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Developing an Instrument for Assessing Learning Efforts among Engineering Students

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ABSTRACT

Assessment of learning efforts is important in providing a better understanding of learners of different disciplines. Lack of a valid and reliable instrument is making the assessment of learning efforts difficult. This paper describes the design and development process of a learning efforts instrument to be used among engineering students. The learning efforts items were generated based on Carbonaro's learning efforts model. He proposed that learning efforts constitute three components, namely, intellectual effort, rule-orientated effort and procedural effort. The draft instrument was judged by experts on its face validity and was subsequently distributed to 360 engineering students, who were instructed to rate their agreement to given statements. The subsequent reliability analysis and exploratory factor analysis supported the existence of two components. In conclusion, the data provided evidence that the efforts construct may be different from the learning efforts model proposed by Carbonaro in 2005. However, further analysis showed the existence of two components instead of three for the learning efforts construct that would fit the Malaysian education context. Thus, this paper provides evidence that replication research using the same instruments in cultural differences can provide differences in answers and outcomes.

Keywords: Exploratory factor analysis, instrument development, learning efforts

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INTRODUCTION

Intuition suggests that learning efforts are associated with academic achievement. Thus, learning efforts are of great interest to educators. Findings from studies on associations between learning efforts and academic achievement have not been consistent. While some have found positive associations (Mijid, 2014, pp. 11–14; Li, 2012, p. 178), others have failed to do so (Patron & Lopez, 2011, p. 6; Von Konsky, Ivins & Robey, 2005, p. 8). The inconsistency could be due to the lack of a valid and reliable instrument for assessing learning efforts as the constructs have not been adequately established. Indicators used to measure learning efforts vary from one study to another and choice of indicators seems to be based on the preference of researchers rather than on solid theoretical foundations. Among the indicators used are time spent on homework and attentiveness in class (Ceballo, 2004), total time spent finishing homework (Mijid, 2014, p. 8), attitude towards a course (Li, 2012), total time spent online (Patron & Lopez, 2011, p. 3) and self-report on efforts made to finish given assignments (Von Konsky, Ivins, & Robey, 2005). Mixed results have been found on the relationship between learning efforts and academic achievement depending on the indicators used. Total time spent on a course was not found to be associated with students' academic achievement (Patron & Lopez, 2011, p. 6). Total time spent on homework was also not found to be associated with success on the course (Mijid, 2014, pp. 11–14). Overall efforts based on self-reports were also not found to be associated with grades (Von Konsky, Ivins, & Robey, 2005, p. 8). Time spent on individual questions and the number of attempts students made to complete a question were associated with their grades (Mijid, 2014, p. 11–14). Attitude towards a course was also found to be associated with grades as shown by Li (2012, p. 179) in a study on the relationship between efforts and grades in a research methods course. Li's attitude scale is made up of four dimensions of attitude namely, affect, cognitive competence, value and interest. In summary, if learning efforts are indeed associated with learning achievement, then some indicators are better indicators for learning efforts than others. Thus, there is a need to identify valid indicators for a learning efforts construct to better assess learning efforts.

The ability to assess learning efforts will help in providing greater understanding on how efforts contribute to academic achievement among students (Li, 2012). Furthermore, some students and teachers feel that there is a need to include learning efforts in allotting grades for students' work (Weimer, 2012) as learning efforts on its own could be an indicator of learning outcomes. However, before the contributions of efforts can be considered in determining grades, they must first be assessed and quantified. To do that, there is a need to have a valid instrument to measure efforts, such as a construct but this has yet to be operationally defined. The purpose of this paper was to provide evidence for the validity and reliability of a new learning efforts instrument that was based on the learning efforts model proposed by Carbonaro (2005).

Carbonaro proposed that a comprehensive model of learning efforts should consist of three components namely, rule-orientated effort, procedural effort and intellectual effort. The rule-orientated effort entails students' compliance with the most basic rules and norms required by their learning institutions as well as refraining from misbehavior (Carbonaro, 2005). It can be viewed as students' attitude when bound by rules set by an institution. This component seems reasonable as compliance with rules has been shown to benefit learning; it has been shown that those who attend school regularly are at the advantage of performing better academically than those who fail to display this attitude (Korir & Kipkemboi, 2013, p. 90). Compliance efforts, however, can be influenced by other factors. For example, quality of relationship between students and teachers was also one variable that significantly predicted learning for the entire racial or ethnic group (Lundberg & Schreiner, 2004). It was the strongest predictor in the model of Asian/Pacific students, Mexican and American students. In designing the rule-orientated effort items for the new instrument, frequency of attendance, compliance with rules and adhering to norms by institutions were the main indicators used.

The second component i.e. procedural effort refers to the effort made in relation to meeting the demands of a specific course. The procedural effort requires students to try to meet specific demands set forth by a teacher, including completing assignments on time and participating in class discussion (Carbonaro, 2005). Procedural effort is an important indicator as student and faculty interactions, peer involvement and accessibility cues are significantly related to GPA. For the new instrument, data on respondents' procedural efforts were gathered from a report on students' tendency to follow rules set by lecturers.

The last component, intellectual effort, refers to efforts made in overcoming learning challenges. When students apply their cognitive faculties towards understanding any intellectual challenges posed by the curriculum, they are said to be making intellectual effort (Carbonaro, 2005). An example of intellectual effort is drill and practice, which is good for learning new skills as people become more proficient at what they practise. Such indicators for intellectual effort are easier to measure since any sort of training and self-development is considered individual behaviour that helps one to face challenges. A strong positive and consistent relationship has been found between the time students spent on and engaged in learning and their subsequent achievement performance (Ceballo, 2004). Figure 1 illustrates Carbonaro's model for learning efforts. Carbonaro also provided the sources that were used to establish the indicators for a learning effort model. The references and sources used by Carbonaro to support and explain the learning efforts model are Cullinan (1992), Ceballo (2004), Bloom (1974), Korir and Kipkemboi (2013) and Lundberg and Schreiner (2004).

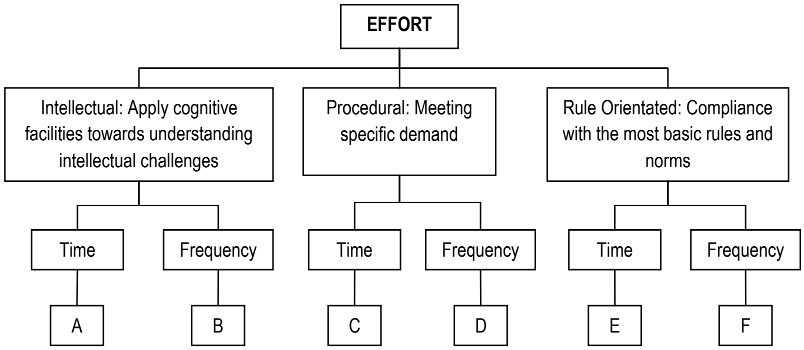

Figure 1. Carbonaro's tri-componential learning efforts model

METHODOLOGY

Best practice on instrument development suggests a three-stage instrument development process namely, designing (formulating a conceptual definition, choosing an operational definition, identifying indicators, developing test items), evaluating and validating, refining and confirming. Based on Carbonaro's (2005) conceptual definition of efforts, 30 items were constructed initially. The items were refined in terms of language accuracy and grammar. The draft instrument was printed on A4 paper and prepared for evaluation. A 5-point Likert scale was used for recording responses from respondents. The respondents were asked to state their level of agreement to given statements, where 1 indicated 'Strongly disagree' and 5 indicated 'Strongly agree'.

The initial draft instrument was evaluated by experts on its content and face validity. Items found to be lacking were subsequently refined. Only qualitative feedback was gathered at this stage. After the first revision, instrument evaluation was carried out on a group of engineering students. Questionnaires were distributed to 400 respondents, who were first-year engineering diploma students from Universiti Tun Hussein Onn Malaysia (UTHM) and University of Malaysia Perlis (UniMAP). First-year students were chosen as they were at the stage where intentional effort is at the highest due to being newly enrolled in a university. Three hundred and sixty questionnaires were completed and analysed. Subsequently, reliability coefficients were estimated using Cronbach's Alpha and exploratory factor analysis was conducted on the completed questionnaires.

Thirty items were divided into three constructs, each construct having 10 items. Efforts were measured in terms of intellectual, procedural and rule-orientated aptitudes. The measurement conditions followed a set of measurable actions of time and frequency. In the frequency consideration, the respondent's repeatability or consistency in tasks was considered as effort, while time spent on learning and practicing to obtain knowledge was considered one of the measureable components. Demographic background was used as descriptive information regarding the respondents. The reliability measure using Cronbach's Alpha was conducted to estimate the reliability of the scales. Due to redundancy and weak inter-item correlation, seven items were deleted from the original instrument, resulting in only 23 items being retained in the final draft. The reliability estimates for each component of the effort scale are shown in Table 1.

Table 1
Reliability estimates for the effort scale

Item	Number of items	Alpha value
Intellectual scale	9	0.84
Procedural scale	7	0.84
Rule-Orientated effort	7	0.82
Total	23	0.92

Exploratory Data Analysis (EDA) was conducted to ensure that the data were screened with respect to sampling distribution, accuracy of data entry, detection of mistakes and missing data treatment. Statistical tests including normality and homogeneity were carried out to ensure suitable data for further analysis. The analysis of data began with descriptive statistics.

RESULTS

The demographic characteristics of respondents relating to gender, age, institutions and programme taken are shown in Table 2.

Table 2
Demographic profile (n=360)

Variables	*f*	%	Variables	*f*	%
1. Gender			2. Institutions	246	68.30
Male	185	51.40	UTHM	114	31.70
Female	175	48.60	UniMAP	360	100.00
Total	360	100.00	Total		
3. Age (years)			4. Programme of study		
18-20	279	77.50	Mechanical Engineering	144	40.00
21-25	76	21.10	Civil Engineering	137	38.10
26 and above	5	1.40	Electrical Engineering	79	21.9
Total	360	100.00	Total	360	100.00

Further investigation into the structure and validity of the items was carried out using the Exploratory Factor Analysis (EFA) method. EFA was used to access the underlying structure of a new construct for Carbonaro's (2005) learning effort model. The EFA helped to reduce the numerous variables to a limited number of latent variables that were inter-correlated. Prior to conducting the Exploratory Factor Analysis (EFA), statistical assumptions such as univariate normality, adequate sample size, linearity, factorability and others were conducted to check the suitability of the data. First, the researchers checked the normality tests using skewedness and kurtosis, and the results showed that the sample distribution was normal. Sampling adequacy was proven using the Kaiser-Myer-Olkin measure of sampling adequacy (KMO) and sphericity was tested using Bartlett's test. The results indicated that the KMO measure was 0.910, which is greater than 0.5, while Bartlett's test of sphericity was significant ($p<0.5$, $P=0.00$), thus the null hypothesis was rejected. Bartlett's test suggested that the sample inter-correlation matrix did not come from the same population, while the KMO result suggested that there was correlation among the items tested and the degree of common variance among the variables was "marvelous." Since the KMO measure of sampling adequacy and Bartlett's test of sphericity were fulfilled, factorability was assumed. According to Salleh, Sulaiman and Gloeckner (2015), the KMO index ranges are from 0 to 1, and if the KMO value is above 0.60, it is considered suitable for factor analysis. Similarly, Beavers et al. (2013) suggested that the KMO measure of sampling adequacy is a test of shared variance between the items. They suggested the guideline for assessing the measure that is shown in Table 3.

Table 3
Interpretation guideline for the Kaiser-Meyer Olkin Test (Beavers et al., 2013)

KMO Value	Degree of Common Variance
0.90 to 1.00	Marvelous
0.80 to 0.89	Meritorious
0.70 to 0.79	Middling
0.60 to 0.69	Mediocre
0.50 to 0.59	Miserable
0.00 to 0.49	Unacceptable

The EFA, using the maximum likelihood method with oblique rotation, was conducted to assess the underlying structure for 23 items. The correlation matrix indicated that the correlation coefficients were over 0.4. In this analysis, the factor extraction method using the Eigen value and scree plot were employed to determine how many factors would remain. Two factors were eventually extracted when the Eigen value was greater than 1 and was prefixed along with the scree plot breaking point (or elbow) at two factors. Figure 2 illustrates the scree plot with Eigen values on the y-axis and factor numbers on the x-axis. The figure suggests that two factors may have been appropriate for retention of the breaking point where the curve flattens. The post-rotation sum of squared loading explains the comparison between the two factors, with each factor having almost similar small loadings. Thus, the communalities after factor extraction were acceptable.

A rotated factor loading of at least 0.40 or greater is to be considered in new variables, with loadings less than 0.40 omitted to improve clarity. Additionally, the direct oblimin rotation method with Kaiser Normalisation was performed. After removing all items with standardised loadings of less than 0.40, the resulting two factor solutions appeared. The factor pattern matrix showed the two factors and consequently, 18 items were retained in the new construct. The result from the pattern matrix was used to interpret the factors. The factors reproduced 38.82% of the variance of the measured variables in Factor 1 compared to 9.02% in Factor 2. The total communality coefficients for the overall factors were 47.84%. Finally, the factor saturation in the EFA revealed the presence of a two-factor solution, with a ninth loading preferentially on Factor 1 and a ninth on Factor 2. The first factor appeared to represent Intellectual Effort, while the second factor represented 'Compliance Effort'. Table 4 shows the new factors and explains the percentage of variance.

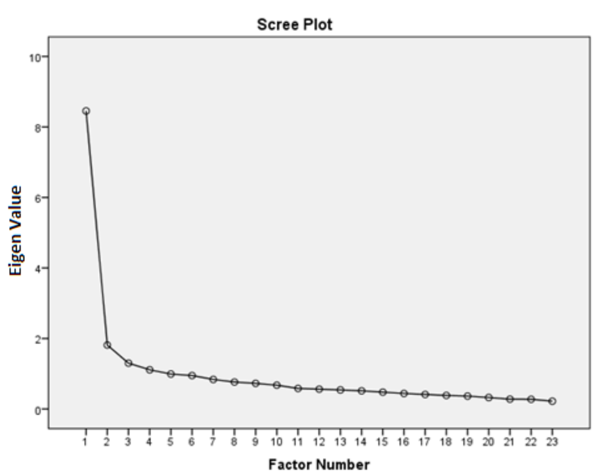

Figure 1. Scree plot for effort items

Table 4
New construct of effort with percentage of variance

Scale Items	Factor Loadings		Com
	Factor 1	Factor 2	
I am keen to ask whenever I do not understand a lesson.	0.733		0.469
I spend time practicing in order to enhance my skills before any test.	0.643		0.427
I always desire to adopt the techniques of learning of friends who are successful.	0.632		0.367
I always contribute to ideas during brainstorming sessions in a group.	0.587		0.319
Whenever I study, I tend to write notes in order to remember and answer successfully in exams.	0.587		0.358
I spend time asking friends questions in order to make sure that I understand everything regarding the lesson whenever I have time to do so.	0.571		0.347
I always join small study groups before an examination.	0.505		0.242
I spend time to learn consistently.	0.489		0.333
I follow a schedule for class.	0.449		0.393
I always send most of my assignments on time.		0.853	0.674
I always send my assignments on time.		0.847	0.610
I always finish my assignments according to the specifications set by the lecturer.		0.730	0.602
I am always on time for classes.		0.634	0.515
My attendance for a year has never been less than 80%, qualifying me to sit the final examination.		0.621	0.338
I always try to achieve 100% university attendance.		0.620	0.375
I always abide by the attire code set by the university.		0.586	0.450
I always abide by university rules.		0.485	0.300
I consult the schedule for class.		0.466	0.353
Eigen values	6.988	1.624	
% of variance	38.824	9.021	

Note: Loadings < 0.40 are omitted
Com = Communalities

DISCUSSION AND CONCLUSION

The findings of this study contradicted with Carbonaro's proposed model. While Carbonaro proposed that three factors constitute learning efforts, data from the Malaysian study only confirmed two factors namely, intellectual effort and compliance effort. Although the findings were different from the proposed model (Carbonaro, 2005), the findings were expected. In Asian culture, compliance with social norms is expected. A person who is wise would abide by their society's norms (such as an institutional regulations) and would be less likely to go against them (Salleh & Sulaiman, 2012). Anyone who respects social norms would also tend to abide by procedures set by people in authority such as lecturers or teachers since the culture respects and values authority and their set rules. This is in contrast with Western culture, where personal freedom of choice is highly valued. So a person orientated to Western culture, who abides by an institutional rule may not act similarly when confronted by a set of prescribed procedures. As a consequence, the two components, which may be observed as two separate constructs based on responses from a Western-based culture, merge to become one construct for data based on responses from the East. Thus, the two-component construct for learning efforts is supported.

The instrument can be said to be valid and reliable for assessing learning efforts of engineering students in Malaysia. This study is of great relevance as it provides evidence for differences in construct definition where cultural differences exist; this highlights the need to reassess the validity and reliability of an instrument when used on a new target group that is different from the original intended application. Further confirmatory studies can be conducted to establish the generalisability of the findings.

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