A study on the effects of spatial ability in promoting the logical thinking abilities of students with regard to programming language

David W.S. Tai, Chao-Huang Yu, Liang-Chu Lai & Sue-Jane Lin

National Changhua University of Education
Changhua, Taiwan

ABSTRACT: The purpose of this study is to investigate the effects of cognitive style and spatial ability on the logical thinking and problem solving abilities of students with regard to programming language. Most of the efforts of this study focus on developing and refining instructional materials, performing experimental teaching, and analysing the experimental data. Study results include the following: students with high spatial ability scored significantly higher than those with low spatial ability in logical thinking ability. Also, those students with more positive attitudes towards Computer-Assisted Learning (CAL) had significantly higher learning achievements in computer programming. Furthermore, those students who scored high in logical thinking also had significantly better learning achievements in computer programming than those with lower scores. However, there were no significant differences found between students in heterogeneous cooperative learning groups (wherein one is field independent and the other is field dependent) and homogeneous cooperative learning groups (wherein both are either field independent or field dependent) with regard to achievements in computer programming.

INTRODUCTION

Looking forward into the 21st Century, the challenges that face each country will mainly come from the following three aspects: greater freedom in global trade; more protection of ecology and the environment; and an acceleration of the information society. It has also been envisaged that knowledge property will be extremely powerful in determining economic growth in this century.

Technological society is very dependent on information processing and problem solving. In order to satisfy skills for survival and life, it is asserted that everyone should possess abilities in organising computers, processing information and problem solving.

The main goals of informational education are to foster students' computer utilisation abilities and information processing skills, as well as their logical thinking and problem solving abilities. Students can then adapt to the demands of the informational society of the future. At the same time, enterprises face the challenge of obtaining highly demanded quality workers, thereby seeking to maintain a leading position in global technological competition. Hence, education must cultivate talented people in technology.

The purpose of this study is to investigate the effects of cognitive style and spatial ability upon the logical thinking and problem solving abilities of students with regard to programming language. This study primarily focuses on developing and refining instructional materials, performing experimental teaching, and analysing the experimental data. The researchers also suggest methods to promote college students' professional competence in information technology and logical thinking abilities. Finally, some conclusions and suggestions are made.

BACKGROUND

Psychologists and educators have focused on the learning process of students in the field of science knowledge and skills in scientific procedures for cognitive psychology. Specifally, the factors focused on covering those that impact upon the effectiveness of student learning with regard to individual differences, such as the personal characteristics of each student, his/her cognitive style, logical thinking ability, etc [1][2].

Saracho contended that cognitive style contains stable attitudes, preferences or habitual strategies that distinguish individual styles of perceiving, remembering, thinking and problem solving [3]. The prime components of thinking or reasoning include: purpose, question, information, inference, assumption, point of view, concepts and implications [4]. In fact, the logical thinking ability affects the problem solving process of students, and can help students to think, reason and analyse.

In other words, the design of educational environment has to match the differences of each individual learner. Based on the theory of adaptive teaching, the general assumptions are as follows: some mode of teaching material is helpful to some students in learning; likewise, students with different characteristics may learn effectively by another kind of teaching material [5].

Winn also pointed out that if the method of teaching corresponds to an individual learning style of the student, greater learning efficiency would be achieved [6]. Thus, if the instructor can capture the learning style of students, he/she will be able to choose the appropriate methodology and teaching strategy. Based on the idea of *teach students in accordance with their aptitude*, education authorities and/or instructors should develop various kinds of individual learning courseware [1][2][7][8].

The methodology of cooperative learning has been widely researched and used in classrooms around the world since the 1970s. Cooperative learning is the instructional use of a small heterogeneous group of students who work together in order to maximise their own and each other's learning. Cooperative learning skills incorporate the five basic elements of positive interdependence, promotive interaction, individual and group accountability, collaborative skills, and group processing [9]. Many researches have proven that this methodology can be very effective in encouraging student interaction and developing positive attitudes towards school. Furthermore, cooperative learning can produce positive effects upon students' achievements [9-12].

METHODS

Participants

The sample involved in this study was comprised of 88 freshman students majoring in computer programming and who were enrolled in the Department of Industrial Education and Technology at National Changhua University of Education, Changhua, Taiwan, in 2002. One class (40 students) was randomly selected as experimental group 1 (students in heterogeneous cooperative learning, wherein one is field independent and the other is field dependent). Another class (48 students) was also randomly selected as experimental group 2 (students in homogeneous cooperative learning, wherein both are either field independent or field dependent).

Research Design

The experimental design adopted for this study is a quasi pre-test/post-test design. Pre-tests were administered to all subjects and collected information with respect to students' prior attitudes towards computer programming. They also measured students' existing spatial abilities, logical thinking abilities and cognitive styles, as well as previous computer programming performance. The treatments were applied for 12 weeks, which is the normal period of time used during a semester for presenting the concepts of data processing, input and output, alternative and loop control statements, array, pointer, function, file management, class, string and character. During the experiment, students in experimental groups 1 and 2 received computer programming logical thinking instruction in Computer-Assisted Learning (CAL) courseware. After the experiment, post-tests were administered to all subjects. The contents of the post-tests were found to be the same as that of the pre-test, except with regard to the parallel computer programming achievement test and computer programming scale.

Instruments

Six instruments were utilised in this study. The instruments consisted of the cognitive style test, spatial ability test, logical ability test, computer programming achievement pre-test and post-test test, computer programming attitude scale, and logical thinking CAL courseware [2][13]. Based on the pilot test, the spatial ability test, which includes three dimensions (spatial visualisation, mental rotation and spatial organisation), its reliability coefficient (KR-20) is 0.88. The logical thinking ability test, which includes five dimensions (ie proportions reasoning, controlling variables, probability reasoning, combinatorial logic and correlation reasoning), has a reliability coefficient (KR-20) of 0.74. The pre-test and post-test of the computer programming achievement test, which includes 30 items, have reliability coefficients (KR-20) of 0.72 and 0.83 respectively.

Data Analysis

After gathering the post-test data, ANOVA and one-way MANOVA were performed for statistical analysis.

RESULTS

Table 1 shows the results of an analysis of variance. There is a significant difference between those students with a high spatial ability and students with low spatial ability in logical thinking ability ($F=6.56$, $p<0.05$). Next, by comparing means, those students with a high spatial ability ($M=11.48$) were found to score significantly higher than students with a low spatial ability in logical thinking ability ($M=10.10$) ($t=2.56$, $p<0.05$).

Table 1: Results of an analysis of variance for spatial ability with regard to logical thinking ability.

Source of variance	df	SS	MS	F
Main effect	1	28.55	28.55	6.56*
Residual	58	252.43	4.35	
Total	59			

*p<0.05

Table 2 lists the results of an analysis of multivariate variance, showing that there is a significant difference in the performance of computer programming between students with a positive attitude towards CAL and those with negative attitude (wilks' $\Lambda=0.90$, $p<0.05$). Then, by the comparison of means, those students with positive attitude towards CAL ($M=16.23$) were found to be score significantly higher in achievement of computer programming compared to those with a negative attitude ($M=12.02$) ($F=9.20$, $p<0.01$). However, there was no significant difference found between attitude towards computer programming ($F=0.08$, $p>0.05$).

Table 2: Results of a multivariate variance analysis for attitude towards CAL in the performance of computer programming.

Source of Variance	df	SSCP		Wilks' Λ	F	
		Attitude	Achievement		Attitude	Achievement
Main effect	1	3.74 36.39	354.04	0.90*	0.08	9.20**
Residual	86	3902.33 -167.19	3283.85			
Total	87					

*p<0.05; **p<0.01

Table 3 presents the results of an analysis of multivariate variance. It shows that there was a significant difference in the performance of computer programming between those students who have attained higher scores in logical thinking ability and those students who have lower scores (wilks' $\Lambda=0.88$,$p<0.05$). Then, by a comparison of means, those students who have achieved a higher score in logical thinking ability ($M=16.92$) are significantly higher than those with scoring lower in the achievement of computer programming ($M=12.67$) ($F=7.81$, $p<0.01$). However, there is no significant difference in attitude towards computer programming ($F=0.05$, $p>0.05$).

Table 3: Results of a multivariate variance analysis for logical thinking ability for performance in computer programming.

Source of variance	df	SSCP		Wilks' Λ	F	
		Attitude	Achievement		Attitude	Achievement
Main effect	1	2.29 25.43	281.97	0.88*	0.05	7.81**
Residual	61	2699.06 -231.34	2237.96			
Total	62					

$^{*}p<0.05$; $^{**}p<0.01$

Table 4 exhibits the results of an analysis of multivariate variance. It indicates that there is no significant difference in the performance of computer programming between students in heterogeneous cooperative learning groups (one is field independent and another one is field dependent) and homogeneous cooperative learning groups (both are either field independent or field dependent) (wilks' Λ=0.94; $p>0.05$).

Table 4: Results of a multivariate variance analysis for cooperative learning groups for performance in computer programming.

Source of Variance	df	SSCP		Wilks' Λ	F	
		Attitude	Achievement		Attitude	Achievement
Main effect	1	36.00 -25.59	18.20	0.94	0.59	1.5
Residual	42	984.69 193.47	1288.77			
Total	43					

$^{*}p<0.05$

DISCUSSION AND CONCLUSION

There are four conclusions that can be drawn from the major results of this study. These are listed below.

Firstly, those students with a high level of spatial ability also have a significantly higher logical thinking abilities than those with a low level of spatial ability. Manrique, Niall, Sullivan and Klein pointed out that learners with high spatial ability respond significantly faster and are more accurate on a rotation task than those with low spatial ability [14]. This result is similar to the findings of the researchers [2][5]. The individual differences of each student's learning generate some factors (such as personal character of the student, cognitive style and logical thinking ability); these affect the student's learning process of science knowledge and his/her skills in scientific procedures.

Secondly, those students with more positive attitudes towards CAL attained significantly higher learning achievements in computer programming. Over recent years, computers have provided the multimedia resources of image, sound, music, animation and virtual reality. Moreover, computers can offer feedback and interaction, so that they provide students with a brand new learning experience. Swenron and Anderson contend that to provide the positive reinforcement after accurate responses not only gives an impetus for the continuous appearance of accurate reactions, but also encourages the learner's learning interest [15]. It is fair to say that students enjoy learning in a multimedia CAL study environment; they can continuously amend or alter their thinking patterns and subsequently build up their understanding of logic and principles of application [2][16].

Thirdly, those students who scored highly with regard to their logical thinking ability also had significantly higher learning achievements in computer programming than those who scored lower. These results are similar to other findings in this field [2][17][18]. The components of thinking or elements of reasoning are as follows: purpose, question, information, inference, assumption, point of view, concepts and implications [4]. In fact, the logical thinking ability impacted on the problem solving process of students; further, it can help students how to think, reason and analyse. Based on the theory of adaptive teaching, the general assumptions are as follows: some mode of teaching material is helpful to some students in learning; likewise, students with different characteristics may learn effectively by another form of teaching material [5].

Fourthly, there were no significant differences found between students in heterogeneous cooperative learning groups (wherein one is field independent and the other is field dependent) and homogeneous cooperative learning groups (wherein both are either field independent or field dependent) with regard to their achievements in computer programming. Dalton found that heterogeneous groups benefited the most able students, but did little for the least able [19]. Also, Hooper and Hannafin determined that low ability students demonstrated higher performance in heterogeneous groups, but high ability students performed better when grouped homogeneously [20]. Cooperative learning is not simply a matter of grouping students heterogeneously, it also needs to be understood that groups of students are more inclined to function better in group settings than individually [9]. Therefore, the use of this methodology in the classroom would be consistent with the learning preferences of students.

RECOMMENDATIONS

From the findings of this study, it would appear that those students who have a high spatial ability also have a significantly higher logical thinking ability. Also, those students with more positive attitude towards CAL and a higher score in logical thinking ability realise significantly higher learning achievements in computer programming. More research into this area is needed and should be encouraged by persons in the computer programming community. Key recommendations for further study and for teachers of computer programming listed below.

The Promotion of Students' Spatial Abilities, Logical Thinking Abilities and Problem-Solving Abilities

It is a real challenge for a beginner to learn to write computer programs. It requires a complex ability to develop algorithms, as well as to test and debug the computer programming. In order to achieve the purpose of the teaching goal, students' interests should be stimulated and the quality and effectiveness in the teaching environment should be promoted. As educators, we should set the direction for developing an open, flexible and coherent framework of computer programming in order to foster students' spatial abilities, logical thinking abilities and problem solving ability and improve the quality of students through effective teaching and learning.

The Encouragement of Teachers to Make Use of CAL Courseware as Supplemental Lecturing

CAL can continuously amend or alter students' thinking patterns so that they subsequently build up their understanding of logic and specific principles of application. Teachers should be encouraged to make use of CAL courseware as supplemental lecturing and in teaching strategies, and even to take part in development of CAL courseware. However, designing and developing CAL systems should be constructed based on a construction model and flowchart. Furthermore, it should combine course experts, teachers, students, professional art designers, musicians and programmers.

The Use of Cooperative Learning Group for the Instruction of Computer Programming

Cooperative learning is the instructional use of small heterogeneous groups of students who work together in order to maximise their own, and each other's, learning. Cooperative learning encourages students to discuss, debate, disagree and, ultimately, to teach one another. It is very effective in encouraging student interaction and developing positive attitudes towards a student's school; further, it can produce positive effects upon a student's achievements.

It is envisaged that future requests for student abilities will be multidirectional, not just focused on knowledge. In other words, it will be important to provide indicators that can test the abilities of each student, including each student's level of logical thinking ability, creative ability, spatial ability and problem solving ability. It is also ethically important to advance personal relationships that contribute to learning in society. Hence, the ability of students should cover all directions in the future.

Educators should be concerned with those factors that significantly affect the performance of computer programming, especially on student learning concerning individual differences. For example, educators should set the direction to develop an open, flexible and coherent framework in order to improve the quality of students through effective teaching and learning.

REFERENCES

1. Tai, D.W.S., Chen, W-J. and Lai, L-C., Study of the effectiveness of different feedback styles of multimedia computer-assisted learning systems on the performance of engineering drawing. *Proc. 1st UICEE Annual Conf. on Engng. Educ.*, Melbourne, Australia, 258-261 (1998).
2. Tai, D.W.S., Yu, C.H. and Hu, C-H., The study of spatial ability, logical ability and computer assisted learning on the performance of computer programming. *Proc. 3rd East-West Congress on Engng. Educ.*, Gdynia, Poland, 298-301 (1996).
3. Saracho, N.O., Teachers' and students' cognitive style in early childhood education (ERIC ED 413081) (1997).
4. Elder, L. and Paul, R., Critical thinking: distinguishing between inferences and assumptions. *J. of Developmental Educ.*, 25, **3**, 34-40 (2002).
5. Donelson, F.L., The development, testing and use of a computer interface to evaluate an information processing model describing the rate of encoding and mental rotation in high students of high and low spatial ability (ERIC ED 326 396) (1990).
6. Winn, W., Recall of the pattern, sequence, and name of concepts presented in instructional diagrams. *J. of Research in Science Teaching*, 25, 375-386 (1988).
7. Frey, D. and Simonson, M., Cognitive style, perceptual modes, anxiety, attitude, and achievement. (ERIC ED 323 929) (1990).
8. Hong, J.C., A study of discovery learning with different learning styles in a CAI environment. *Math. Sci. Technical Educ*., 4, **2**, 70-80 (1994).
9. Winston, V., Effects of cooperative learning on achievement and attitude among students of color. *J. of Educational Research*, 95, **6**, 359-364 (2002).
10. Johnson, D.W. and Johnson, R.T., Towards a cooperative effort: a response to Slavin. *Educational Leadership*, 46, **7**, 80-81 (1989).
11. Reid, J., The effect of cooperative learning with intergroup competition on the math achievement of seventh grade students (ERIC ED 355106) (1992).
12. Slavin, R.E., *Cooperative Learning Theory, Research, and Practice* (2nd edn). Boston: Allyn &Bacon (1995).
13. Wu, J.J., *Embedded Figure Test*. Taipei: Yuai-Liou Publishing (1974).
14. Manrique, F., Niall, K.K., Sullivan, H.J. and Klein, J., Effects of spatial ability levels and presentation platform on performance of a pictured rotation task (ERIC ED408357) (1997).
15. Swenron, R.P. and Anderson, C., The role of motivation in computer-assisted instruction. *Creative Computing*, 8, **10**, 134-139 (1982).
16. Jonassen, E.H., Learning vs. information. *J. of Educational Multimedia and Hypermedia*, 1, 3-5 (1992).
17. Foreman, K., Cognitive style, cognitive ability, and the acquisition of initial computer programming competence (ERIC ED 295 638) (1988).
18. Nlaz, M. and Lawson, A.E., Balancing chemical equations: the role of development level and mental capacity. *J. of Research in Science Teaching*, 22, 41-51 (1985).
19. Dalton, D.W., The effects of prior learning on learner interaction and achievement during interactive video. *J. of Computer-Based Instruction*, 17, 8-16 (1990).
20. Hooper, S. and Hannafin, M.J., Cooperative CBI: the effects of heterogeneous versus homogeneous group on the learning of progressively complex concepts. *J. of Educational Computing Research*, 4, **4**, 413-424 (1988).