Can Fragmentation Learning Promote Students' Deep Learning in C Programming?

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Abstract. In order to reduce students' difficulties in programming learning, this study developed a mobile platform called Dquiz with the advantage of distributed effects, which can provide 2-3 multiple-choice questions per day. The study applied it to C programming courses and explored whether the system can improve students' learning outcome and which factor influence the outcome. A total number of 74 freshmen were randomly divided into two groups. One group can practice every 3 days at least. The other students practice once a week. Both groups of students practice the same number of questions. The result showed that the students who used the platform several times a week score higher than students who used it once a week. The factors that affect students' learning outcomes during their practice include intervals of platform usage, correctness and the total number of comments.

Keywords: programming learning, practice platform, mobile learning, fragmentation learning

1 Introduction

Cultivating computational thinking is becoming an important issue widely concerned over the field of education. In higher education of China, programming is the most important way to cultivate computational thinking. It becomes a foundation course for all students. However, for beginners, learning a new programming language is difficult because of the complexity, abstraction, and flexibility of programming languages. Moreover, every topic of programming is closely related. Students would be lost in the next topic if they don't master the previous topic. Confusion about syntax and algorithms can reduce the efficiency of students' programming, and even lead to a problem that some students afraid to program after the course. It is necessary for novices to spend more time practicing basic knowledge. Continuous practice can help students retain knowledge [1].

In China, there is usually scheduled 2-4 hours per week for non-computer students to learn coding in the classroom, which is far from enough for students to practice, so finding some new way to learning programming is necessary. According to statistics, up to 90% of students have their own mobile devices [2]. Using mobile devices to support students' practice is a feasible solution, which can make full use of the fragmentation time of students. Therefore, the study developed a mobile platform for students to practice C programming anytime, anywhere. However, some scholars worry that fragmentation learning can lead to students' learning content become scattered. This kind of learning lacks depth and breadth, and it is difficult to form a holistic and systematic knowledge system and promote deep reflection of learners, which is not conducive to application, and migration of knowledge [3]. Therefore, in the fragmentation learning environment, how to design an effective tool to guide students to learn in depth is worth considering.

This research aims two questions. 1) Finding out how to design and developed a mobile platform to support students to practice basic concepts and algorithms of programming in the fragmentation learning environment. 2) Exploring whether fragmentation learning can improve the performance of students and understand the factors that affect students' learning.

2 Literature Review

In programming learning, practice is beneficial for the novice to master the basic facts, features and being able to consciously plan and carry through a problem solution in specified areas [4]. However, the invalid practice not only wastes students' time but also result in cramming. Dunlosky and Rawson suggest that effective practice need to consider both content and time of practice [5]. As mentioned above, the free time of students is limited and the knowledge of programming is related closely, so it is reasonable to select the most important concepts for practice tests and the practice need to cover the prior knowledge, which require students to retrieve from long-term memory. Through continuous extractive exercises, students can better retain basic knowledge. It is better to use free recall or short-response formats, such as multiple-choice questions, which can help provide learners with clues to extract in the final performance [6].

Students can benefit more from the practice with feedback. Giving feedback about the reason why the answer is correct or incorrect can increase the proportion of correct responses and correct erroneous answers [7]. Students can view the content of discussions, compare their opinions with others' opinions and reflect on their leaning. Through feedback of system and communication between peers, students can solve problems that encountered in programming practice timely. This will not only help them learn the next topic better but also enhance their confidence.

There are many platforms for students to practice in programming learning. For example, Hovemeyer and Spacco introduce CloudCoder to the classroom, a web-based programming exercise platform, which designed for reinforcing concepts and mastering basic skills of novice [8]. A typical problem asks the student to write a

function or complete program to perform a simple task. Pritchard and Vasiga offer Computer Science Circles for beginner to practice. The platform can offer kinds of exercises formats like short answer questions and multiple choice as well as coding exercises. In the system, students can also ask the teacher for help so that they can receive feedback timely [9]. Marcelino et al. develop an application called H-SICAS. It is a handheld algorithm animation and simulation tool and students can build and simulate his own algorithms [10]. Tillmann et al. introduce TouchDevelop for students to programming [11]. It can also allow students to publish, download and discuss the programs.

Teachers often use these platforms to post a large number of assignments, and most students tend to log in the system to complete these practices at once. Although the mass practices make learners get better performance immediately after the end of learning, it can't promote the retention of knowledge [12]. The much better approach to improving the efficiency of practice is that spreading the practices over a period [13].

Fragmentation learning is consistent with this kind of practice that is defined as distributed practice [14]. It has been shown in existing researches that distributed practice is effective for mastering knowledge and developing complex skills [15]. Hsiao's research team has developed a web-based platform, QuizIt, which supports distributed practice for novices on C programming. The platform provides students a multiple-choice question to practice every day. The data showed the positive effect of learners' usage of the tool [16].

However, it is not convenient to use the computer to practice, students will spend a lot of time in the process of starting the computer and platform. Our previous study found that students are more willing to practice with mobile devices [17]. Studying anytime and anywhere can enhance the students' learning experience and commitment [18]. Therefore, it makes sense to develop a mobile platform to support fragmentation learning that students can practice a small number of topics at anytime, anywhere.

3 Design of Dquiz

3.1 Architecture of Dquiz

Dquiz system is a mobile platform inspired by QuizIt. It was developed using HTML5 so that it can be applied to different systems. The platform architecture can be divided into three major contents: presentation layer, business logic layer, and data layer (see Fig.1). The interface layer is an interface between the user and the system. Students or teachers can access the server through a mobile terminal and communicate with the data of the server. The business logic layer includes information management module and interaction module, mainly processing the request from the application layer. The corresponding database information is called

according to the request, and the result is fed back to the application layer. The data layer responsible for storing and providing data, which is mainly composed of the user information database, exercise database, forum database, and students' behavior database.

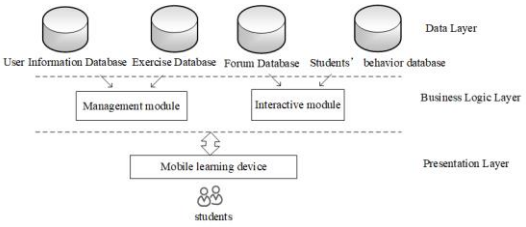

Fig. 1. Architecture of Dquiz

3.2 Function design of Dquiz

Dquiz mainly consists of two modules: student module and teacher module, the functions of the two modules were described below.

Student function module. The functions of the student module mainly include practice and discussion. When students log in the platform, they can see a calendar interface showed Figure2. There are different color squares on the calendar to represent the students' state of practice, which can help students judge whether they have completed the practices. Then, students can choose any date from the calendar to enter the exercise interface and complete the exercise of that day. The practices are presented in the format of multiple-choice questions (see Fig.3). The multiple-choice question can enhance retention of the materials tested and boost performance on later tests [6]. The study offers different types of multiple-choice questions so that students can cultivate different abilities. For example, students need to analyze the results of program output, supplement programs and find out the errors of the program. These exercises require students to read and analyze a complete program, which can help students understand grammar, semantics, and algorithm. Dquiz can offer 2-3 fixed practices per day and students could practice for a few minutes each time anywhere.

After the students submit the answer, they can receive simple feedback on the fact whether the answer is correct or not. Students can also check the answer, answer explanation, or collect the question when they finish the current exercise. Providing appropriate explanations for each alternative in the multiple-choice question can enhance students' learning [19]. Then, students have a choice to access to other questions of the day or jump to a certain date by the buttons of the previous day, the next day or the calendar.

Fig. 2. Calendar interface

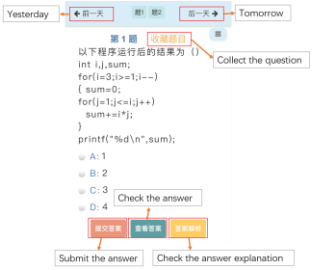

Fig. 3. Practice interface

The practices that students have done will be automatically generated in the review area (see Fig.4). The topics in the review area will be organized according to the knowledge points of the course. The questions that students have made wrong will also be marked accordingly. Students can choose the appropriate practices according to their mastery level of knowledge.

In order to encourage students to share their knowledge with each other, Dquiz provides a forum below each question for discussion (see Fig.5). When the students complete the exercise, whether they are right or wrong, the student can enter the forum to ask questions, answer questions and praise a question or an answer. According to the learning situation of each student, the system will award different levels of medals to the students. Giving Students medals can help students to monitor their learning progress. Novices who are able to monitor their own learning can help them learn conceptual and strategic knowledge so that they can program better [20].

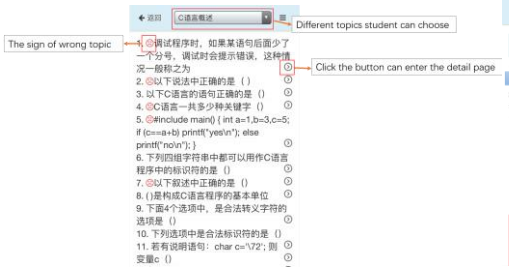

Fig. 4. Review interface

Fig. 5. Forum interface

Teacher function module. There is a web-based management platform that is used by teachers to set questions and monitor the learning of students. Teachers can not only check the correctness of each student, but also each question. The correctness reflects the level of students' mastery of knowledge. The teacher would explain some questions that correctness is lower. Moreover, Students with low correctness or slow progress can be promptly reminded and instructed by the teacher or assistant.

4 Evaluation of academic performance

4.1 Data collection

The management platform recorded all learning activities of students with a timestamp. The study classified all data into five indicators, including the interval of platform usage, the total amount of practice, the total number of comments, online time and correctness. The specific indicators are shown in Table 1. A five-point scale was used to understand the student's programming basis and other study time that students spend on the C programming learning after class expects using Dquiz. At the end of the course, the students took part in the standard unified examination. The final exam score was used to evaluate students' performance.

Table 1. Indicators of students' activities.

Indicator name	Description
Interval of platform usage	Average number of days between two consecutive practice
Total amount of practices	Total number of topics a student practice on average
Total number of comments	Total number of comments made by a student
Online time	The time a student spends on Dquiz
Correctness	The percentage of a student's correct responses on his all submission

4.2 Methodology

The research has involved 74 freshmen students, including 27 boys and 47 girls, of Beijing Normal University majoring in non-engineering and participated in the course of C programing language. Their average age was 19.09(SD=0.50) years old. The course lasted for 16 weeks. Students should take the course once a week and each class spent 210 minutes, with 10 minutes break every 45 minutes. The study provided students with Dquiz and they were all willing to use Dquiz as a tool for practice. The students were randomly divided into two groups. Both groups of students practice the same number of questions every week. The difference is that the experimental group needs to practice every 3 days at least, while another group just need to complete the practices once a week. The number of questions that are available for students to answer is 225 and the topic is determined by the teaching progress. At the end of class every week, the teacher would require the students to complete this week's exercises on the platform before the next class. The teacher uses the data recorded by the system to check whether the student completes the exercise as required. For the unfinished student, the teacher will give a reminder with instant messenger.

4.3 Result

The study firstly performed a t-test to explore the differences in performance of practice and learning outcome between two groups. The result is shown in Table2. It indicates that there was no significant difference in the basis of programming between the two groups before taking the class. The programming basis of the experimental group is 2.00(SD=1.18) and the control group is 1.73(SD=0.95). However, there was a significant difference between the two groups in learning outcome, the interval of platform usage, the total number of comments and correctness. The average final exam score of the experimental group is 84.73 (SD=11.95) and control group is 72.67 (SD=15.66). In terms of the performance on the system, students of the experimental group used the system to practice every 3.31 days (SD=1.55) and control group students practice every 7.99 days (SD=2.99). Figure 6 shows the number of students using Dquiz per day for both groups of a semester. The results showed that the practice time of the students in the experimental group was distributed in different time periods of the week, while the practice time of the students in the control group was periodic, basically concentrated on Thursday. Both groups practiced more on Thursday because it is the time of C programming course. The total number of comments experimental group posted and reviewed, on average, is 22.68 (SD=21.33) while the control group is 12.86 (SD=9.87). The experimental group's correctness of practice in the system is about 67% (SD=7%) and control group is 61% (SD=2%).

Table 2. T-test between experimental group and control group.

	experimental group(N=38)		control group(N=36)		t-value
	M	SD	M	SD	
programming basis	2.00	1.18	1.73	0.95	1.06
Final exam score	84.73	11.95	72.67	15.66	3.74***
Interval of platform usage	3.31	1.55	7.99	2.99	-8.37***
Total amount of practices	224.29	3.66	224.53	1.59	-0.44
Total number of comments	22.68	21.33	12.86	9.87	2.56*
Online time(min)	981.90	846.37	827.42	658.52	0.87
Other study time(min)	338.03	236.42	309.17	198.73	0.57
Correctness	0.67	0.07	0.61	0.02	2.84**

*p<0.05, **p<0.01,***p<0.001.

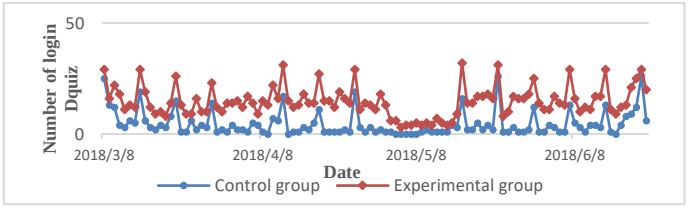

Fig. 6. The number of students using Dquiz per day for both groups

In the next place, the study calculated the correlation coefficient between the indicators and learning outcome. The result described in Table 3. The study can find that interval of platform usage had a negative correlation with outcome. It means that the shorter the interval, the better the students' learning effect. Other factors including the total number of comments and correctness are both positively associated with final exam score.

Table 3. The correlation between all indicators and final exam score (N=74).

	Interval of platform usage	Total amount of practices	Total number of comments	Online time(min)	Other study time(min)	Correctness
Final exam score	-0.42**	0.23	0.33**	0.20	0.55	0.71**

*p<0.05, **p<0.01.

5 Discussion

The Dquiz is designed to give students more opportunity to practice anytime and anywhere. The study expects the platform can promote students to understand the basic concepts and algorithms of programming, and thus improve the results of students' programming learning outcome. The result of data analysis is in line with our expectation. Students who complete the practice several times per week perform better than students who practice once a week when both of them practice the same number of questions. Moreover, the correctness of the experiment group is higher than the control group. The result is in accordance with the opinion that distributed practice is more effective than massed practice [14]. There will be some interval between exercises when students distribute practices over a period. Intervals can cause students to forget, which makes more difficult for them to extract information next time [21]. In other words, students who adopt a distributed strategy will input more time and energy to retrieve related information from memory when they are practicing. By connecting old and new knowledge and reprocessing knowledge, students can deepen their understanding [22]. Therefore, although fragmented learning leads to fragmentation of learning time and learning content, if organizing learning materials systematically and structurally and providing clues every time to guide students to connect new and old knowledge, it can help students to transform fragmented knowledge into systematic knowledge and achieve in-depth learning.

Dquiz also provides a forum for students to communicate so that they can share opinions and discuss questions, which can help students to construct individual knowledge and to reflect on their own learning [23]. Reflective learning promotes the understanding, application, and migration of knowledge, and ultimately reaches the level of deep learning [24]. The data showed that the number of comments on the experimental group was higher than the control group. It indicates that students in

the experimental group are more willing to devote themselves to discuss the questions online. Students can discuss a topic during each practice, which not only helps students solve problems, but also improves their learning engagement. Studies have shown that students with higher participation are more likely to adopt deep learning strategy [25].

6 Conclusion and future work

This study developed a mobile platform and applied it to the C programming course. The study found that students who use the fragmented time to practice topics that are organized systematically in the platform, can improve their learning outcomes in C programming. The factors that affect students' learning outcomes during their practice includes intervals of platform usage, correctness and the total number of comments. Further discussion found that students with frequent usage engage more in practice. They work hard to extract information and reprocess information so that they can deepen understanding and retain more knowledge.

In the future, the study will further study the online behavior patterns of students, and explore deeply the impact of students' online learning behavior on learning outcomes.

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