The Impact of CABLE on Teaching Computer Programming

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Abstract: This paper reports the second of two studies on the impact of a Cognitive Apprenticeship-Based Learning Environment (CABLE) in the teaching of computer programming. The pedagogical model used in this study employs a combination of instructional strategies including directive support, responsive cognitive apprenticeship, collaborative learning, stimulating metacognition, using technologies via the use of tele-apprenticeship and online discussion. In an earlier study, students who participated within the CABLE project scored more highly on test scores, relative to comparable students who did not participate within CABLE, but these effects were found to be restricted to high-ability students. In the present study, students who participated within CABLE scored more highly than those participating within the non-CABLE group. However, with an enhanced CABLE environment, the benefits of CABLE were now evident in both ability groups, with the effects being more prominent within the low-ability group.

Keywords: Cognitive apprenticeship, collaborative learning, tele-apprenticeship, metacognition.

1 Introduction

Computer programming is a difficult and challenging subject area which places a heavy cognitive load on students [1, 2]. After two years of learning programming, most novice programmers are still struggling to be proficient [3, 2]. From an examination of current research in this field, it can be postulated, that one reason computer programming instruction seldom results in the successful transfer of problem solving skills, lies in a lack of understanding about good instructional approaches in this direction [4, 5].

This paper reports the second of two studies on the impact of a Cognitive Apprenticeship-Based Learning Environment (CABLE) in the teaching of computer programming that would promote problem-solving skills of university students in Samoa. The main instructional approach used in this study is described as cognitive apprenticeship. The notion of apprenticeship stems from Vygotskian psychology, but we based our approach after the work of cognitive psychologists such as Collins, Brown and Newman [6] and others. Cognitive apprenticeship places emphasis upon reflective thinking as a metacognitive experience. The approach encourages metacognitive thinking, the use of directed teacher instruction to guide problem solving, and the use of scaffolding. The pedagogical model researched in the two studies represents our attempt to devise a viable instructional model based around the construct of apprenticeship. The aim was to achieve this goal through using a combination of instructional strategies working in concert to
provide the learners with a highly demanding but responsive instructional experience that differed from those derived within more traditional learning environments.

Cognitive apprenticeship is a model of instruction that involves the effective communication of domain knowledge in such a way that the students become aware of the thought processes involved in knowledge construction within that domain. As an instructional approach it is directed at teaching processes that experts use to handle complex tasks, characterized by a number of teaching methods [6]. The first of these, is modelling where the teacher models his or her thought processes in solving problems within a domain. The second of these methods is guided practice or coaching where the student attempts to solve the problems for themselves with the support of the teacher to answer specific queries. A third method is scaffolding, where the teacher assists students to manage complex task performance and then gradually withdraws support from the student (fading). Other key components of this approach include articulation, where the students are encouraged to reflect on how they approached tasks and solved problems, possibly by discussion with other students and, finally, exploration which is intended to encourage learner autonomy and problem formulation by students.

Another instructional strategy that is gaining prominence as an effective teaching method and is integrated into the learning environment being trialled is collaborative learning. There are many approaches to collaborative learning but all have the following characteristics in common [7]. It is a learning activity suitable for group work; it is small group based (usually 2-5); it has tasks which encourage cooperative behaviour; it is characterized by student interdependence; individual student accountability and responsibility for task completion.

Our starting assumption is that the computer can be used as a tool assisting in both cognitive apprenticeship and collaborative learning. An important element of the CABLE learning environment is its use of computer-mediated communication techniques for implementing aspects of cognitive apprenticeship such as scaffolding, coaching, feedback and modelling. Computer-mediated communication refers to communication using a computer. Examples of computer-mediated communication include email, computer conferencing and electronic bulletin boards. How these techniques are utilized to support the learning process is referred to as electronic apprenticeship or tele-apprenticeship. Tele-apprenticeship or online apprenticeship refers to the use of computer mediated communication techniques, for the implementation of cognitive apprenticeship [8]. Computer mediated communication techniques used in implementing tele-apprenticeship in the current study include email, online notes, interactive tests and a bulletin board.

As mentioned earlier, the term used to refer to this pedagogical model, is the cognitive apprenticeship-based learning environment or CABLE, because although it is based on the cognitive apprenticeship approach, the approach used in this study, is further enhanced by the incorporation of elements of metacognition and collaborative learning, instructional elements, which studies have proven to be conducive to effective learning. Furthermore some elements of this cognitive apprenticeship based approach will be implemented electronically by means of email, bulletin board, online notes and interactive quizzes. This is referred to as tele-apprenticeship and a subsidiary aim of this research was to investigate the impact of computer-mediated communication in enhancing student learning. CABLE is a hybrid learning environment and it is implemented both in face-to-face and online mode.

This paper reports the findings of our second study on the impact of CABLE. In the initial study, results showed that students who participated in CABLE scored more highly on a post test measure of mastery of Java programming, relative to comparable
students who did not participate within CABLE. However, these effects were found to be restricted to high-ability students. These results were disappointing in that the hope was to develop instructional procedures that would provide a richly motivating and responsive educational context that would appeal to low-ability students. One goal of this program lies within reducing variance within student achievement levels. From these findings our team re-evaluated our procedures and modified CABLE to include more scaffolding and more online resources. The effectiveness of this enhanced CABLE model is evaluated in the present study.

2 Methodology

2.1 Research design

Students participating in University Foundation Computer Studies class at the National University of Samoa were allocated to either the CABLE treatment or were taught in accordance with the traditional university model of teaching (i.e. Non-CABLE methods). This division was achieved through students being enrolled within different class times. Although the initial total enrolment was 80 students, complete data were able to be collected from 39 students within the CABLE group, and 33 students from the traditional group. Participants were students within their first year of studies from the Foundation (64%) and non-Foundation (36%) programs. The Foundation program was for students who entered at a higher GPA and were preparing for studies in overseas universities whereas the non-Foundation program was for those who entered at a lower GPA and intending to pursue study locally. The approximate average age of the participants was 19 years. Student records were available from previous computing courses in the form of test scores.

The design of the present study was very similar to the first study. After six weeks of exposure to the treatments, all students completed the final test paper, and also completed a questionnaire intended to tap into their evaluations of their course experience. The post-test consisted of six questions which evaluated their knowledge of Java commands and also practical questions which tested the application of these Java skills and knowledge to solving a problem. Students were given program codes to explain, to troubleshoot and to predict program output. Furthermore, the assumption made here was that computer programming was a form of problem solving and hence these scores represented the problem-solving ability of these students.

The questionnaire consisted of Likert items which gauged students’ attitudes towards the learning environment, effectiveness of feedback, effectiveness of collaborative learning, the effects on self-confidence, and students’ love of learning. A diary of students’ interviews was kept in order to provide some qualitative, narrative and descriptive data on the study.

It is important to point out that there was considerable overlap in the instructional approaches in the two treatments. Students in both the cognitive apprenticeship and traditional groups were given the same set of notes and exercises on JAVA programming. Both groups were exposed to elements of the cognitive apprenticeship based approach such as feedback and coaching. In both groups, the teacher modelled computer programming theory and JAVA programming concepts using worked examples and real-life examples.

A main difference between the two groups was in the provision of feedback to the students. In the control group, as was characteristic of didactic instruction, feedback was
student initiated. With the experimental group, feedback was more structured and was given on a weekly basis. Feedback was provided by an online system where the lecturer provided individualised feedback via individualised emails sent to and received from each student. On a weekly basis, the students were expected to send an email to the lecturer, answering several questions. The first question required them to describe what activities and topics they had done during the week, and to indicate how they felt about their progress. The second and third question required them to describe any areas they are having problems with. The last question required the student to reflect upon what they have learnt and how useful they thought what they had learnt would be to them.

The lecturer would then respond to each student via email by way of feedback and encouragement. From the individualised feedback, the lecturer could gauge areas most students were having problems with and then use their information to post some frequently asked questions (FAQs) and solutions on the class web-site, providing further feedback and guidance to students in the class. It was assumed that this feedback system would provide students with the opportunity to articulate their thoughts and ideas and also to reflect upon their work and their progress in class.

A second differentiating factor between the two groups was metacognition. A key component of the cognitive apprenticeship based approach was the provision of a rich metacognitive experience to the learner, thus facilitating them to learn. This was facilitated within the cognitive group by encouraging students to reflect on their progress, problems encountered, what they had learnt, the usefulness of what they had learnt and also by the articulation of their thinking processes in the form of “think-alouds”.

The third differentiating factor between the two groups was the incorporation of elements of collaborative learning. Within the cognitive apprenticeship based group, coaching and mediation would also be provided by a more capable peer as the students were be paired, with the more capable student collaborating with the weaker student in carrying out their programming tasks in class.

3 Results and Discussion

3.1 Achievement Test Scores

The two treatment groups were found to be similar on non-Java prior test scores from earlier completed course units but diverged on the Java post-test scores. Results showed that there was an effect for CABLE treatment on post-test scores. That is, people who participated in CABLE scored more highly on the Java post-test than those who were in the traditional treatment. Statistical ANOVA procedures were used and showed a significant overall effect for treatment, $F(1,53) = 8.48, p = .005$. For further investigation, the two treatment groups were then split into two groups on the basis of the prior test scores. The prior test scores were taken as a measure of ability level. The median value of 50 was used, to generate a classification of high-ability and low-ability students. From an inspection of the data from the two ability levels separately, it was apparent that although the CABLE treatment had benefited both ability groups, the effect was more prominent in the less able group. The treatment effect was stronger in the less able group, with the F ratio increasing to 9.13 ($p =.006$). Inspection of effect-sizes (Cohen’s procedure) yielded $d = 1.22$ for low-ability and $d = 0.66$ for the more able group [The coefficient $d$ is expressed in standard deviation units]. In other words, although the CABLE treatment benefited both ability groups, the effect was stronger for the less able group, as indexed upon through their prior achievement scores. This interaction effect is shown in Figure 1.
3.2 Questionnaire responses

A measure of general course affect (or ‘liking’) was generated through summing the responses to 11 items on the questionnaire. It was found that on this measure, the two treatment groups exhibited similar levels. Out of a possible score of 44, the actual mean was 34.1 (SD of 3.96), which indicated a very high level of course approval (Note: the natural midpoint on the scale was 27.5). In short, students from both treatment groups evidenced very high levels of liking for their course experience. The levels of course affect was found to be independent of either treatment mode or ability status.

3.2.2 Responses to the Unstructured questions

Responses to Question xviii: Probe: Problems encountered (if any) during treatment

For the traditional treatment, 6 out of 24 students reported having no problems in using this learning mode. The main problem students identified was the difficulty in understanding Java programming (12 out of 24 students). Other problems reported included (a) not enough time to do work, (b) difficulty in accessing the lecturer, and (c) difficulty in specific Java concepts such as declaring types, running the program. In the CABLE treatment, 4 out of 24 students reported having no problems with the learning environment. As in the traditional group the main problems students reported were (a) difficulty in understanding Java, and (b) too many Java terms to learn.

Responses to Question xix Probe: List reasons why you think this is an effective or ineffective form of learning environment

Fifteen out of 24 students in the traditional treatment agreed it was an effective learning mode. The following reasons were given: (a) it kept students alert, occupied and provided experience of working under pressure, (b) it prepared students for programming independent of the lecturer, (c) improved student understanding of Java, (d) the provision
of a balance of both practical and theory improved understanding of Java, (e) provided encouragement to learn, and (f) provided more computing knowledge and skills. Five students found the learning environment ineffective. One claimed it was because it was the first time they had studied computers, while another resented disruptions from other students. For the CABLE treatment, 15 of 24 students reported the learning mode as effective. The main reasons given were (a) the use of both practicals and lectures facilitated a better understanding of Java, (b) increased motivation and improved confidence in learning Java, (c) improved understanding of Java and, (d) the use of email. Two students found the learning environment ineffective, one of them giving the reason as insufficient coverage time for topics.

3.2.3 Effectiveness of Online learning

To gauge the effectiveness of online learning, three data sources were used, (a) the responses to the questionnaire questions 12 – 17 administered only during the cognitive apprenticeship based treatment, (b) responses from personal student interviews, conducted in weeks 6 and weeks 12 of the study, and (c) an analysis of products, processes and perceptions based on the Triple Framework approach for evaluating online environments [9]. Questionnaire questions and interviews with students focused on four main issues:

(a) The effectiveness of email for feedback
(b) The effectiveness of online notes on class website
(c) The usefulness of posting sample test solutions online
(d) Whether students like working in pairs

(a) The effectiveness of email for feedback

The majority of the students interviewed agreed on the usefulness and effectiveness of email as a means of feedback. The main source of frustration was technical problems preventing effective access to email. Most of the students regarded email as very helpful as it gave useful and immediate feedback.

(b) The effectiveness of online notes on class website

All of the students interviewed liked online notes, giving the main reason for liking, as the ease of access and also that they could access the online notes at any time. Students also found the interactive self tests useful as a means of reviewing before the Java test. Again, the main complaints were technical.

(c) The usefulness of posting sample test solutions online

All of the students interviewed liked the idea of sample solutions online as they said they could i) access them any time, ii) useful for revision and iii) were useful for doing test corrections.

(d) Whether students liked working in pairs

All of the interviewees liked working in groups as they could help each other sharing ideas, especially when there were some things that the other group members knew, that they had no knowledge of.

Another important source of data was the log of student email. According to Salomon as cited in [9], there are 5 stages in the development of an online learning
community. The first stage is when community members develop the motivation to access and use the web environment proficiently. In the second stage, members are able to establish online identities and take the initiative to socialise with others online. Stage three is characterised by participants initiating the process of assisting and providing mutual support in information exchange. The process develops to stage four when course related group discussions eventuate and there is increased collaboration amongst members of the online community as they devise various means of collaborating in online work. Finally, the last stage, stage five, is characterised by members of the online community showing how the online learning has facilitated the achievement of personal goals and an ability to reflect on the learning process. Inspection of the log of student emails indicated that from the perceptions, processes and products of online learning using the Triple P Framework as developed by Ryba, Selby and Mentis [9], showed that the online community in Project 2, had progressed to stage three of the five stage model where students were involved in information exchange using email and the discussion forum.

In terms of processes, the students were not only proficient in using the online environment, but were also using the online environment for receiving coaching, feedback and scaffolding. Students were also using the email facility for online discussion forums and for a few of them, the ability to use it for reflection on their work.

In terms of products, student participation in email included:

- Technical messages relating to the website or managing of the helpdesk.
- Questions related to course work

Lecturer participation was in the form of providing encouragement to the students, providing feedback on student queries and bringing to the notice of students valuable features of the online environment. Hence the effectiveness of the online learning environment is suggested from student interview responses, an examination of the perceptions of students, an analysis of the content of student email messages and the processes students engaged in.

### 3.2 Conclusion

In essence it was found that:

- **CABLE**, as a viable model of conceiving and delivering a high quality instructional aid system, receives a measure of strong positive support from the present results. The results showed that on the overall, students were advantaged through their participation within this program. However, at the group level, significant achievement effects for the CABLE treatment were more prominent in the case of students in the less able group as indexed on prior achievement scores.
- In terms of positive attitudes towards the learning environment, results of the study indicate that, all the participants showed strong positive feelings towards their allocated treatment.
- There is positive evidence for the effectiveness of online learning in all of the student interview and questionnaire responses and also from the analysis of email content and the processes students were engaged in.
- The results indicate the effectiveness of CABLE as a viable instructional model for teaching Computer programming. However the results of the two studies differed in terms of which groups had benefited. In our initial study the high-ability students were clearly advantaged by CABLE. However in the current study, the low-ability students appeared to benefit slightly more than the high-ability students, although both ability groups showed clear advantages in the CABLE. Why might two similar studies yield
slightly different findings? The solution we favour is that our CABLE model continues undergoing development firstly in terms of improvement and familiarity with procedures. Also in the second study the lecturing team placed relatively greater emphasis upon individualised feedback.

It can be noted that the two studies differed slightly in the composition of the participant groups. In the first study, all the participants were from the Foundation program. These were generally the more able students, entering with high GPA’s. In the second study, 64% of the participants were from the Foundation program. However there were also 36% from the non-Foundation program, generally entering with low GPA’s. Despite the difference in ability levels of these two groups, there was no interaction between program and treatment, as CABLE had a positive effect on achievement levels of participants from both programs.

Hence, the results of the present study have boosted the confidence of our team in the viability of CABLE. It has also confirmed that the provision of excellent instructional procedures in a richly motivating and responsive educational context can have appeal and positive effects on students who may not otherwise perform to a high level. In this respect CABLE can enable us to achieve the ultimate goal of reducing variance within student achievement levels. This is encouraging, especially within the context of teaching computer programming as the subject area is very challenging and cognitively demanding. Hence an effective instructional model would certainly improve the quality of instruction of such an inherently demanding subject and ultimately result in improved achievement levels of Computer programming students within the university.

References