Search for Causal Predictors of Achievement in Distance Education Using the Path Analysis

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Abstract

The purpose of this study is to present a causal model of achievement in distance education using the path analysis technique. Two types of research instruments, an Evaluation Questionnaire for Distance Education (EQDE) and a Distance Education Achievement Test for Teachers (DEATT), were developed and used for the study. Both instruments were validated and tested for reliability to ensure their merit and worth as measuring instruments. Two levels of achievement were defined, i.e., the first level achievement, measured by an achievement test score and the second level achievement, determined by the grades of students. The results of the path analysis showed that feedback and learner-learner interaction are significant predictors of the persistence rate; metacognition and the persistence rate of first level achievement; metacognition, teaching effectiveness, learner-material interaction, learner-learner interaction, persistence rate and the achievement test score of second level achievement.

Abstrak

Tujuan kajian ini adalah untuk membentangkan Model Kebetulan untuk kejayaan pendidikan jarak jauh menggunakan teknik analisis lintasan. Dua jenis instrumen kajian, soal-selidik penilaian untuk pendidikan jarak jauh dan ujian kejayaan pendidikan jarak jauh untuk guru dibangunkan dan digunakan untuk kajian ini. Kedua-dua instrumen disahkan dan diuji untuk kebolehpercayaan untuk mengenal pasti merit dan juga nilai sebagai instrumen pengukuran. Dua paras kejayaan ditakrifkan, yakni kejayaan paras pertama diukur dengan skor ujian kejayaan dan kejayaan paras kedua ditentukan melalui gred pelajar. Dapatan daripada analisis lintasan menunjukkan bahawa maklum balas dan interaksi pelajar-pelajar adalah prediktor yang signifikan terhadap kadar penerusan, metakognitif dan kadar penerusan kejayaan paras pertama, metakognitif, keberkesanan pengajaran, interaksi pelajar - bahan, interaksi pelajar-pelajar, kadar penerusan dan skor ujian kejayaan paras kedua.

Introduction

Causal modelling procedures provide social scientists with powerful methodological tools to examine complex causal relationships in socio-logical and educational investigations. These modelling techniques help simplify the enormity of events, facts, relationships and actions that exist in the real world. One procedure that has gained popularity in the analysis of causal relations among variables in social science and educational research is the path analysis. The efficiency of the path analysis makes it one of the central frameworks that characterise most empirical and mathematical approaches in social research (Bradley & Shaefer, 1998).

The path analysis was introduced by social scientists to the field of behavioural and educational research in an attempt to reformulate verbal social theories in terms of empirically-based language (Keeves, 1988). As a multivariate analytical technique, the path analysis provides quantitative estimates of the plausible causal connections between variables. It is not a method for discovering causes; rather, it is a tool intended to examine underlying causal relationships of the variables arranged in a causal model. This causal model is formulated by the researcher based on logic, common sense notions, existing knowledge and theoretical considerations (Pedhazur, 1997).

This study applied the path analysis in a causal model of academic achievement in distance education. The causal model specifically developed for this study identified nine dimensions of the distance learning system. These dimensions were subsumed under three major distance education subsystems, namely, personal circumstances, instructional materials and student support. The dimensions were the locus of control, metacognition, and social and work integration (the personal circumstances subsystem); teaching effectiveness, learner-material interaction and workload requirements (instructional materials subsystem); and tutor support, learner-learner interaction and feedback (student support subsystem). Other variables used in the causal model were the persistence rate and two measures of achievement, i.e., the test scores and grades (or general weighted average) of distance learners.

It is important to know the predictors of achievement in distance education in order to arrive at a better understanding of the meaning and nature of

distance learning achievement. Many of these factors may not be easily detected because they exist within the learners. Other important factors are embedded within the learning environment, but may have direct influence on the learner. An analysis of these factors, therefore, will help identify the variables that explain the success of distance learners for the purpose of enhancing achievement as well as improving the delivery of the distance learning mode of instruction.

The Conceptual Framework

The focus of the study was to find out the underlying causal effects of certain predictors on achievement in distance education. The causal effects were determined through the application of the path analysis, a powerful methodolo-gical analytical tool that provides quantitative estimates of the plausible causal connections among variables. Three distinct types of variables were defined in the causal model. These were the exogenous, endogenous and residual variables. An exogenous variable is one that is influenced by factors outside the causal model but affects other factors within the causal model. An endogenous variable is one whose variation is explained by other variables within the causal model. Finally, a residual variable is one that is not actually measured in the model but affects the endogenous variable in the causal model.

The relationship among the variables is graphically presented in a causal model or path diagram (Figure 1). In the causal model, the nine dimensions of distance education are the independent, exogenous variables; the persistence rate and achievement test score are the endogenous variables and used in the causal model both as dependent and independent variables in different regression functions; the general weighted average (GWA) is the endogenous dependent variable. The e's are the residual or error terms, representing factors outside the causal model but affecting the endogenous variables.
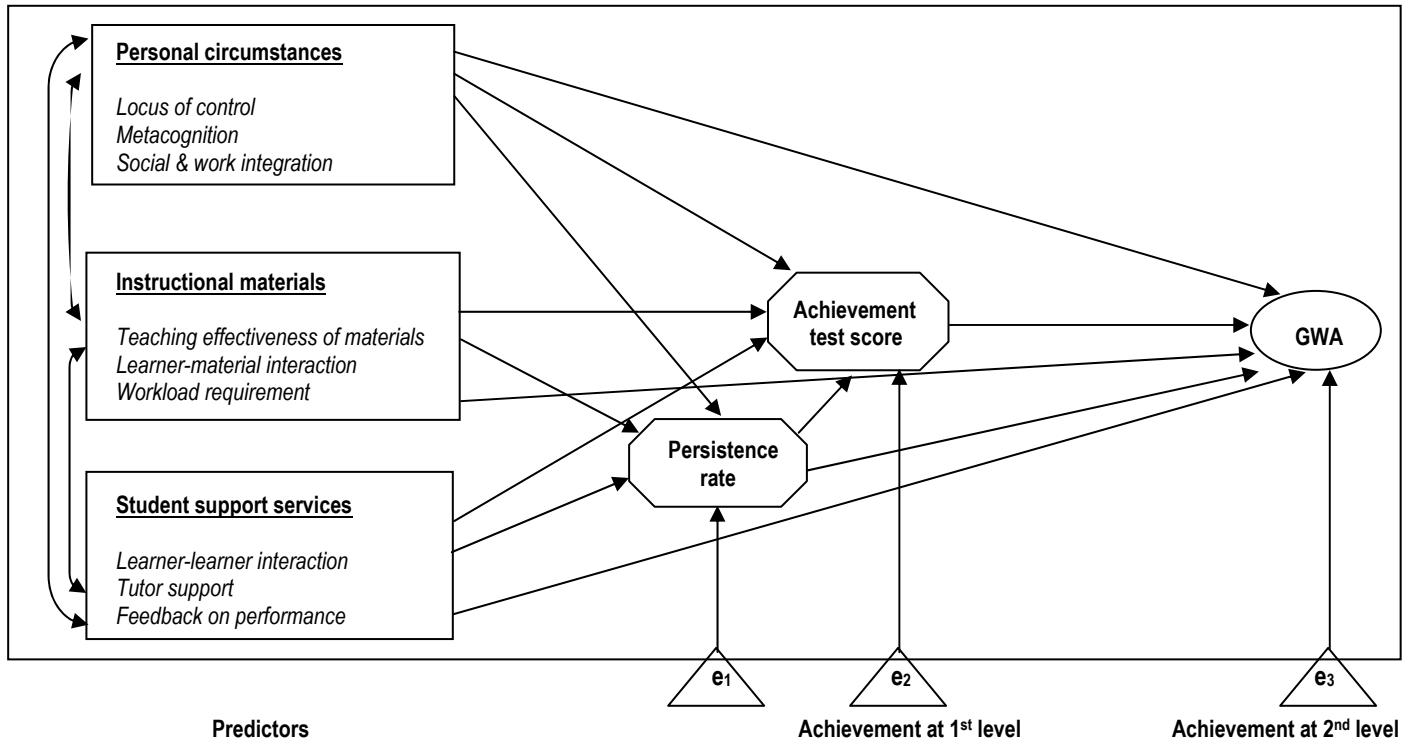
Figure 1

Figure 1   The Path Diagram Showing the Predictors of Distance Education Achievement

Independent, exogenous variable

Dependent, endogenous variable

Endogenous variable serving both as an independent and as a dependent variable

Error or disturbance term, residual variable

As shown in the path diagram, the direct straight arrows indicate causal effects while the curved two-headed arrows imply correlation. The correlations between exogenous variables, represented by the two-headed arrows, are not given causal interpretation in the path analysis. Moreover, the variable to which an arrow points is the dependent variable, and the variable from which an arrow originates is an independent variable.

The research process began by measuring the nine dimensions of distance education using an Evaluation Questionnaire for Distance Education (EQDE). The nine dimensions were operationally defined using a set of statements in a Likert-type five-point scale. The persistence rate was measured in terms of the completion rate (in percentage) of the required assignments and examinations, averaged per semester. The first level achievement was measured using the student's score in the Distance Education Achievement Test for Teachers (DEATT). Achievement at the second level, expressed as the GWA, was determined using the student's average grade in all courses taken in at least a four-semester period of study.

Method

The research design
The study adopted a survey-correlational design. Specifically, a cross-sectional static survey model was applied to a sample of randomly selected respondents. Using the static model requires that the variables be measured at just one point in time, which is a requirement in the application of the path analysis in social science and educational research (Tacq, 1997).

The participants
Participants were taken from the roster of students enrolled in the teacher education programmes of a state-owned distance learning institution. At the time of the study, all respondents were actively engaged in the teaching profession, either as teachers or trainers, at all levels of the educational ladder from the pre-school to the college levels. Table 1 presents the profile of respondents considered in the study.

Table 1 Profile of respondents

Degree	Gender					Age Group
Programme	Male	Female	Below 31	31-35	36-40	Above 40
DLST/MAEd	11	48	18	17	10	14
DMT	11	19	11	8	9	2
DSSE	9	15	7	8	3	6
DST	9	43	23	15	3	11
PhD in Ed	3	9	1	2	5	4
TOTAL (177)	43	134	60	50	30	37

DLST/MAEd - Diploma in Language Studies for Teachers/Master of Arts in Education
(major in Language Studies)
DMT - Diploma in Mathematics Teaching
DSSE - Diploma in Social Studies Education
DST - Diploma in Science Teaching
PhD in Ed - Doctor of Philosophy in Education (major in Science Education)

Among the 200 randomly drawn student-respondents, only 177 had provided complete data and were actually included in the study. Of these, 134 (75.7%) were females and 43 (24.3%) were males. A greater number of female respondents was observed across the five degree programmes included in the study. The mean age of the respondents was 32 years, with the range from 22 to 55 years.

The Research Instruments
Two types of instruments were developed and used to gather pertinent information and data. These were the Evaluation Questionnaire for Distance Education and the Distance Education Achievement Test for Teachers.

The Evaluation Questionnaire for Distance Education (EQDE)
The Evaluation Questionnaire for Distance Education (EQDE) is a two-part self-administered instrument. The first part was used to collect information about the respondents' general profile. The second part contained items which describe the nine dimensions of distance education. These items were a combination of 90 positive and negative statements, on a 5-point Likert-type scale. Respondents were asked to indicate their general perceptions (i.e., degree and disagreement) of the dimensions of distance education.

Before the pilot test was conducted, the content validity of the items was determined in order to ensure their effectiveness and worthiness as measures of the subsystems and dimensions of distance education. More specifically, EQDE items were examined and reviewed by two experts in terms of a set of criteria for writing and revising Likert-type items. Most of the items met the criteria. Those that did not were revised based on expert review.

After the content validation, the questionnaire was pilot tested in one study session class of the distance learning institution. Pilot test data were used to perform reliability analysis of the items using Cronbach's alpha, an internal consistency measure. An alpha value of at least 0.65 was used as index to retain the items. Reliability analysis of the EQDE items resulted in the retention of 58 items from the original 90 (Table 2). Cronbach's alpha for the entire questionnaire was 0.86, while alpha values for subsystems and dimensions of distance education ranged from 0.66 to 0.90. On the average, there were six to seven items retained in each distance education dimension.

Table 2 Cronbach's alpha values of retained items by distance education subsystem and dimension

Subsystems/Dimensions of distance education	Number of items		Cronbach's alpha
	Original	Retained	
Personal circumstances			0.89
Locus of control	10	5	0.66
Metacognition	10	6	0.71
Social & work integration	10	7	0.83
Instructional material			0.90
Teaching quality	10	7	0.82
Learner-material interaction	10	7	0.84
Work requirements	10	7	0.77
Student support			0.88
Tutor support	10	6	0.84
Learner-learner interaction	10	7	0.76
Feedback	10	6	0.80
TOTAL	90	58	0.86

The Distance Education Achievement Test for Teachers (DEATT)

The Distance Education Achievement Test for Teachers (DEATT) has been developed with the help of three subject matter specialists, one for each of the subject areas crucial to, or common among, teacher education programmes. These subject areas are Pedagogy (teaching principles and strategies), Educational Foundations (Educational Psychology Philosophy and Socio-Cultural Foundations) and Measurement and Evaluation.

The initial version of the achievement test consisted of 187 items measuring the content of the areas as presented and discussed in the course materials used by the students. Content validation of the achievement test was performed by the researcher with the assistance of a measurement expert, making sure that items matched the specifications based on the course materials prescribed for the three subject areas. After content validation, the instrument was pilot tested on the same group used for the EQDE.

Pilot test data were used to perform both item reliability and item analyses of the achievement tests. Reliability of test items was determined using the Kuder-Richardson (KR) 21' procedure, an internal consistency measure. Internal consistency of the entire test was quite high, with a reliability coefficient of 0.89 (Table 3). In the subtests, Measurement and Evaluation was the most reliable (r=0.72), followed by Educational Foundations (r=0.70) and Pedagogy (r=0.68).

Table 3   Number of items, means, standard deviations and KR 21' coefficients by subtests

Subtest	Number of items	Mean	Standard deviation	KR 21' coefficient
Pedagogy	40	24	5.36	0.68
Educational Foundations	61	28	6.33	0.70
Measurement & Evaluation	80	45	7.45	0.72
Overall test	187	97	18.31	0.89

Item analyses were also done by determining the difficulty and discrimination indices of the test items. Items that were very difficult, very easy and poorly discriminating were discarded; easy, moderately difficult and difficult items that were marginally and reasonably discriminating were revised or improved; and moderately difficult and difficult items which were discriminating or very discriminating were accepted.

Item reliability and item analyses of the test resulted in the retention of 125 items or 67% of the initial 187 test items (Table 4). Of the three subject areas, the most number of items retained were in Pedagogy (87%), followed by Measurement and Evaluation (63%) and Educational Foundations (57%). The final set of test items provided a somewhat equitable distribution of items across the three subject areas.

Table 4   Number of initial and retained test items by subject areas

Subject area	Initial pool of test items	Retained test items	
		f	%
Pedagogy	46	40	87
Educational Foundations	61	35	57
Measurement & Evaluation	80	50	63
Total	187	125	67

The data analysis procedure

Mean scores and standard deviations were used to describe student perceptions of the EQDE items. Responses to the Likert-type 5-point scale were coded such that a score closer to five indicated a more positive or favuorable perception toward an item, while a score closer to one implied a more negative or unfavuorable perception toward an item.

Means and standard deviations were also used to present and describe the persistence rate, achievement test scores and the GWAs of students. The t test was used to examine if significant differences in achievement (test scores and the GWAs) between males and females existed. On the other hand, the F test was deployed to determine significant differences in

achievement across age groups and degree programmes. The Tukey's Honestly Significant Difference (HSD) Test was applied for significant F values obtained. Tukey's HSD is a pair-wise comparison of the means technique used for identifying the nature and sources of significant differences found by the overall F tests. By applying Tukey's HSD, the researcher was able to determine which pair(s) of means brought about the significant F value.

Variables found to have significant beta coefficients at a=.05 were retained as important predictors. The causal paths or direct effects, as well as indirect effects of significant predictors, were examined and are presented in a fitted path diagram.

Results and Discussion

Dimensions of distance education
As a result of the validity and reliability analyses conducted on EQDE items, 19 items were retained in the personal circumstances subsystem, 20 in the instructional materials subsystem and 19 in the student support subsystem. Of the three subsystems, respondents gave the most favourable ratings to personal circumstances (M = 4.00, SD = 0.89), moderately favourable ratings to instructional materials (M = 3.70, SD = 0.91) and quite favourable ratings to student support (M = 3.18, SD = 1.12).

More specifically, respondents expressed highly affirmative perceptions on the locus of control and metacognition dimensions. The results imply the respondents' strong belief in their control of the various aspects of their learning situation (M = 4.27, SD = 0.86). They were also confident of their own abilities and limitations to enable them to acquire relevant knowledge and skills that have direct application to them (M = 4.02, SD = 0.85). Respondents also gave quite a high rating on their present circumstances as working, adult learners (M = 3.70, SD = 0.92). This is evidence of their competence and ability to attend to the requirements posed by work, family and social obligations in addition to the demands of their studies.

The respondents had a positive attitude toward the teaching effectiveness of materials (M = 4.10, SD = 0.86) and the quality of learner-material interaction (M = 3.84, SD = 0.96). The findings suggest that distance

learners generally perceived the course materials as well designed and carefully developed to satisfy the materials' main intent as instruments of effective instruction. Moreover, the course materials were considered user-friendly, providing a sense of "inter-personal relationship" between the learner and the materials, making the latter good substitutes for the face-to-face interaction in the traditional classroom. However, there was a general feeling among respondents that these materials created a heavy workload (M = 3.15, SD = 0.93) in terms of time and effort required from the students.

Distance learners expressed dissatisfaction with the lack of help obtained from fellow distance learners (M = 2.70, SD = 1.11). However, there was quite a favourable perception on the quality of support provided by tutors (M=3.53, SD=1.12). Distance learners who had a chance to interact with tutors perceived that tutors were a big help in facilitating high achievement among students, in explaining the requirements and objectives of the course, and in encouraging free expression of student ideas. Finally, the feedback dimension was given a nearly neutral rating (M = 3.30, SD = 1.12), to which respondents indicated that time-liness of feedback provided by tutors and faculty-in-charge (FIC) was quite poor.

The persistence rate
The persistence rate of distance learners was examined in terms of the percentage of assignments submitted and examinations completed, averaged per semester. Variations in the persistence rate according to gender and age groups were too small to yield significant differences. On the other hand, significant differences were found across degree programmes, $F_{(4, 176)} = 16.15$, p = .00. High persistence rates were observed among language studies (82%), social studies (80%) and PhD students (79%), while low persistence rates were exhibited by science teaching (59%) and mathematics teaching (71%) majors. A lower variability in persistence rates was also observed among the more persistent students, namely, language studies (SD = 10.4), social studies (SD = 15.7) and PhD (SD = 13.4) students. Science teaching majors significantly differed from all other students with respect to the persistence rate. Homogenous subgroups formed using Tukey's HSD analysis showed that language studies, social studies and PhD programmes clustered as one group, while science teaching and mathematics teaching programmes formed another group.

Achievement test scores

Item reliability and item analyses conducted on the achievement test resulted in the retention of 125 items from the original pool of 187 items. The average score (i.e., percent correct answers) for the entire achievement test was a little more than one-half or 51 percent. The highest mean score by subject area was observed in Measurement and Evaluation (56% correct answers), followed by Pedagogy (50%) and by Educational Foundations (46%). The greatest dispersion of test scores was obtained in Measurement and Evaluation, indicating that there was a wider spread of test scores among examinees in this subtest compared to the other two subtests.

Differences in test scores according to gender and age groups were not significant. However, the analysis of variance for degree programmes indicated significant differences in test scores, $F (4, 176) = 3.64$, $p = .01$, with language studies, social studies, and PhD students obtaining the highest scores. On the average, PhD students obtained 57% correct answers, followed by language studies and social studies majors, each with 53% for the entire test. Mathematics teaching students, who had the highest variability in the achievement test scores, achieved slightly lower scores (52% correct answers). The poorest test performance was exhibited by science teaching majors (46%). The pair-wise comparison of means using Tukey's HSD test revealed significant differences between the means of science teaching students and those of language studies and PhD students.

The general weighted average

The student's GWA was computed by averaging the student's grades in all subjects taken in at least a four-semester period of study. On the other hand, the grade in each subject was based on student performance in tutor-marked assignments, faculty-marked assignments and FIC-graded examinations.

The GWA, a longitudinal measure of achievement, was used to complement the achievement test, which is a one-time measure of achievement. The GWA is considered a summative indicator of achievement since it measures student performance not only on selected courses, as determined by the achievement test, but on all courses completed over a period of time. The intention of having a second

measure of achievement was to gain a better understanding of the nature and meaning of achievement and to find out what factors could bring about achievement, as measured in this study, in two different ways.

Differences in the GWA across gender and age groups were not significant. On the other hand, differences in the GWA across degree programmes were significant, $F (4, 176) = 18.13$, $p = .00$), with social studies, language studies and PhD students showing higher GWAs than the rest. Social studies and language studies majors both obtained mean GWAs of 1.94, followed closely by PhD students with a mean GWA of 2.01. The lowest academic performance was among the majors of science teaching ($M = 2.61$, $SD = 0.48$) and mathematics teaching ($M = 2.21$, $SD = 0.61$). These findings were similar to those found earlier for achievement test scores. Students with high achievement test scores also obtained high GWAs (DLST, DSSE and PhD); those with low achievement test scores also obtained low GWAs (DMT and DST). As found in the achievement test, wide dispersions in the GWAs were observed among mathematics teaching and science teaching majors.

Pair-wise comparisons of mean GWAs across degree programmes using Tukey's HSD test showed significant differences between the mean GWA of science teaching students and those of the students in the other degree programmes. This is not surprising because the mean GWA of science teaching students were extremely low ($M = 2.61$) compared to those of students in other degree programmes. This was further confirmed by Tukey's HSD which displayed only two homogeneous subgroups, the science teaching students and the rest.

Causal predictors of DE achievement
The direct, indirect and total causal effects of the significant independent variables are presented on Table 5. The application of the path analysis produced a total of ten significant independent variables with direct effects on the dependent variables and six with indirect effects.

In the fitted path diagram (Figure 2) for the first linear regression, learner-learner interaction (beta=0.36) and feedback on performance (beta=0.19) were the significant independent variables for the dependent variable persistence rate; in the second linear regression, metacognition (beta=0.17) and the persistence rate (beta=0.65) were the significant independent

variables for the dependent variable achievement test score; and finally, in the third linear regression function, metacognition (beta = -0.10), teaching effectiveness of course materials (beta = -0.09), learner-material interaction (beta = -0.20), learner-learner interaction (beta = -0.11), the persistence rate (beta = -0.79) and the test score (beta = -0.16) were the significant independent variables for the dependent variable GWA. With regard to indirect effect, metacognition, for instance, has an indirect effect on the GWA through the achievement test score.

Table 5   Causal effects of significant predictors of achievement

Regression Functions (RF)	Independent Variables	Causal Effects (beta)		
		Direct	Indirect	Total
RF 1 DV: Persistence rate	•Feedback (SS)	.19	-	.19
	•Learner-learner interaction (SS)	.36	-	.36
RF 2 DV: Test score	•Metacognition (PC)	.17	-	.17
	•Feedback (SS)	-	.12	.12
	•Learner-learner interaction (SS)	-	.24	.24
	•Persistence rate	.65	-	.65
RF 3 DV: GWA	•Metacognition (PC)	-.10	-.03	-.13
	•Learner-material interaction (IM)	-.20	-	-.20
	•Teaching quality (IM)	-.09	-	-.09
	•Feedback (SS)	-	-.17	-.17
	•Learner-learner interaction (SS)	-.11	-.32	-.43
	•Persistence rate	-.79	-.11	-.90
	•Test score	-.16	-	-.16

IM - instructional materials dimension
PC - personal circumstances dimension
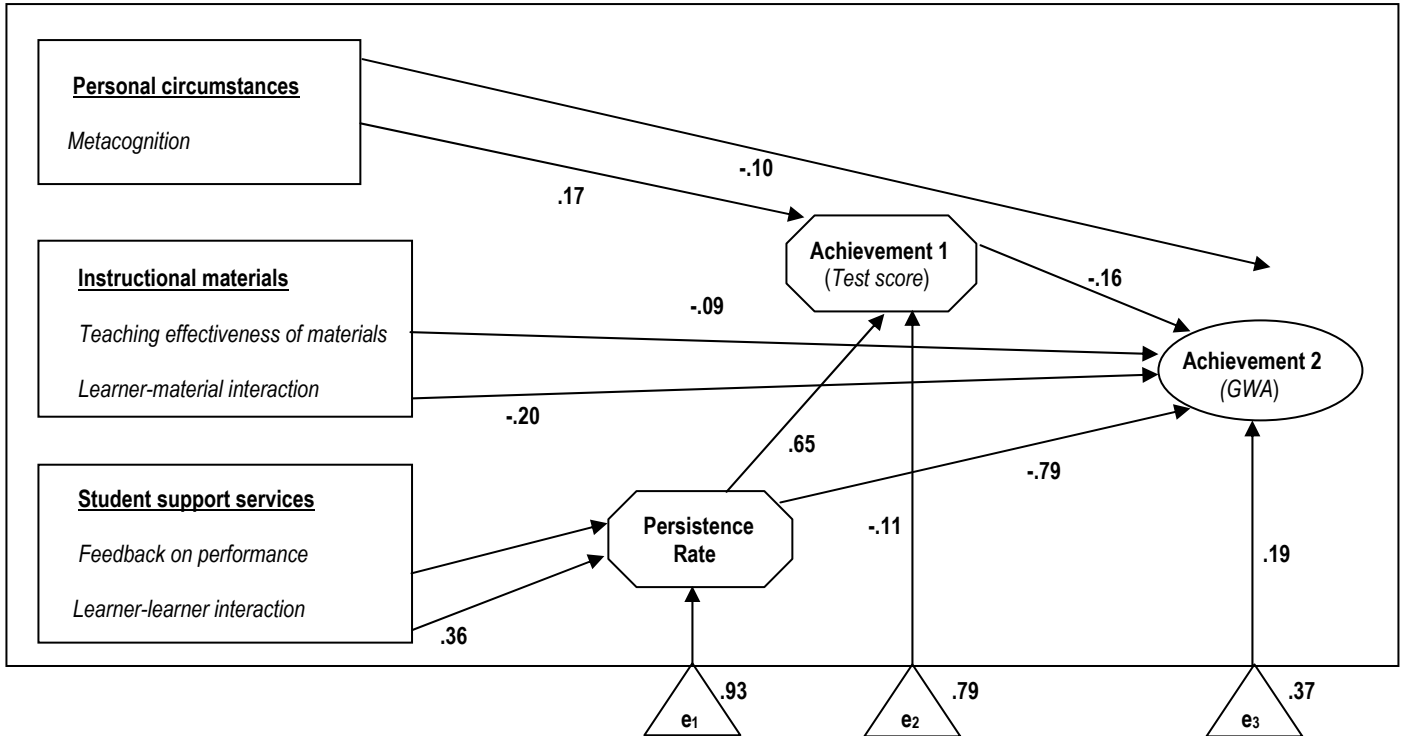SS - student support dimension

Figure 2

Figure 2   The Fitted Path Diagram Showing Significant Paths

It is also apparent that other independent variables affecting the dependent variables were not accounted for by the causal model. This is indicated by the path coefficients of the error components. The error components (e_s) or residual variance are factors not actually measured in the model but which do affect the endogenous variables. The path coefficient value of e is equal to $\sqrt{1 - R^2}$. Figure 2 shows the path coefficients of error components in the linear regression model, $e_1 = 0.93$ for the persistence rate, $e_2 = 0.79$ for the achievement test score and $e_3 = 0.37$ for the GWA. The coefficient 0.93 means that $(0.93)^2$ or approximately 86% of the variance in the persistence rate is not explained by the combined effects of the independent variables within the causal model affecting it. The value of 86% is the same as the unexplained variance in the persistence rate. For the achievement test score, the coefficient 0.79 suggests that $(0.79)^2$ or approximately 62% of the variance in the achievement test score is not explained by the combined effects of the independent variables within the causal model affecting it. Finally, for the GWA, the coefficient 0.37 implies that $(0.37)^2$ or approximately 14% of the variance in the GWA is not explained by the combined effects of the independent variables within the causal model affecting it.

Conclusions and Recommendations

While a number of significant predictors of achievement has been revealed in this study, the most valuable and common for both measures of achievement are metacognition and the persistence rate. It is also important to note that the only variables found to significantly affect the persistence rate are the dimensions of student support services such as feedback and learner-learner or peer interaction. Furthermore, the achievement test score provided an important prediction of student's grades. These factors seem to have the greatest influence on achievement in distance education. Distance education administrators whose desire is to enhance the achievement of distance learners should prioritise and give greater importance to improving these aspects of distance learning.

As regards metacognition, distance learning institutions can administer psychological tests to obtain the students' psychological profile, which may include aspects like readiness to accept the distance mode of study, learning style and work habits. The results of these psychological tests

can be used in designing specific student intervention programmes that capitalise on the strengths of the students while addressing their weaknesses.

Feedback is an important motivational factor which helps distance learners succeed in their studies. Not having a sense of how they are doing may be a drawback to the students' achievement motivation and hence, academic performance. It is, therefore, necessary that students be informed of their strong points as well as the areas for improvement. Timely response, mentoring and nurturing comments would also be very helpful.

On the dimension of learner-learner interaction, distance education providers should examine the feelings of isolation experienced by distance learners and address them appropriately. Students in this study have expressed the lack of support from fellow distance learners. With the implementation of online tutoring, students no longer have the opportunity to meet each other as they used to in face-to-face tutorial sessions. This could have further contributed to the feeling of isolation among students. Distance education providers should then consider this matter when using technology in the delivery of services, such as in tutorials. They may have to supplement technological innovations, such as online tutoring, with occasional group meetings among students for social interaction purposes. Study groups were particularly found useful in helping distance students develop effective study skills and for overcoming problems with the instructional materials.

With regard to the aspects of learner-material interaction, distance learning institutions should ensure that contents of the distance learning materials are more user-friendly, easy to comprehend and less burdensome in terms of allowing the learners to extract necessary information from the materials. Course developers should then improve these important aspects of the learning materials. On the other hand, the workload aspect of the instructional materials could be addressed in the periodic post-course assessment to determine the general perception of the students on the volume, difficulty level and pacing of academic work as presented in the materials. The results of such assessment should guide distance learning institutions in revising materials to address the perceived difficulty of instructional course materials because of their heavy workload requirements. This should guide course writers in incorporating the

adequate amount of workload into the materials that meets the learners' resources, capabilities and abilities, while maintaining the objectives of the course. This would then enable distance learning institutions to provide effective quality education without defeating the purpose of learning through the distance mode.

Finally, results of the achievement test provided a general picture of student performance on some important subject matter areas. These results should direct academic programme managers in distance learning institutions in improving certain aspects of relevant academic disciplines, which may be done through regular programme evaluation and curricular reviews. Results of these evaluations and reviews should then guide academic planners in the revision or refinement of the programme and curriculum design to better suit the needs and abilities of distance learners.

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