Real-Time Feedback Learning System Based on Programming Logs Analysis

Sheng-Bo Huang[1], Chin-Feng Lai[1], Yu-Lin Jeng[2]

[1] Department of Engineering Science, National Cheng Kung University, Taiwan
[2] Department of Marketing and Logistics Management, Southern Taiwan University of Science and Technology, Taiwan
n98074037@ncku.edu.tw, cinfon@ieee.org, jackjeng@stust.edu.tw

Abstract

With the development and growth of information technology computational thinking has become a crucial skill. Therefore, using programming courses is a common way of training students in computational skills; however, students usually have poor academic performance when it comes to programming courses. The main reason is that they do not have enough background knowledge to recognize compiler messages, which makes it difficult for them to learn these courses. Therefore, this study developed a Real-Time Feedback Learning System (RTFLS) to help students learn programming. The proposed system integrates a real-time module, a search module, and a push technology module. Therefore, when students practice programming, the RTFLS can monitor their compiler messages, filter and parse them while searching for reference resources and their instant response messages on the Internet.

Although the RTFLS has a positive impact on the students' learning performances there are some problems with low relevance in the response messages of the RTFLS. This is because certain compiler messages do not appear in the programming syntax, but can cause errors. Therefore, in some cases, the RTFLS cannot effectively provide highly-relevant response messages.

Keywords: Real-Time Feedback, Computer science, Push technology

1 Introduction

With the development of information technology computational thinking has become an important skill and it has attracted a lot of attention from scholars. According to [14, 17], computational thinking is a useful skill; it is not only a problem-solving skill but also a method of understanding human behavior through basic computer science. Therefore, many universities have actively established different disciplines related to computer science in recent years. Moreover, some studies believe that the development of computer science education is necessary because it not only cultivates the students' innovative ability, but also trains them to use computers for thinking and work experience [6-7]. Some researchers have pointed out that to effectively train computational thinking talents, programming design is a way of cultivating the students' computational thinking ability, and it has a positive impact on their knowledge of computational thinking [15-16]. Also academic performance in programming courses requires intensive practice to understand the basic theoretical concepts and skills of programming, and if students do not have adequate background knowledge they will have difficulty recognizing compiler messages [1-2]. This means that programming is difficult for students to learn, especially when they do not understand compiler messages. Programming is a hierarchical skill, lack of basic knowledge may prevent them from learning it effectively [5].

However, to improve the students' programming learning abilities, this study developed a Real-Time Feedback Learning System (RTFLS), which is integrated with real-time technology to provide response messages to help students learn. The proposed RTFLS can monitor the students' compiler messages. When an error message occurs, the system automatically collects the compiler messages and sends them to the server to parse the content. In addition, the RTFLS also integrates a search function, the purpose of which is to cultivate the students' programming experience. The RTFLS can search for some information related to the compiler messages from the Internet for students to read and learn. After searching, the response messages are generated and then the push module will push the response message as reference resources for the student.

Teachers encourage students to refer to response messages to solve problems and to complete learning activities independently, which further trains them in the programming learning experience. RTFLS's main purpose is to help them learn to recognize compiler messages through reference response messages, which can not only stimulates their thinking skills but also

*Corresponding Author: Yu-Lin Jeng; E-mail: jackjeng@stust.edu.tw
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cultivates their basic knowledge to independently recognize compiler messages. Therefore, the research questions of this study are as follows.

- Are the RTFLS response messages highly relevant to the compiler messages?
- Do the RTFLS response messages have a positive impact on the students' learning performance?

2 Literature Review

2.1 Computational Thinking and Programming Courses

The continuous development of technology has had a profound impact on our daily lives. Therefore, the government is actively promoting information and communication technology-related disciplines in universities. Some researchers have also emphasized the importance of computational thinking. Researchers believe that computational thinking is a problem-solving skill, a system design, and a method of understanding human behavior through the basics of computer science which is useful for everyone [14, 17]. However, another study also pointed out that computer science education not only cultivates the students' practice of algorithmic problem-solving and the application of interdisciplinary computing, but it also promotes the students' understanding of how to make the computing process take on problems in other fields [13]. This means that it cultivates the students' computational thinking skills and trains them to solve basic problems at the same time. According to [15-16], the use of program design is a way of cultivating the students' computational thinking ability which not only has a positive influence on their knowledge of computational thinking, but also improves the level of their practical ability.

Literature shows that computational thinking has become an indispensable skill. It is not only useful for computer courses, but it is also a useful skill for everyone [13-16]. On the other hand, letting students learn computational thinking processes can also train them to solve problems and apply computer knowledge. To cultivate the students' computational thinking skills this research proposes an RTFLS, which integrates real-time and push technologies to help students build their computational thinking. Students can immediately obtain relevant response messages through real-time push technologies, and then try to complete their learning activities to further develop their knowledge on computational thinking.

2.2 Log Analysis

There are different types of information systems in the digital era. The log has become important data because it not only diagnoses the state of the system, but is also useful for tracking system information (especially when a system failure occurs) [8]. This means that a log analysis will help users to get more information about the system, for tracking, and for fixing problems faster. Also, logs can be used to analyze user behavior patterns. In terms of web systems, Google has developed a weblog analysis tool, which supports users to enable JavaScript code to one's website. When the user views or clicks the button or web page, the JavaScript code sends the log information to the Google Analytics service. The user can then clearly view and track user's usage information and behavior [10]. Use of logs can be used to permanently record data during use, but it can also be used to analyze the current use of system functions [9]. Researchers point out that logs are generally used to store valuable information and user interactions on a hard disk and store them in plain text format as log files. As the log file is very large, it is difficult to filter or sort. The log data is typically used by system administrators and digital investigators [11-12].

Therefore, as far as learning strategies are concerned, it is appropriate to integrate the logging mechanism into the learning environment. The teachers can analyze the logs to track the learning level of students to further explore their views in this learning activity. This study integrates the logging mechanism into the system. The proposed system can monitor the compiler log and permanently record the user log while sending it to the server to analyze the data. Therefore, the teacher can understand the student's learning situation, based on the log data.

2.3 Real-time System

In the real-time system, real-time properties are a crucial factor that impacts the user's experience.

For e-commerce platforms, real-time data is a key factor because it is a method of processing data to distinguish normal behavior in real-time, i.e. within a few milliseconds. [3]. In [4] a similar view is mentioned that real-time systems should be able to process millions of messages per second, so it requires continuous monitoring, high scalability, and parallel processing of the data to extract information and make it meaningful and effective. Therefore, in recent years, real-time technology has become a popular technology in various industries because it can provide users with useful information. This means that it is important to effectively provide meaningful information in real-time systems. According to [18], the timing of the results is one of the key factors because incorrect results can lead to functional failure and affect the satisfaction of real-time properties, so in order to make the real-time results correct predictive behavior is adopted to ensure the accuracy of a real-time system.

Real-time computing is a popular technology in the digital age, and the main reason for this is that it can provide useful messages within a few milliseconds. Also to make real-time message processing meaningful,

the system must analyze the information and process the data in a parallel manner to extract the information. Based on this principle, this study integrated the real-time mechanism into the system. Students can receive real-time messages and then they can try to solve the problem by themselves. It not only cultivates the students' learning experience, but also increases their basic knowledge. In addition, to let more real-time messages meet the learning situation, the system can collect the students' compiled messages and further analyze the content before pushing the real-time messages.

3 Research Approach

The RTFLS developed by this study contains five modules and instructions. Students can receive push response messages which are relevant to the compile errors that are currently occurring. Thus, students can refer to the response message to try to solve the problem and complete their learning tasks.

3.1 Participants

The participants of this study were recruited from the "Advanced Programming for Mobile Commerce" course offered by the Dpeartment of Information Technology, which is an advanced course in information technology. The 24 participants are junior students, from the Department of Information Management of a University of Science and Technology in Taiwan, and are aged between 20 and 21 years old. They are suitable for this experiment because they have all taken relevant programming courses, including Object-Oriented Analysis and Design.

3.2 System Framework

The "Advanced Programming for Mobile Commerce" course is based on Java programming language. Java has a certain level of difficulty for novice students, thus the RTFLS developed by this study can be used to help the students learning Java. The RTFLS is very convenient to install in the Windows Operating System (OS) and students only need to install the .Net framework to use it. The RTFLS is designed based on the Net framework and can run in parallel with Android Studio while calling the module to perform specific tasks. Also, to enable students to receive the RTFLS system response messages the students have their own accounts, created using their student ID.

The system framework is shown in Figure 1. There are five main modules in the RTFLS, including the "Log Collector", "Log Analyzer", "Message Generator", "Push Module", and the "Search Module", described as follows:

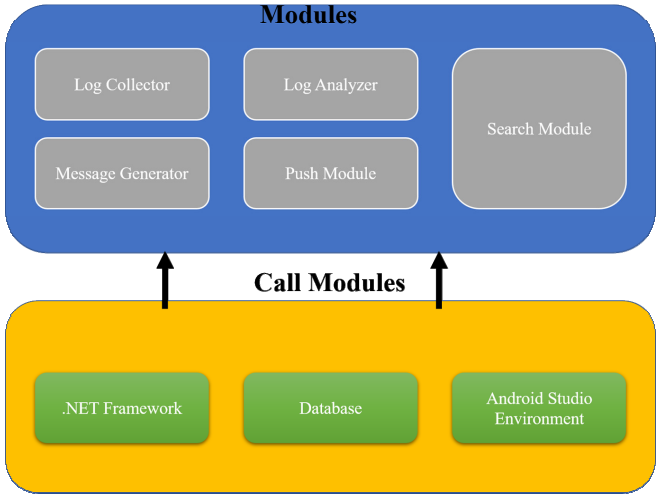

Figure 1. System Framework

Log Collector: The log collector continuously checks the status of the compiler messages. When the compiler generates a message, it automatically collects it.

Log Analyzer: Before saving, the analyzer analyzes the collected compiler messages, and at the same time, identifies the compiler messages and finds the main cause of the student errors.

Search Module: This module searches for relevant resources from the Internet, based on the user's compiler messages. Therefore, before searching the log module and log analyzer collect and parse the compiler messages to generate keywords, and use them to search for related resources. This module also incorporates a filtering mechanism that enables students to read high-quality, or more useful resources from the Internet. The Stack Overflow website states that voting is an important factor, which contains questions and answers with a level of useful or good content. The search process is shown in Figure 2.

Message Generator: The message generator will classify the log analyzer messages and generate response messages as reference resources for students based on the results of the research module.

Push Module: After the search module finds the reference resources, and then pushes the response messages to the student.

In general, these modules can support students in real-time programming learning; not only can they monitor the students' compiler messages, but also parse and filter compiler messages to generate search keywords to find the relevant resources. Also, the search module integrates a filter mechanism which allows students to read high-quality, or more useful resources and to try solve problems.

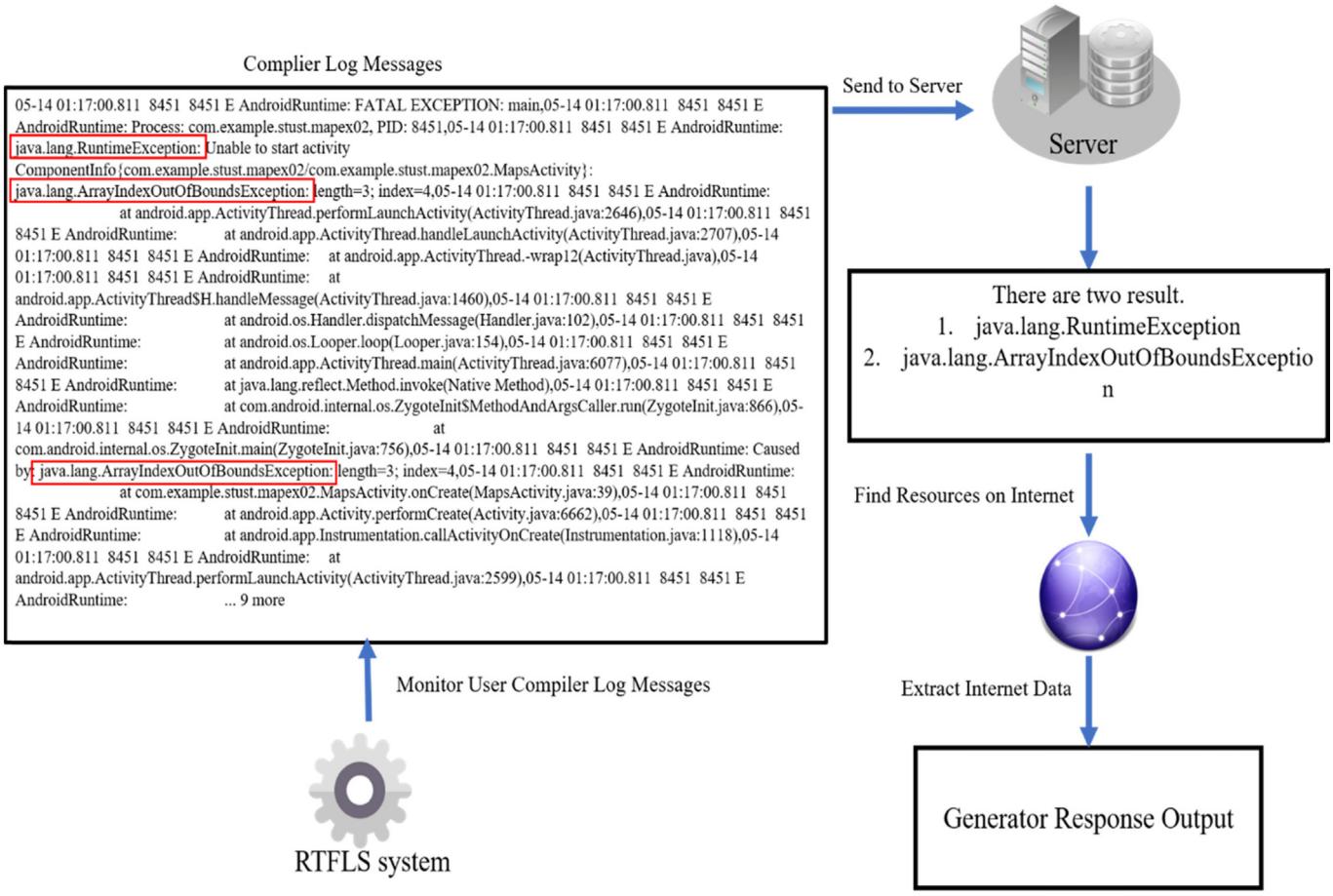

Figure 2. Search External Resource Process

3.3 Search Mechanism

The RTLFS can automatically search for relevant resources, so that the students can use as reference to solve problems. Therefore, to achieve this goal the search mechanism is integrated with the algorithm to filter the extracted data. Also, to help the students become more familiar with the learning concent, the number of votes is used to filter the content in the system. According to the "reputation and moderation of stack overflow" statement, voting is an important factor in the Stack Overflow website. This means that good content is displayed at the top; on the contrary irrelevant content is displayed at the bottom. Therefore, this mechanism lets users read better and more relevant content, while they are trying to solve problems and to further understand the programming concepts. The search algorithm consists of three steps, as detailed below. This study also defines symbolic task behavior, as shown below. Overall, the search algorithm is shown in Figure 3.

SI = {si^1, si^2, .., si^m } is a finite element of the search index, contains different URLs

VT: the user number of votes

SK = {sk^1, sk^2, .., sk^m} is a finite element of the search keyword, containing the exception name, search tag.

```
Input: A threshold value setting by lecturer
Output: A set of output results
Method:
for (i = 0; i < SI.length; i++) {
  for (k = 0; k < SK.length; k++) {
    VT = ExtractNumberOfVote(SK[k], SI[i])
    if (VT >= thresholdValue)) {
      output = SearchTheResource(SK[k], SI[i])
      break;
    }
  }
}
return output;
```

Figure 3. Search Mechanism Algorithm

- Start state: Before performing the search task, the teacher sets the search algorithm threshold. On the other hand, SI defines some URLs. The purpose is to use different URL search results to compare, and find the most voting answers at the same time. The setting of SK comes from the result of the message filter of the student compiler, each exception has a different array setting, and the parameters include search flags, exception types, etc. The search results process is in the next state.
- Compare the search results status (VT > = thresholdValue). This task checks whether the search results exceed the threshold, otherwise, it

continues to search according to the next SI and SK array parameters, until VT reaches the threshold.

- Complete state. The task complete. This task extracts data, and responds to high-value data while generating response data, and then respond to students.

However, the students can receive response messages based on the search algorithm, which is based on the students' compiler messages and filters them to generate keywords. On the other hand, the search algorithm combines the voting and frequency mechanisms, so that the algorithm can effectively find resources related to the compiler messages and useful resources.

3.4 System Usage Scenario

To develop the students' computational thinking skills, this study also designed learning activities and practices, including practical programming, example practice, implementation practice, etc. As the students may show poor academic performance due to a lack of background knowledge to recognize compiler messages, programming requires in-depth practice is needed to help the students better understand the concept of programming skills [1-2, 5]. On this basis, our RTLFS was implemented in the course to encourage students to complete the learning tasks and learning activities.

The RTLFS system not only can filter error log messages but also search for relevant resources to provide relevant response messages to guide students in their learning. The RTLFS is very suitable to help students learn they may not have enough background knowledge to complete their learning tasks. The RTLFS can provide students with reference resources to encourage them to complete the learning tasks on their own. Overall, the RTLFS not only reduces the burden on students to recognize compiler messages but also helps them to solve problems through RTLFS system response messages. The RTLFS usage scenario has consisted of six stages, as described below. The RTLFS system process is shown in Figure 4.

(1) Monitor the Complier Log Messages: Students practice programming code and compile in the Android Studio environment and the RTLFS system will monitor student's compiler messages and then the compiler messages are sent to the log analyzer.

(2) Parser Log Messages: The log parser parses the compiler message and extracts the keywords where the error occurred, such as NullPointerException, ClassCastException, etc.

(3) Send to Server: The parser result keywords are then sent to the server for storage and forwarding to the search module.

(4) Find Relevant Resources: The search module automatically searches for relevant resources from the Internet based on the keywords, while filtering and parsing unnecessary information to send to the message generator.

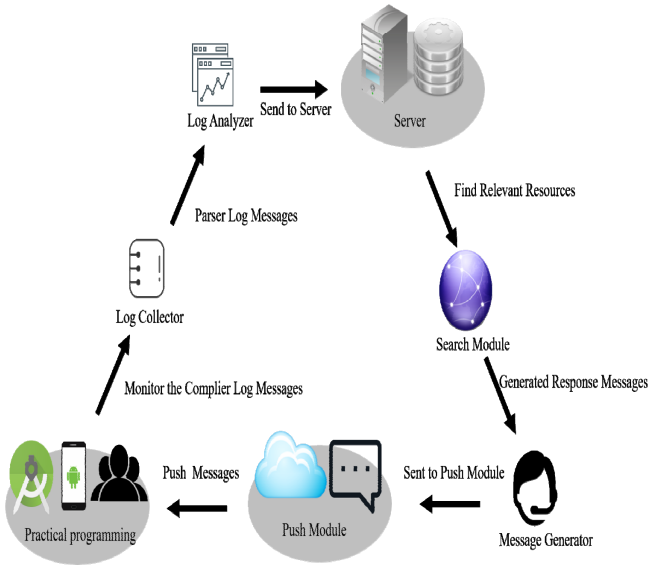

Figure 4. System Process

(5) Sent to Push Module: The message generator generates response messages, including compiler messages, reference resources, and advice messages, and then sends the generated response messages to the push module in preparation for responding to students.

(6) Push Messages: The response messages are generated and sent to students as reference resources for reference.

3.5 Learning Activities

As the students may not have sufficient background knowledge, and their unfamiliarity with the operation of the system affects their academic performance, before the midterm exam, the teacher gave lectures on basic knowledge and programming editor tools introduction. The purpose was to help students familiarize themselves with Android Studio tools and the RTLFS. Hence, the teacher provided time for students to practice programming code, while the teacher was on the side to help students practice and manipulate programming to facilitate learning tasks. It can help students have a basic understanding of Android Studio and the RTLFS. After the midterm exam was over the teacher arranged final projects for the students. Each student was given a different topic to complete and implement.

3.6 RTLFS System Response Messages

The response message consists of three parts, including the "Compiler Message", the "Advice Message", and the "Reference Resource". The response message architecture is shown in Figure 5, and the screenshot of the RTLFS system is shown in Figure 6. The compiler message block comes from the user's compiler message, which is filtered and parsed by the system. On the other hand, the response message is also integrated with the "Advice message". In terms of advice messages, the teacher provided some advice to help students establish links with

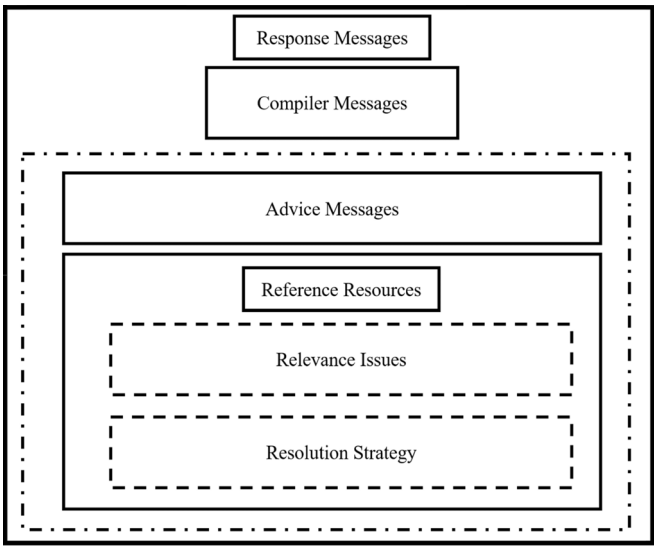

Figure 5. Response Messages Architecture

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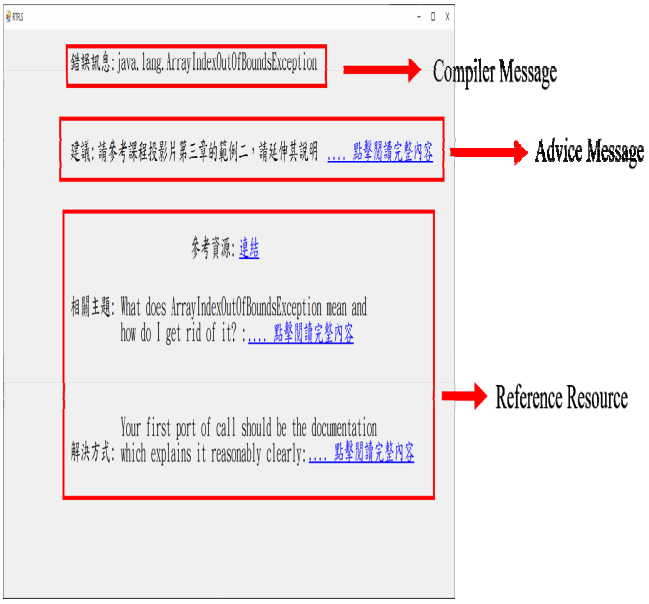

Figure 6. Response message of the RTFLS screenshot

learning materials. For instance, advice messages suggest learning materials for students to understand, and search mechanisms provide relevant reference resources so that students can extend their understanding of the learning materials and use them to solve problems. The purpose is to encourage students to solve the problem by themselves. Also, to make it easier for students to understand the compiler messages we have integrated an external search mechanism, which automatically finds relevant resources based on the filtered compiler messages. Moreover, the system collects user compiler messages, analyze and parse the content to find the keywords from the Internet. The resources from the Internet are displayed in the reference resource block which consists of two parts, namely, the problems related to compiler errors and the strategies to solve the problems. The purpose is to use related problems to guide students to try to solve the problem while training their programming learning experience and to further enhance the basic programming knowledge of the constructor. Thus, some related problems and solutions are used as examples for students to read, and to further understand the compiler message errors.

3.7 Measure

3.7.1 Learning Performance

This research integrates the RTFLS into the curriculum. To explore the impact of RTFLS on the students' learning, this study collected the students' midterm and final exam scores as academic performance evaluations, and to further explore the changes in their academic performance. In the midterm exam the teacher will set up some key factors to evaluate students' learning performance. The concept includes two parts: concept and programming ability. In the concept part, the teacher sets up some basic programming concept questions to assess students' conceptual learning levels. In the programming implementation part, the teacher will set some programming topics to enable students to implement programming. Finally, the teacher will integrate the students' concepts, programming codes, and programming implementation results to evaluate the exam scores.

In the final exam, students are required to introduce their final project which includes programming concepts, programming logic, and problem-solving process. Teachers can comprehensively evaluate students' academic performance based on their final project scores as final exam scores.

3.7.2 Search Accuracy Measure

The RTFLS system developed by this study can collect and analyze the students' compiler messages, and then automatically search for relevant sources for the students. This means that the students do not need to fully understand the compiler message but can refer to the response message to try solve the problem. Therefore, to measure the accuracy of the resource results, this study uses a "level of relevant response messages questionnaire" survey to evaluate the relevance of the response messages. The questionnaire uses a Likert scale, which is filled out by invited experts. The scale ranges from 1 to 5, in which 5 stands for "strong relevance", 4 stands for "relevance", 3 stands for "normal", 2 stands for "irrelevant", and 1 stands for "strong irrelevant". There are 10 questions in the questionnaire consisting of three parts including the compiler messages, analysis results, and search resource results. Finally, we invited 15 experts who have at least two years of relevant programming work experience or who have taught programming courses

for more than five years. The accuracy measurement design of the questionnaire is as follows.

1. The experts read and analyze the compiler messages to judge the main cause of the programming errors, and compare them with the system analysis results.
2. The experts evaluate whether the response message meets the students' requirements based on their professional experience.
3. The experts evaluate the relevance between the response messages and the compiler messages.

4 Results and Discussions

4.1 Research Question 1: Are the RTFLS Response Messages Highly Relevant to the Compiler Messages?

According to Figure 7 and Table 1, the survey results scores ranged from 1.33-4.47, which means that most experts believe that the relevance level of RTFLS response messages is normal (average = 3.1), but there is a gap in questionnaire scores (S.D = 1.37). Therefore, we further explored the expert's evaluation results and found that there were five questions with a score of less than three, which means that some RTFLS response messages have a low relevance with compiler messages.

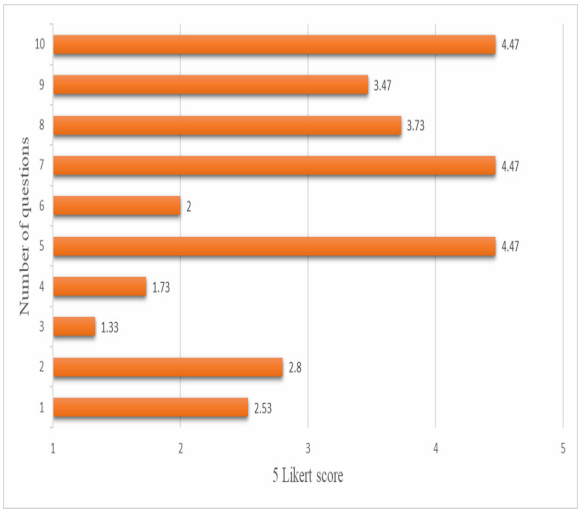

Figure 7. The Result of Relevance Level of RTFLS Response Messages

Table 1. Result of Expert's Assessment (N = 15)

	Mean	S.D.
Questionnaire score	3.1	1.37

4.2 Research Question 2: Do the RTFLS Response Messages Have a Positive Impact on the Students' Learning Performance?

Although a total of 24 students participated in this study, only 22 of them participated fully and we deleted the data of the other two students. Students can use the RTFLS during the experiment. To measure the changes in their academic performance the student's exam scores were collected. The scores were then analyzed using paired-sample t-test.

According to Table 2, RTFLS results in significant differences in learning performance. The score increased from 66.23-70. This means that RTFLS can help students learn certain programming skills. On the other hand, the standard deviation score decreased slightly (S.D. 14.51-13.35), indicating that the average gap in student exam scores had narrowed. Overall, the research indicated that RTFLS not only promotes the learning of programming skills among students but it also has a positive impact on the students' academic performance.

4.3 Discussion: Some Response Messages Have a Low-relevance

The RTFLS developed by this study integrates the log collection mechanism and the search algorithm mechanism. The purpose was to collect and parse the compiler messages for students and automatically search for relevant resources from the Internet. Therefore, students do not need to fully understand the compiler messages; they can receive response messages and try to solve the problem by reading the content of the response messages. It not only reduces the burden of students recognizing compiler messages but also cultivates a deeper knowledge of programming.

However, according to Figure 7 there are five problems with a score of lower than 3, which shows that experts believe that some response messages are less relevant to compiler messages. We will further explore the number of questions and the results of expert assessments. Overall there is a major factor affecting the accuracy of the response message in this study, namely:

Table 2. Learning performance

	Midterm exam		Final exam			
	Mean	S.D.	Mean	S.D.	t-value	p-value
Test score (N = 22)	66.23	14.51	72.00	13.35	-2.093	.049*

*$p < 0.05$. **$p < 0.01$.

Some compiler messages cannot identify the cause, and make the search mechanism unable to search for resources through the corresponding compiler message keywords, which also affects the relevance of the response message.

The RTFLS developed by this study can monitor and collect the students' compiler messages, but it is difficult to identify the main reason for them. The main reason is that sometimes multiple compiler messages are generated at once, and the minor error messages are caused by a major error. The RTLFS system searches for resources from the Internet which not only adds some irrelevant data to the RTLFS system but also reduces the degree of relevance of the response messages. Moreover, we also analyzed the evaluation results of the exploration experts and compared them with the students' compiler messages. We found that the compiler messages came not only from the programming syntax but also from hardware settings, permissions settings, etc. In this case, because the RTFLS cannot effectively identify the type of compiler messages, it is difficult to provide accurate response messages, which is why experts believe that some response messages are less relevant.

5 Conclusions and Future Works

This study developed the RTFLS that is integrated into the programming curriculum. The aim is to reduce the burden on students and help them to recognize compiler messages while helping them to construct context and experience. Also, to explore the impact of the RTFLS on the changes in the students' academic performance, we had collected their' midterm exam scores as a pre-test, and collected the final exam scores as a post-test. This study also investigated the relevance of response messages, so we invited 15 experts to participate by filling in the level of relevant response messages questionnaire. In general, this study had the following two results: (1) The RTFLS has a certain positive impact on learning programming; and (2) Some search results of the RTFLS of the search algorithm have a low relevance.

In future work, the RTFLS can collect error log messages from a large number of students. Therefore, the teacher can further analyze the error log messages and view the students' learning situation to explore the reasons for the common occurrence of error log messages among students. Besides, RTFLS can also integrate deep learning to classify error log messages and find more relevant solutions for students to respond to messages. According to [19-20], deep learning constitutes a modern technology for data analysis and is also used in various fields. As more complex models can be used, which improves classification accuracy in addition to efficiency Also, the teacher also added some search keywords to the RTFLS based on teaching experience. The purpose is to make the RTFLS search mechanism focus on specific content. For example, many programming languages also have SQLiteException, so teachers can add search keywords "android-sqlite" and "android-database" in "SQLiteException", and the search results are focused on the android sqlite database issue.

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Biographies

Sheng-Bo Huang is a PhD student in the Department of Engineering Science at National Cheng Kung University. His main research interest is the study of e-learning and learning styles.

Chin-Feng Lai is professor in in the Department of Engineering Science at National Cheng Kung University. His main research interests include body sensor networks, e-healthcare, mobile cloud computing, cloud-assisted multimedia network, embedded systems.

Yu-Lin Jeng is an associate professor in Department of Marketing and Logistics Management at the Southern Taiwan University of Science and Technology. His main research interests include e-learning, artificial intelligence, database management, cloud software application, mobile software development.