A PREDICTOR FOR SUCCESS IN AN INTRODUCTORY PROGRAMMING CLASS BASED UPON ABSTRACT REASONING DEVELOPMENT

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Abstract

The purpose of this study was to create and validate a tool which could be administered to students enrolled in or considering enrollment in an introductory programming course to predict success in the course or alternatively to segregate enrolled students into fast and slow paced sections. Previous work which met the criteria of a self contained predictive tool included the work of Barry Kurtz [5] of the University of California, Irvine using abstract reasoning development as the predictive measure. The test Kurtz developed had been tested only on a small sample (23 students) in a controlled environment (one instructor - the researcher) and the test required up to 80 minutes to complete.

This study modified the Kurtz test to require 40 minutes and administered it to 353 students learning two different languages from a variety of instructors. This predictor successfully predicted the advanced students from average to below average students. When used in conjunction with other known factors, e.g., GPA, the authors feel it is a viable tool for advising and placement purposes.

Introduction

Increasing enrollments at many schools have created waiting lists to enroll in the introductory computer science course. The desire to provide a rigorous introductory course in computer science must recognize the disparity of ability that students possess when they enroll. Large numbers and diverse ability levels motivated the development of a test which could be administered easily and which could predict the success of a student in the first computer science course. Our first computer science course principally involves the study of problem solving techniques and secondarily involves the learning of a programming language. Two purposes were to be met: one, we wished to be able to screen students considering computer science as a major as part of an advising function and two, we wished to be able to segregate the enrolled student into those who were likely to be able to accelerate through the material and those who were not prepared for accelerated presentations.

Jean Piagets' intellectual development (ID) levels describe the ability of the student to think abstractly. Given that problem solving requires developed abstract thinking ability, we chose to focus upon the development of a predictive tool based upon the measurement of these levels [6]. Piagets' levels of intellectual development are shown in Figure 1.

Figure 1: Piaget's Intellectual Development Levels

Pre-Operational	Concrete	Formal
Age 2-7+ Perceive static states	Perceive static states and modification Classification and generalization Serial ordering 1 - 1 correspondence Reality to theory	Abstract thinking Transfer from theory to reality Combinatorial reasoning Examine own logical reasoning

The first stage, preoperational reasoning is the only one affected by chronological age and usually is present in children roughly 2 to 7 years of age. Additional learning development seems unrelated to age. At the preoperational a person would perceive the transfer of water from a wide jar to a narrow jar and conclude that the higher level in the latter jar as indicative of more water. Concrete level starts about 7 years of age and some people never progress past this level. The concrete level person would be able to accomplish the conservation of water problem, above, conclude that all dogs are animals and not all animals are dogs (classification and generalization) but would not comprehend ratios. For instance, a likely solution to the ratio problem 6 to 8 and 15 to X would be to add 9 to 8 because 15-6 = 9. Using known characteristics of the intellectual development levels, problems can be created to ascertain a person's Piaget thinking level. In this study we divided concrete and formal into early and late categories. An early prefix indicated the student exhibited some of the characteristics of the category, a late prefix indicated they exhibited most or all of the characteristics.

A shortened version of an existing test created by Kurtz [5] was used. This shortened test was administered on a voluntary basis to all students enrolled in Computer Science 200 one semester at Kansas State University and the results statistically analyzed using the SAS package.

Method

The Kurtz test had 15 questions with the reasoning skills required shown below.

Number	Type	ID Level
1	Conservation of Volume	Concrete
2	Direct Proportion	Early Formal
2	Probabilistic Reasoning	Early Formal
2	Inverse Proportion	Formal
2	Propositional Reasoning	Late Formal
2	Correlational Reasoning	Late Formal
1	Deductive Logic	Late Formal
1	Separation of Variables	Formal
1	Permutations	Late Formal
1	Combinations	Formal

We reduced these 15 questions to 11 by removing the questions which duplicated the direct proportion, probabilistic reasoning, inverse proportion, and correlational reasoning. Since the questions on propositional reasoning were difficult, both questions were left in the test and success on either was considered success in propositional reasoning when the test was graded. The slowest student required 45 minutes to complete the test.

Three hundred fifty three students (150 female, 203 male) voluntarily took the examination in the first week of the semester. These students were taught by 10 different instructors in 15 class sections learning two different programming languages. The mean final course grades were 3.58 (C+) for females and 3.18 (C) for males.

The predictor as constructed had four self reporting questions, 1. previous programming experience, 2. previous programming classes, 3. GPA, and 4. enjoyment of programming. The correlation between the final grade in the course and the self-reported GPA was 0.34357. Only forty-five students had any previous programming experience; of these only five had more than a minimal amount of high school experience. The enjoyment of programming was hand coded into four categories, liked, disliked, undecided, and omitted. Two hundred twenty-four indicated they liked programming, forty-nine disliked it, fifty-seven were undecided and twenty-three omitted the answer.

The test was graded by hand with the formal reasoning questions being graded right or wrong. The Intellectual Development (ID) levels were established following the criteria used by Kurtz [5] in his study. A student had to fail both direct proportion and probability to be classified late concrete (both of these formal reasoning techniques tend to develop chronologically before the others tested for). If either was passed then the student was classified as early formal. To be classified as late formal, the student must be classified as early formal and in addition pass three of the following four areas: correlation, permutation, deductive logic, and propositional logic.

Results

The percent of correct responses on each of the ten abstract thinking characteristics is given in Table 1, which also shows a comparison with the results obtained by Kurtz [5].

Table 1

Percent of correct responses on Individual reasoning tasks

Type of reasoning	This study %	Kurtz study %
Separation of variables	92.6%	91.3%
Inverse Proportion	88.7	73.9
Conversion of volume	84.1	100.0
Probability	76.2	65.2
Direct proportion	74.8	78.3
Correlation	54.7	56.5
Combinations	47.8	78.3
Permutations	46.7	60.9
Deductive logic	16.7	27.3
Propositional logic	11.6	13.0

The students were categorized by the test into ID levels as shown in Table 2.

Table 2

ID Levels for Test Population

ID Level	Number	Percentage
Late formal	37	10.5%
Early formal	384	80.5%
Late concrete	32	9.0%

The evaluation of course performance was based solely on the student's final course grade. The frequency of final course grades is given in Table 3.

Table 3

Final course grade distribution of test population

Grade	Number	Percentage
A	61	17.3%
B	132	37.4
C	86	24.4
D	44	12.5
F	30	8.5

An analysis of variance was performed on grade in the course by ID level. The ANOVA table is given in Table 4 while Table 5 gives means standard error, frequency, and a grouping indicator for the grades associated with the three ID levels: late concrete, early formal, and late formal. Entries with the same grouping letter are not significantly different at the 0.05 level.

Table 4

ANOVA table-Final grade in class by ID level

Source	df	Sum of sq.	Mean Sq.	F-value	pr > F
Between levels	2	9.234	4.617	3.46	0.0325
Within levels	350	467.026	1.334		
Total	352	476.261			

Table 5

Grouping by means

Group	Grouping	Freq.	Mean Grade	Std. Error
Late Formal	B	37	3.73	0.190
Early Formal	B	284	3.43	0.069
Late Concrete	A	32	3.00	0.204

The two tables of information indicate that there is a significant different (at the 0.05 level) between the mean of the late concrete level and the means of the early and late formal levels.

A chi-square test was run to see if there was independence between the ID levels and the performance levels as measured by final course grades. This test provided the information that if one divides the students into categories by course grade of A, B-C, and D-F as Kurtz [5] did, then this study finds the ID level is independent of grade at the 0.05 level of significance (see Table 6). However, if instead of using the test to differentiate the A students and D-F students, we use it to differentiate the students who achieved an A or B from the student who achieved a D or F, the test shows there is a dependence at the 0.05 level of significance (see Table 7).

Table 6

Contingency Table for chi-square ID level vs Performance (Kurtz's) level

	High A	Average B-C	Low D-F	Total
Late Formal	11 29.7%	19 51.4%	7 18.9%	37
Early Formal	48 16.9%	178 62.7%	58 20.4%	284
Late Concrete	2 6.3%	21 65.6%	9 28.1%	32
Total	61	218	74	353

chi-sq=7.257 df=4 p=0.1229

Table 7

Contingency table for chi-square ID level vs Performance (author's) level

	High A	Average B-C	Low D-F	Total
Late Formal	27 73.0%	3 8.1%	7 18.9%	37
Early Formal	155 54.6%	71 25.0%	58 20.4%	284
Late Concrete	11 34.4%	12 37.5%	9 28.1%	32
Total	193	86	74	353

chi-sq=11.901 df=4 p=0.0181

The pattern of grade distribution exhibits a trend. The people considered late formal showed a trend to high performance (73% received A or B). The people considered early formal received a smaller percentage of A or B within their group (54.6%). While only 34.4% of the people considered late concrete received an A or B, i.e., 65.6% received a C, D, or F in the course.

Conclusions

The use of the shortened Intellectual Development (ID) predictor in a much less constrained situation with a larger population failed to produce the spectacular ID-level versus final course grade correlation obtained in the Kurtz [5] study, 0.11615 for our study versus 0.7954 for Kurtz. However, we feel this 30-40 minute test when used in conjunction with other advising information provides a useful predictor of course performance (course grade A or B versus C, D or F). It also could be helpful in segregating incoming students into accelerated and non-accelerated sections of our introductory computer science course or even of setting priorities for classroom placement when a long waiting list exists for the introductory course.

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Appendix

Brief Description of ID Test Items

Item 1: Conservation of Displaced Volume (Karplus and Lavatelli, 1969)

Students are shown a picture of two identical containers filled to the same level with water. There are two weights of the same shape, but different densities. Shown a picture of the water level displaced by the light weight in one container, students are asked to predict the level of water (higher, lower, same) displaced by the heavy weight in the other container.

Item 2: Inverse Proportion

Suppose that you are investigating the running abilities of a horse and a dog. You find that each time the horse takes a step, the dog also takes a step. You measure the stride of the horse and find that it is 12 feet long. This horse can run a particular course in 30 seconds. If the dog has a 4 foot stride, how long will it take the dog to complete the course?

Item 3: Correlational Reasoning (adapted from Lawson, 1978)

Shown a picture with 6 birds having long beaks and short tails, 2 birds having short beaks and short tails, 2 birds having long beaks and long tails, and 6 birds having short beaks and long tails, students are asked if there is a relationship between the length of beak and the length of tail.

Item 4: Separation of Variables (Lawson, private communications)

Students are shown four pictures: (1) a healthy plant that received a tall glass of water and light plant food, (2) an unhealthy plant that received a tall glass of water, dark plant food and leaf lotion, (3) a healthy plant that received a small glass of water, light plant food, and leaf lotion, and (4) an unhealthy plant that received a small glass of water and dark plant food. Told that another plant is receiving a small glass of water, light plant food, and no leaf lotion, students are asked to predict how the plant is doing.

Item 5: Direct Proportion (Kurtz, Karplus, 1979)

Students are told that in a particular photograph a mother is 8 cm high and her daughter is 6 cm high. If the picture is enlarged so that the daughter is 15 cm high, students are asked to predict the mother's height.

Item 6: Propositional Reasoning - 1 (Lawson, Karplus, Adi, 1978)

Students are asked to test the truth or falsity of the following hypothesis: if a rat has lipids in its blood, then it will be fat.
Students are asked:
(i) Given blood samples with lipids, would you need to know if they came from fat or thin rats?
(ii) Given blood samples with no lipids, would you need to know if they came from fat or thin rats?
(iii) Given several fat rats, would you need to know if there are lipids in these rats' blood?
(iv) Given several thin rats, would you need to know if there are lipids in these rats' blood?

Item 7: Deductive Logic (Karplus and Karplus, 1970)

Shown a picture of four island, named bean, bird, fish, and snail, students are given the following clues:
Clue 1: There is a way to fly between bean island and bird island.
Clue 2: There is no way to fly between bird island and snail island.
Clue 3: There is a way to fly between bean island and fish island.
The students are asked:
Is there a way to fly between bird island and fish island?
(yes, no, not enough information. Why?)
Is there a way to fly between fish island and snail island?
(yes, no, not enough information. Why?)

Item 8: Permutations (adapted from Longeot, 1965)

Students are given a hypothetical situation in which four stores (a barber shop, a discount store, a grocery store, and a coffee shop) are to be arranged side-by-side on the ground floor of a shopping center. The students are asked to list all the possible ways that the stores can be arranged.

Item 9: Combinations (Lawson, 1976)

Students are told that biologists are dissecting crab stomachs to find out if they are eating red, yellow, blue, or green algae (all locally plentiful) or other food. They are to list all possible varieties of algae the crabs might be eating (assuming order is not important).

Item 10: Probabilistic Reasoning (adapted from Lawson, 1977)

Three blue chips and seven red chips are placed in a container on the left, while two blue chips and four red chips are placed in a container on the right. Students are asked which container they would choose (left, right, doesn't matter) to have the best chance of drawing a blue chip on the first try.

Item 11: Propositional Reasoning - 2 (after Wason and Johnson-Laird, 1972)

Students are asked to test the truth or falsity of the following rule: If a card has a vowel on one side, then it has an even number on the other side. Students are shown successive pictures of cards displaying E, 4, K, 7 and, in each case, asked "Would you need to know what is on the other side of this card?------Why?"