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Study of Metacognitive Strategies' Impacts on C Language Programming Instruction

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***Abstract*—Based on a revised scale and half-open questionnaire, 110 undergraduates majoring in computer science of a university in Jiangsu Province in China were investigated with an aim to evaluate the relationship between metacognitive strategies instruction and C Language Programming achievements. The results indicate that metacognitive strategy instruction has a positive effect on students' program design proficiency. The metacognitive strategy instruction is beneficial to develop students' all-round abilities in planning, monitoring and evaluating and making them to be autonomous learners.**

Keywords*—metacognitive strategies; metacognitive knowledge; learning strategies; program design proficiency

I. INTRODUCTION

C Language Programmming, one of the most important courses in the discipline of computer science, can not only lay the foundation for students to study professional courses and engage in computer professional work, but also cultivate students' ability to analyze and solve problems. However, computer program is not an easy job. It is a complex and recursive process that needs internalizing what one has learned and then producing something new. Designing a practical program requires learners with a rich knowledge of cognitive processes and strategies for planning, revision and program production. Therefore, C Language Programming has been a big headache haunting computer science learners, especially for those studying in a university all the time.

In the computer teaching context of China, the fact is that many college students' program designing ability is far from satisfaction. Many causes are attributed to the current situation of College computer teaching in China. The majority of program designing teachers in China teach between 40 and 60 students in one program class. The class size is so large that teachers cannot conduct individual conferences with learners, which is believed to be one of the most effective strategies in program designing instruction. On the other hand, most students are passive learners. They very often just follow their teachers' rules and fail to think over their own learning behaviors in order to monitor and regulate their cognitive learning. They frequently have limited knowledge about programming process as well as difficulties with cognitive processes and strategies which are believed to be essential for effective programming.

In face of the present situation, how to improve college students' programming proficiency has got much concern. In the past two decades, many researches have been conducted in the field of program instruction. In China, previous study has mainly focused on the teaching methods in students' computer programming. (Tang, Chen & Hu, 2016; Zhou, Dong & Li, 2016; Liu, 2015; Liu, Liu & Zhang, 2010)

Cognition psychology, named information processing psychology, is regarded as one of best ways to solve problems by analyzing, analogy, thinking and finding problems with information processing as the core. Since it emerged in the mid-1950s and has developed rapidly, cognition the mainstream of psychology today and gradually permeated the study of all areas of social life, especially in education. Cognitive psychology emphasizes that cognitive structure; cognitive process and meta-cognitive ability are the direct causes of determining learning outcomes and learning efficiency. Metacognition was first put forward by American psychologist J. H. Flavell in the 1970s. He holds that the main components of metacognition are metacognitive knowledge and metacognitive experience. Metacognitive strategies are a series of skills used by learners with particular metacognitive knowledge in mind. Metacognitive strategies play a very important role in learning, which are always helpful for learners to reduce in learning factors such as blindness, rashness and irrationality.

In the last two decades, researchers have attempted to prove that metacognition is beneficial not only in general learning but also in specific subject areas such as reading, program, mathematics, social studies, and problem solving (Rubin, 1975; Baker & Brown, 1984; Brown, 1987; Gourgey, 2001; Hartman, 1998; Schraw, 2001). Rubin (1975) initiates the study of learning strategies in the article of "What the good language learner can teach us" in TESOL Quarterly in America. She states that there are differences in metacognitive strategy use between more successful learners and less successful learners. Linguists (Porte, 1988; Vann, et al. 1990) make researches on the unsuccessful learners of SLL and EFL by means of interviews and introspective thinking aloud techniques and conclude that successful and unsuccessful learners differ in the quantity, quality, and/or variety of strategies they used in different settings. They also find that many of the poor learners appear to be active strategy-users, but they often fail to apply strategies appropriately to the task at hand. Oxford (1990) presents his opinion on how to apply metacognitive strategies in EFL program in his Language Learning Strategies System. O'Malley and Chamot (1990) conclude that metacognitive strategies are applicable to a variety of learning tasks and to learners of different proficiency levels.

Some researchers (Wen 1996; Wen & Wang, 1996) in China have made researches on metacognitive strategy use. They conclude that metacognitive strategy use is closely related to variables like learner beliefs, learning proficiency, gender etc. Meanwhile, these variables are interrelated in a highly complex manner. Wu and Liu (2004) from Beijing Foreign Language University have designed a questionnaire paper which could wholly reflect the students' metacognition. The research indicates that metacognition is positively correlated with EFL program outcome. Fang and Zhou (2004) have trained for one year 35 non-English major freshmen in Guangdong Industry University to practice the metacognitive strategies in their teaching of program lengthy compositions. The result indicates that by this kind of training, students' metacognitive awareness will be raised which leads to the improvement of their program outcomes as well as their language competence. Lu (2006) has done a research to investigate the relationship between metacognitive strategy preference and English program in the college. He has found that there are significant differences between successful writers and unsuccessful writers in the use of metacognitive strategies in English program. In addition, a positive correlation exists between metacognitive strategy use and English program proficiency.

From above, it can be seen that researches on metacognition are mainly centered on language learning. The research on metacognitive strategy is very limited in terms of computer science teaching, not mention the experimental research in this field.

The aim of the study is to explore the relationship between metacognitive strategies application instruction and computer programming proficiency. Based on the above review of existing literature, the underlying hypotheses are proposed: one is that what is the overall level of metacognitive strategies employed by college students of computer majors? Do they need metacognitive strategy instruction? And the other is that does the metacognitive strategy instruction contribute to programming proficiency?

II. Method

Participants and procedure:

In the present study, the subjects are 110 first-year computer majors from a university of Jiangsu Province of China, one class of 54 students (28 males and 26 females) selected as the experimental group and the other class of 56 students (30 males and 26 females) as a comparison group. The two groups of subjects aged from 19 to 21 share the same textbook, the same syllabus, etc. The experimental group receives meta-cognitive instruction while the comparison group is given traditional instruction. In order to control the process of the research, the researcher acts as teacher for both the experimental and comparison groups.

The collected data was input to the computer and a statistical analysis made through the software PASW18.0. First, the descriptive statistics for all measure is calculated to examine our hypotheses. Next, the correlations among all variables are examined.

III. Instruments

Metacognitive Ability & Metacognitive Strategy Scale:

Metacognitive Ability & Metacognitive Strategy Scale which comprises 33 items, is used to measure students' metacognitive ability and the overall level of metacognitive strategy use across four dimensions (that is, the use of planning strategies, the use of selective strategies, the use of monitoring strategies, and the use of evaluation strategies. Each item of the scale is rated using a 5-point Likert Scale (from 1 = strongly disagree to 5=strongly agree). A higher score indicates students' higher level of metacognitive strategies. The overall Cronbach's Alpha reliability for the questionnaire is 0.82. This has reached the statistic requirement ($a \geq 0.70$). Cronbach Alpha is a coefficient index used to test internal reliability. It is usually between 0.00 and 1.00. That is to say, the value of Cronbach Alpha with no less than 0.70 indicates that the Questionnaire has high reliability.

IV. Pre- and Post-course Examinations

Both classes (controlled class and experimental class) took the National Computer Rank Examination (Level One) as pre-course test. Through the analysis of T-test of the pre-course examination scores, the result indicates that there is no big difference in the scores of pre-test between the experimental and comparison groups and they are close in the computer operating proficiency. After one semester meta-cognitive strategy instruction, both classes took the post-course Examination (the National Computer Rank Examination Level Two).

V. Results

Impacts of meta-cognitive strategy instruction on students' programming proficiency:

In general, the meta-cognitive strategy instruction has a great influence on students' ability to program. In order to verify it, the author has compared the results of both comparison group's and experimental group's computer performance in the pre- and post-course computer tests.

Firstly, paired-sample T-test is employed here to ensure whether the statistics are in normal distribution. The results of paired-sample T-test of both classes are presented in the "Table I". According to the results, it can be seen that the significance level of two groups is very low ($t=-7.01$, $p<0.01$), which shows that there is a linear relation between the two groups of data at the significance level. In other words, there is a significant difference between pre-test and post-test which implies the effectiveness and statistically importance of the strategy instruction.

TABLE I. PAIRED-SAMPLE T-TEST

Class	N	Test	Mean	SD	T	Sig.(2-tailed)
EG	54	Pre- and Post	-2.42	2.763	-7.01	.00
CG	56	Pre- and Post	-1.05	2.437	-5.56	.00

TABLE II. COMPARISON OF EG'S COMPUTER TESTS (PRE- AND POST-COURSE TESTS)

Test	N	Mean	SD	T	P
Pre-	54	8.53	2.864	−13.46	.000
Post-	54	10.95	2.071		

TABLE III. COMPARISON OF CG'S COMPUTER TESTS (PRE- AND POST-COURSE TESTS)

Test	N	Mean	SD	T	P
Pre-	56	8.57	2.783	−2.46	.000
Post-	56	9.62	2.185		

TABLE IV. COMPARISON OF EG AND CG'S POST-COURSE COMPUTER TESTS

Class	N	Mean	SD	T	P
EG	54	10.95	2.071.	−8.045	.000
CG	56	9.62	2.185		

[a] CG refers to the comparison group; EG refers to the experimental group

[b] S.D. refers to standard deviation

As can be seen from "Table II", with the metacognitive strategy instruction, students in the experimental group have improved their programming proficiency significantly. In the pre-course test, the mean and standard deviation is 8.53 and 2.864 respectively while the mean and the standard deviation is 10.95, and 2.071. These results suggest that the strategic instruction can be effective in a natural classroom and has a promise for improving students' programming proficiency.

From the "Table III", it can be seen that the comparison group has also made some progress in the pre- and post-course program tests. The mean in the pre-test is 8.57 while 9.62 in the post-test. However, compared with mean scores of the comparison group, the experimental group's program performance at the post-course program tests is far better. In other words, the experimental group has outperformed the comparison group in terms of program performance. The comparison result is shown in "Table IV".

Accordingly, on the one hand, these results have suggested that the metacognitive strategy instruction can be effectively implemented in real classroom settings. The instruction can develop students' metacognitive strategy knowledge which will contribute to growth of their program proficiency. The finding has also verified previous researches by other researchers (e.g. O'Mally and Chamot, 1990; Oxford, 1990; Englert, et al., 1991) that the strategy instruction is an essential component of an effective program instruction. On the other hand, the research results have shown that traditional instruction is sufficient too. So it is advisable for a teacher to adopt a proper teaching method according to real-life educational environment. Teachers should integrate the metacognitive strategy instruction with regular class activities according to different students' needs in the process of computer instruction. Only by doing this, can it be available to improve computer program instruction and improve students' performance in program designing.

VI. IMPACTS OF METACOGNITIVE STRATEGY INSTRUCTION ON LEARNERS OF DIFFERENT PROGRAM DESIGNING LEVELS

From above, it can be concluded that implementing metacognitive strategy treatment in the computer class is feasible and appropriate metacognitive strategy use can help college students improve their program proficiency. The question comes to which level of programming learners benefit most from the instruction. According to the score of pre-test, the students in the experimental group are classified into three groups: the high program achievers, the medium program achievers and the low program achievers. The present study has collected the data from the pre- and post-course program tests, the statistics results are shown in the "Table V".

TABLE V. DESCRIPTIVE STATISTICS OF EG'S PRE- AND POST-PROGRAM SCORES

	High			Medium			Low		
	N	Means	SD	N	Means	SD	N	Means	SD
Pre-test	10	12.20	0.4216	18	9.17	1.0981	14	5.14	0.9493
Post-test	10	12.70	0.8233	18	11.33	1.7823	14	9.21	1.7619

According to the results of "Table V", it can be seen that the high achievers have made the least progress with means 12.2 and 12.7 respectively in the two tests. Low achievers have made greatest progress among the three types of learners (Pre, Mean=5.14; Post, Mean=9.21). As for medium achievers, their progress is evident that the mean of Post is much higher than that of the pre-test (Pre, Mean=9.17; Post, Mean=11.73). Accordingly, it can be concluded that compared with high achievers, the medium and low achievers have made more progress than the high achievers have done at the end of the experiment. The possible reason is: the medium and low achievers do not have clear idea of their own program ability and lack confidence and interests in program before the experiment. With the one-term instruction on the metacognitive strategy use, the students have increased their metacognitive knowledge, and have come to know clearly about their program ability, so they could set a realistic program goal and achieved it. With these successful program experiences, they have gradually built up their confidence in program and so it is no wonder that they can perform better in the program tests.

VII. Conclusion, Limitations and Suggestions

A. *Conclusion*

The study has not only confirmed some theories in the literature, and more significantly, has offered some suggestions for college computer program instruction in China.

Firstly, college students need metacognitive strategy instruction since students' metacognitive strategy of knowledge is at the low level. The metacognitive instruction should be integrated in the computer class in order to improve students' metacognitive knowledge which can enlighten their thinking, and improve their abilities concerning planning, monitoring and regulating the learning process. Ample metacognitive knowledge enables students to apply appropriate strategies to monitor their program process and products in order to achieve successful program.

Secondly, it is advisable to conduct the instruction right after students begin their college computer learning because freshmen are more likely to encounter difficulties in their computer program among four grades of college students and have received the least instruction of learning strategies. The early strategy instruction can ensure freshmen have a better understanding of metacognitive strategies, and help them develop more accurate metacognitive personal knowledge, task knowledge and strategy knowledge of program, which will benefit their computer program as well as other aspects of computer learning.

Thirdly, when implementing the instruction, the instructor should carefully design the instructional activities and procedure. First of all, the instructor should arouse the computer majors' interests in the strategy instruction. As is known to all, many computer majors are passive learners and they are not interested in programming. So making them highly motivated is crucial for the success of the instruction. In order to motivate the students, a questionnaire can be employed. The instructor can use the questionnaire to make the students realize the importance of metacognitive strategy use and their metacognitive abilities. Next, the instructor can allow the students to determine the program topic by group discussions, which undoubtedly will make students actively participate in the program process and they are more likely to finish a successful program since they realize that the program can solve practical problems. Then, the teacher can make some cue cards for the students to remind them to use the appropriate strategies while program. Setting up a cognitive modeling can be another beneficial facilitator to gradually develop students' knowledge of metacognitive strategies. By setting up a cognitive modeling, the composing process is demonstrated clearly very clearly in front of the students. "Setting cognitive model is very beneficial for my program. When teachers think out loud to externalize their thought processes serving as an expert model, they can learn effective ways of using metacognitive knowledge and skills."

Fourthly, the teacher plays a critical role in the classroom instruction. For one hand, the teacher should help students develop a positive attitude towards the classroom metacognitive instruction, and make them realize the importance and necessity of metacognitive strategy use. On the other hand, since different students have different program proficiency, the teacher should give students' individual assistance according to her or his situation and help students find their own learning strategies based on their own strengths and weakness and gradually become independent writers. Meanwhile, the teacher should act as an assistant and coordinator and give students both written and oral evaluation on their program products. In this process of evaluation, some positive comments are very helpful to stimulate students' interests in program and build their program confidence. Meanwhile, the instructor needs to be patient and considerate with his or her students throughout the whole instruction.

B. *Limitations and Suggestions*

Due to the researchers' limited academic knowledge and some practical difficulties, the study has some limitations.

Firstly, the sample size in this research is small: only 110 samples are examined. It is not sure if the results of the present study can be applied to a much larger number of subjects in different colleges thought the country.

Secondly, the results presented in the study rely greatly on the questionnaire. It has to be admitted that the questionnaire itself may have its own limitations. The questionnaire is not comprehensive enough to include all the important program metacognitive strategies. Meanwhile, some of the participants may not respond the instruction appropriately and so they may choose to answer the questionnaire dishonestly which will reduce the reliability of the research to some degree. The time of the classroom instruction is limited. It lasts only one semester. The time period is very limited for a metacognitive instruction so the effectiveness of the instruction may be affected.

Although the study has verified that metacognitive strategy instruction has a positive effect on computer program proficiency, the generalization of the findings is limited due to the above reasons. Therefore, more theoretical and empirical studies on metacognitive instruction are needed to develop program instruction all over the country.

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