DEVELOPMENT OF ONLINE COGNITIVE AND ALGORITHM TESTS AS ASSESSMENT TOOLS IN INTRODUCTORY COMPUTER SCIENCE COURSES

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ABSTRACT

This paper presents the online cognitive and algorithm tests, which were developed in order to determine if certain cognitive factors and fundamental algorithms correlate with the performance of students in their introductory computer science course. The tests were implemented among Management Information Systems majors from the Philippines and among the students of the Information Systems track in a technology high school in Japan. The cognitive factor, Spatial Scanning, correlated significantly with the performance of both student groups in introductory computer science. Among the algorithms, Maze Tracing correlated with the university students' final grade and Binary Search with the midterm exam result of the high school students. The online tests also showed significant correlations among Searching, Sorting and Maze Tracing algorithms. The obtained correlations may be considered in creating assessment tools and in designing learning strategies for introductory computer science courses for both university and high school levels.

KEYWORDS

Computer Science Education, Cognitive factors, Algorithms.

1. INTRODUCTION

Researchers, particularly in the field of Computer Science Education, have endeavored to find ways on how to address the high drop-out rate and the poor performance of students in computing. These studies (Irons D., 1982, Rountree, N., et.al., 2004, Simon, et.al, 2006) attempt to identify the factors that determine success in computing and measure aptitude in programming. In relation to this, the importance of mastering programming early was emphasized by the ACM Computing Curricula 2001 Final Report which proposes programming as a prerequisite for many advanced courses in computer science (ACM, 2001). It is also important to find ways to improve computer science for high school as it is now being considered as an essential subject along with the traditional STEM (science, technology, engineering and mathematics) (CSTA, 2005).

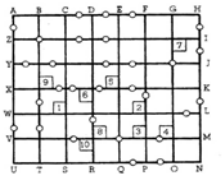
The main goal of this research is to determine which among known cognitive factors and fundamental algorithms correlate with the actual student performance in introductory computer science through online tests. The tests can be used as reference for designing assessment tools for both university and high school students who plan to study computer science and other technology and computing-related degrees. The correlation results may also be used in determining possible ways to help students succeed in introductory computer science, specifically in programming.

2. METHODOLOGY

The first phase of this research covered the initial development of the online cognitive and algorithm tests and their preliminary implementation among sixty-one (61) second year Management Information Systems (MIS) majors at the Ateneo de Manila University. These participants have taken up Introduction to Computing I (CS 21A) and were enrolled in Data Structures and Algorithms (CS 21B) when they took the tests in May 2007. The second phase involved the translation of test instructions to Japanese and their implementation in September, 2011 among forty (40) students from the Information Systems track of TokyoTech High School. At the time of the implementation of the tests, these students have already finished introductory programming but have not yet studied the fundamental algorithms considered in this research.

2.1 The Cognitive Factors Tests

Two sets of online tests were developed for the purposes of this research. One set was based on known cognitive factors from the Kit of Factor-Referenced Cognitive Tests by the Educational Testing Services (ETS), a US-based educational institution. Each cognitive factor has corresponding paper tests. The first cognitive test, Object-Number for the cognitive factor Associative Memory, assesses the ability of the student to learn combinations of words and numbers. The second is Letter Sets Test for Induction, which aims to find the rule that makes the letter sets similar and to identity which set does not fit the rule. The third, Diagramming Relationships test for Logical Reasoning, entails finding the relationships among things in a group, represented by overlapping circles. The last is Map Planning test for Spatial Scanning, the goal of which is to find the shortest route between two points in a city map the shortest possible time and according to a set number of rules (Ekstrom, et.al, 1976). A sample map for the Map Planning Test is shown in Figure 1 below. Previous researches have shown that the aforementioned factors are related to programming aptitude (Irons, 1982; Scanlan, 1988). For the Japanese high school students, Diagramming Relationships Test was not included because this particular test uses English words and the authors have no license to modify and translate actual exam contents.



Sample routes
A to Z passes building 1
E to S passes building 5
P to J passes building 3

Figure 1. Sample map and routes in Map Planning Test

2.2 The Algorithm Tests

Fundamental algorithms, commonly taught in introductory computer science were designed as games that can simulate how the algorithms work. The first set of games is Card Searching which includes Linear Search and Binary Search. The goal is to locate a certain number from among ten (10) numbered cards. The next is Sorting games, where the goal is to simulate Insertion Sort and Selection Sort while sorting ten numbered cards in ascending order. The third game is Maze Tracing which attempts to simulate how breadth-first and depth-first search algorithms work. The last algorithm, Tower of Hanoi, checks the student's ability to think recursively. It was not implemented among the high school students because recursion is not covered in their course syllabus. Figure 2 shows the screen components of Card Sorting.

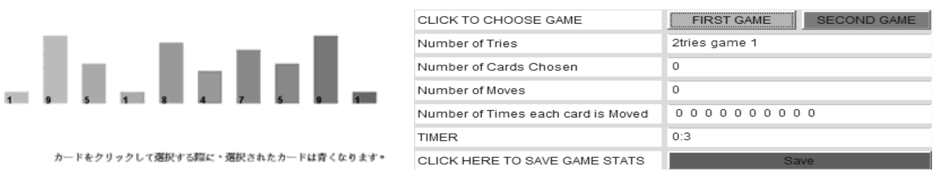


Figure 2. Unsorted cards and data boxes in Card Sorting

3. DATA ANALYSIS

The scores from the online cognitive factors tests were collected. For the algorithm tests, data based on the execution of the games were used to compute the test scores. The test results were then correlated with the actual performance of the students in their introductory computer science course, the grades in CS 21A of the university students and the scores in the mid-term exam on algorithms of the high school students. Data analysis was done using Pearson's R correlation function in SPSS.

3.1 Correlations of Online Tests with Performance in Introductory Computer Science

Among the cognitive factors, Spatial Scanning correlated with the performance of the university students in CS21A (r=.331, R=.1095, sig=.010). This finding is similar to the study of Irons where this factor is one of those considered to be most relevant to programming aptitude. Spatial Scanning is associated with debugging skills as it entails finding "particular configurations representing a pathway through the field". This is considered as a more psychologically relevant factor in predicting programming skill and is greatly related with debugging ability (Irons, 1982). Spatial Scanning also correlated with the midterm exam results of the high school students specifically with their score in the Binary Search problem (r=.383, R=.1466, sig=.015). This can be related with the ability to apply Binary Search algorithm where a certain scheme is employed for locating values in an array. Among the algorithms, only Maze Tracing correlated significantly with the performance of the university students in their introductory computer science class, CS21A (r=.310, R=.0961, sig=.017). In the case of the high school students, the result of the online test on Binary Search correlated significantly with the score in the Binary Search problem in the midterm exam (r=.352, R=.1239=, sig=.026). This particular result implies that it is more substantial to find the correlations between the online tests with the performance in the actual application of the algorithms rather than with the final grade.

3.2 Correlation Results among Algorithms

The results of the online algorithm tests were also correlated against each other as shown in Table 1. Two significant correlation results are similar for both university and high school participants, Linear Search with Binary Search and Insertion Sort with Selection Sort. Linear Search and Binary Search tests are expected to correlate because both are search algorithms and have the same objective, that of locating a value from a given set of cards. The same applies to the correlation between Insertion Sort and Selection Sort.

Table 1. Correlation results among the algorithm tests

Algorithms	**Correlation values**	
	University students	**High school students**
Linear Search with Binary Search	r=.555, R=.3080, sig=.000	r=.859 R=.7378, sig=.000
Insertion Sort with Selection Sort	r=.517, R=.2672, sig=.002	r=.511, R=.2611,sig=.001
Binary Search with Maze Tracing	r=-.314, R=.0985, sig=.023	r=.465, R=. 2162,sig=.002
Binary Search with Insertion Sort	r=.501, R=.2510, sig=.003	
Binary Search with Selection Sort	r=.375, R=.1406, sig=.011	
Maze Tracing with Tower of Hanoi	r=.345, R=. 1190,sig=.007	
Maze Tracing with Linear Search		r=.390, R=.1521, sig=.013

There are a number of differences, though, between the test results of the university students and high school students. For the university students, Binary Search and Maze Tracing are inversely correlated. These students who already knew Binary Search could have implemented the algorithm's strategy in the corresponding online test but tried free search in Maze Tracing. However, for the high school students, Binary Search and Maze Tracing have positive correlations. This may be explained by the fact that searching is naturally applied in maze traversal. Both processes entail some movement from one point to another. Another possible reason is that the high school students have not yet studied Binary Search at the time of the online test implementation. Thus, they could have applied free searching in both algorithm tests, that is, not following a learned method. The same reason may be applied with the positive correlation between Maze

Tracing and Linear Search. Binary Search further correlated with Insertion and Selection Sort and Maze **Tracing with Tower of Hanoi for the online test results of the university students but not for the high school** students. These other correlations may be again due to the fact that the university students have already studied algorithms by the time of online test implementation. Their approach in executing algorithms is more unified and structured. Generally, the correlations may also be due to the natural connection between the concerned algorithms. Search strategies are naturally employed when sorting or tracing a maze.

4. CONCLUSION

Online cognitive and algorithm tests were developed and implemented among university students who are majoring in information systems and high school students who are in a similar course track. The aim was to find out correlations among the known cognitive factors and fundamental algorithms with the performance of the students in their introductory computer science course.

A number of significant correlations were obtained and similarities as well as differences in the correlations between the two groups of participants were observed. The correlation results indicate consistency in the students' performance in the online test and demonstrate certain reliability among the developed algorithm tests. Moreover, the obtained results show close connections among the cognitive factor Spatial Scanning and Maze Tracing and Binary Search, making them possible factors to be considered in learning computing fundamentals.

In summary, the online cognitive factors and algorithm tests that correlated with the performance of the students either with the final grade or exam score may then be considered in designing tools in assessing student ability to succeed in an introductory computer science course. The said cognitive factors and algorithms may also be taken into account in the development of a course outline for introductory computer science and in preparing actual problem exercises for the students.

Future work for this research includes considering other cognitive factors and algorithms for the online tests. The other data on the online test performances that were not used in scoring the algorithm tests may also be used in constructing other formulas for scoring the tests. These data may then be used to further study particular aspects with which the students implement algorithms and determine other factors that can assess aptitude in introductory computer science courses.

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