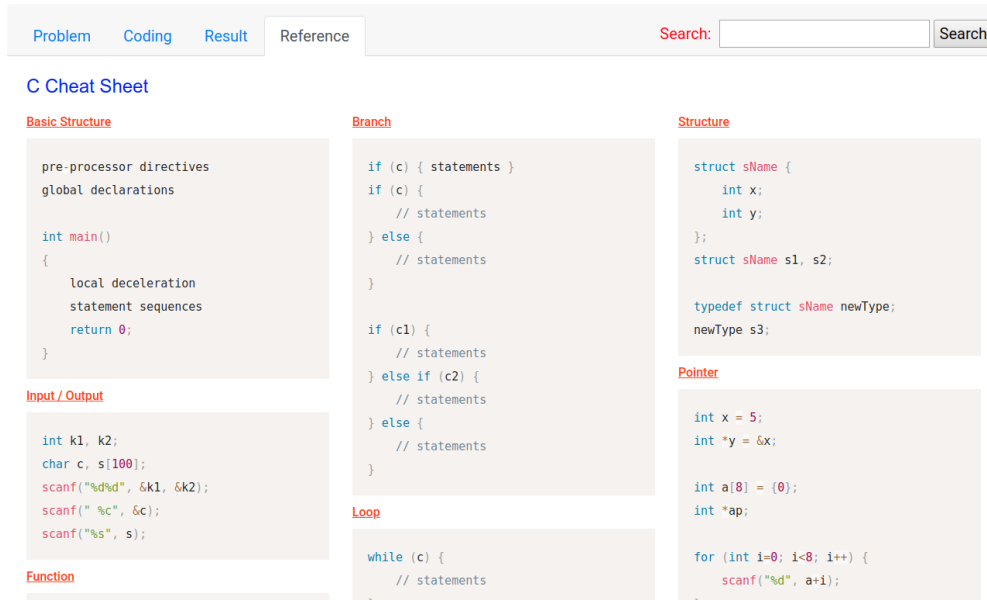


Figure 11: Reference document and “search” function

5 Discussion

5.1 Usage Overview

CodingHere has been tested online since October 2019 and is mainly used for a C programming language course. A total of 4 classes of students (a total of 261 students) have used CodingHere. There were two classes of students in 2019 and 2020, respectively. In the 2019-1 semester, we selected some volunteers for pre-testing. Based on the feedback, we made some changes to the platform. Starting from the 2019-2 semester, CodingHere has been officially used in our courses.

CodingHere provides an easy way for teachers to assign homework. The teacher can set the problems and the start date and due date for each unit. Homework will automatically show or close to students based on the setting. For our course, we created about 137 problems. There are 50 simple problems for beginners to learn programming languages. The purpose of these problems is to allow students to practice program syntax without requiring complex algorithms to solve them.

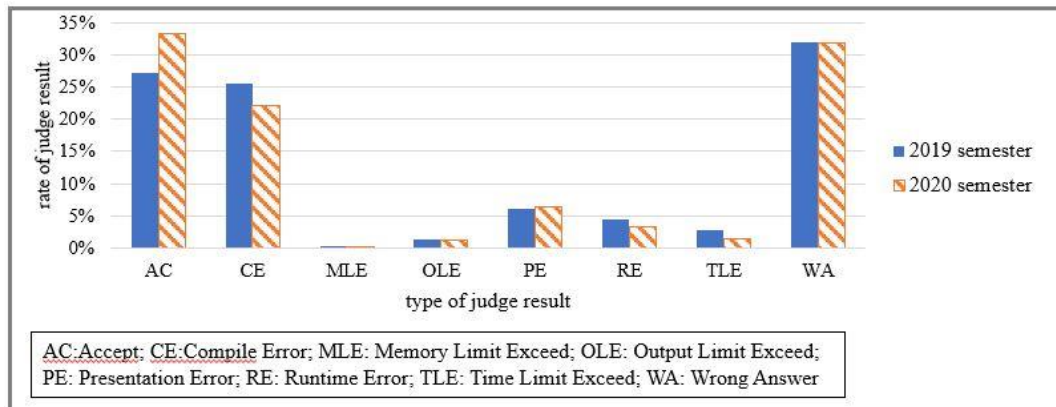


Figure 12: Statics of the judge results

5.2 Some Statistics

CodingHere collected 143,334 submitted codes for all the four class students. We get how much code was submitted for each problem with problem-solving statistics. For complicated problems, students usually practice longer and submit more code. These problem-solving statistics are beneficial for teaching. In addition, we also calculated the statistics of different judgment results. As shown in Figure 12, AC, CE, and WA are the most frequently occurring results.

Xinyu Fu, Chengjiu Yin, Atsushi Shimada, and Hiroaki Ogata Propose a study on Error log analysis [12]. They defined some common types of errors and calculated the frequency of each type of error. We also referred to their research and made further analyses for compilation errors. The result is shown in Table 1. The most common error is the undeclared error, according to the table. We can also analyze the statistical results of a single problem, as shown in Figure 14. It shows the total number of each error type and lists the compiler feedback results of different submitted codes. This information can help teachers find the reasons why students make mistakes.

```

Problem Detail
Problem Title: 倒印數列
Description: 輸入n及n個數，將此n個數倒過來輸出。(n<=30)
Total: 3136
Statistics: AC: 658 WA: 1078 RE: 306 PE: 408 CE: 558 OLE: 101 TLE: 25 MLE: 2
CE types: undeclared: 303 missingCh: 9 semicolon: 99 expectedExpr: 60 missingFunc: 39 reDeclare: 10 preproc: 4

1.
In function 'main':
11:13: error: 'arr' undeclared (first use in this function)
 11 |         arr[N-j-1] = A[j];
    |         ^
11:13: note: each undeclared identifier is reported only once for each function it appears in

2.
In function 'int main()':
5:8: error: 'n' was not declared in this scope
 5 | int a[n],n;
    |     ^
8:8: error: 'a' was not declared in this scope
 8 | cin>>a[i];
    |     ^
In lambda function:
12:12: error: expected '{' before ';' token
12 | cout<<[j];
    |     ^
compilation terminated due to -fmax-errors=3.

3.
In function 'main':
4:8: error: 'n' undeclared (first use in this function)
 4 | int a[n];
    |     ^

```

Figure 13: Detailed information for a problem

Table 1: Types of Compiler Error

Error Type	Description	Total
undeclared	Forget to declare a variable before use.	13819
missingCh	Missing characters such as '}' or ')'.	5800
semicolon	Forget to add a semicolon at the end of the sentence.	3849
redeclare	Declare the same variable multiple times.	1213
expectedExpr	Expression expected / The expression is incorrect, like "for(int i;".	4088
preproc	Include the wrong header file.	547
missingFunc	Wrong function name or wrong parameter.	1109

5.3 Satisfaction Questionnaire to the Students

Students in the 2021-1 semester fill out the CodingHere Satisfaction Questionnaire (Table 2). The score range is 1-5 points; the higher the score, the higher the satisfaction. A total of 129 students filled out the questionnaire. From the score of question 2, providing correct output and program output helps students find bugs in the program. Question 3 shows that CodingHere can train students to pay attention to the coding format. Figure 13 shows the distribution of students' satisfaction scores. More than 80% of the students gave 5 and 4 points, which shows that the students are satisfied with CodingHere.

Table 2: Satisfaction Questionnaire of CodingHere

No.	Question	Score
Q1	CodingHere is easy to use.	4.410853
Q2	Correct output and program output provided by CodingHere helps to find bugs.	4.395349
Q3	The coding format check function can remind me to pay attention to the coding format.	4.395349
Q4	CodingHere helps me learn to program.	4.511628

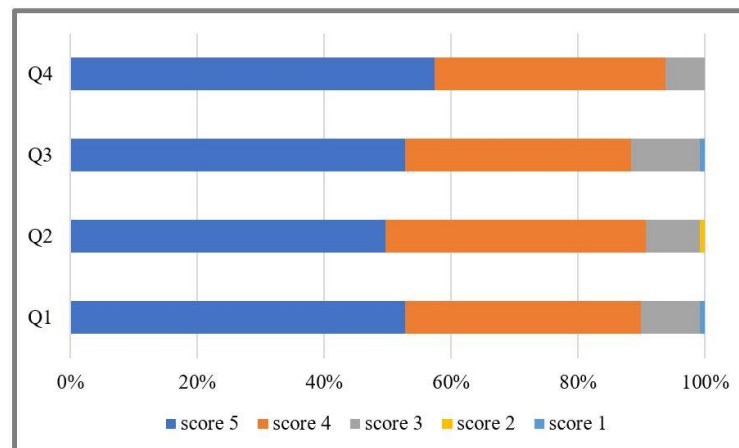


Figure 14: Satisfaction score distribution for CodingHere

6 Conclusion

CodingHere is an excellent help in our programming courses. The Web-based design allows programming language beginners to use it directly without setting up a development environment. The detailed error message can help students find bugs by themselves. Coding format style checking makes students write code with a good format style, making it easier for teachers to help the student debug. A lot of collected code allows teachers to do some statistical analysis. This analytical data helps teachers understand how students are learning. We hope that CodingHere can help more people learn programming languages in the future.

Reference

- [1] M. A. Revilla, S. Manzoor, and R. Liu, "Competitive Learning in Informatics: The UVa Online Judge Experience," *Olympiads in Informatics*, Vol. 2, 2008, pp. 131-148.
- [2] T. Staubitz, H. Klement, J. Renz, R. Teusner and C. Meinel, "Towards practical programming exercises and automated assessment in Massive Open Online Courses," 2015 IEEE International Conference on Teaching, Assessment, and Learning for Engineering (TALE), Zhuhai, 2015, pp. 23-30, doi: 10.1109/TALE.2015.7386010.
- [3] M. Murata and T. Kakeshita, "Analysis Method of Student Achievement Level Utilizing Web-Based Programming Education Support Tool Pgtacer," 2016 5th IIAI International Congress on Advanced Applied Informatics (IIAI-AAI), Kumamoto, 2016, pp. 316-321, doi: 10.1109/IIAI-AAI.2016.107.
- [4] A. Kyrilov and D. Noelle, "Binary instant feedback on programming exercises can reduce student engagement and promote cheating", *Proceedings of the 15th Koli Calling Conference on Computing Education Research*, 2015, pp.122-126.
- [5] B. Boehm and V. R. Basili, "Top 10 list [software development]," in *Computer*, Vol. 34, no. 1, pp. 135-137, Jan. 2001, doi: 10.1109/2.962984.
- [6] L. E. Deimel Jr., "The uses of program reading," *SIGCSE Bull.*, Vol. 17, no. 2, 1985, pp. 5–14.
- [7] D. R. Raymond, "Reading source code," in *Conference of the Centre for Advanced Studies on Collaborative Research*. IBM Press, 1991, pp. 3–16.
- [8] S. Rugaber, "The use of domain knowledge in program understanding," *Ann. Softw. Eng.*, Vol. 9, no. 1-4, 2000, pp. 143–192.
- [9] K. Aggarwal, Y. Singh, and J. K. Chhabra, "An integrated measure of software maintainability," *Reliability and Maintainability Symposium*, 2002, pp. 235–241.
- [10] Xiaosong Li., Christine Prasad, "Effectively teaching coding standards in programming," *Conference: Proceedings of the 6th Conference on Information Technology Education, SIG-ITE 2005*, Newark, NJ, USA, October 20-22, 2005.

- [11] “vera++,” Bitbucket.org. <https://bitbucket.org/verateam/vera/src/master/>. (accessed: May 19, 2022).
- [12] X. Fu, C. Yin, A. Shimada ,and H. Ogata, "Error log analysis in C programming language courses," Proceedings of the 23rd International Conference on Computers in Education, 2015, pp. 641-650.