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FACTOR ANALYSIS IN IDENTIFYING DOMAINS OF A LEARNING TOOL INSTRUMENT

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Abstract

Statistics is one of the most important quantitative subjects in higher education. However, statistics subject is unappealing to many average students with varying background. Traditional teaching method of statistics which tend to emphasize on rote learning and heavy calculations can cause students to have negative perception thus stir anxiety towards statistics learning. Therefore, to address all these negative perceptions, it is important for educators to make a significant improvement in their teaching approach to make learning more dynamic, meaningful and inspiring. This study is aimed primarily to highlight the factors of a research instrument used to evaluate the implementation of a developed interactive learning tool namely XRace game board in providing active learning. An exploratory factor analysis suggested that out of 33 variables evaluated, there are six domains which account for 71.78% of the total variance which considerably reduce the complexity of the data set with 28.82% loss of information. Kaiser-Meyer-Olkin value is 0.895 and Bartlett's test p-value=0.000 < 0.05 indicate factor analysis is feasible for this data set. There is no item removed since the communalities values are all above moderate (min=0.583, max=0.837). The principal component analysis with Varimax rotation method revealed six domains in term of Motivation, Novelty, Fun learning, Commercialization, Product features and Eco friendly. The results suggested that these six important domains were considered in the evaluation of the learning tool and the possibility of utilizing it in teaching any difficult courses in an interesting and engaging way without loss of rigor.

Keywords **–** Innovation in Education; Experiential learning; Learning tool; Statistics; Exploratory factor analysis.

1.0 INTRODUCTION

Most tertiary level students are required to undertake statistics courses as a requirement to complete their programs of study. Unfortunately, they tend to think that statistics is unpleasant and difficult subject for them to score. Educators need to address this problem especially in the era of industrial revolution 4.0 where knowledge and technology is growing exponentially. Recently, there have been increasing number of articles on experiential learning. An experiential learning is the process of learning through experience and it is used as one of the teaching method to develop interest and motivate students in learning statistics. In line with the effort, some researchers developed game boards as a medium to initiate experiential learning among students (Sato & Haan, 2016;); (Ali, Jamil, Ahmad, Mohamed, & Yaacob, 2017). As a result, students reported positive attitudes towards the subjects and enjoyed the learning approach very well.

An interactive learning tool has been viewed as a potential tool for helping students increase motivation, gain a deeper understanding and develop better problem solving skills. It is also becoming an important tool to aid student self-learning. By using the developed tools such as the learning system SMART+ (Botta, Giordana, Informatica, Torino, & Svizzera, 2002), an electronic student response system (SRS) (Cue, 1998), digital lecture board (Geyer & Effelsberg, 1998), psychological or semiotic tools (Wall & Higgins, 2006), ubiquitous mobile technologies (Maag, 2006), reading aloud (RA) (Gibson, 2008), online learning tool (Feild, Lewkow, Burns, & Gebhardt, 2018), and peer observation (Ahmed, Nordin, Shah, Education, & 2018, 2018), students will be able to use the material at their own time, repeatedly until they understand a particular concept.

XRace game board is a game board prototype developed to enhance teaching and learning basic Statistics subject in the Faculty of Computer and Mathematical Sciences, UiTM Negeri Sembilan. It is a multi-level pyramid structure which represents questions at different levels of difficulty. It incorporates game strategy and cooperative learning. In an effort to move away from the traditional formal education, XRace promotes student-centered learning and elements of cognitive and soft skills was enhanced.

In order to assess the learning tool, research instruments were constructed and distributed to 122 basic statistics students who play-tested the tool. The instrument has 33 items on Likert scale response categories ranging from 1(Strongly Disagree) to 10 (Strongly Agree). Exploratory factor analysis (EFA) was then used to analyze and identify a smaller number of factors (or clusters or groups) and categorized 33 variables into these factors or domains. EFA is widely used in many social sciences studies. For example in the study of self-determination students with autism spectrum disorders (ASD)(Chou, Wehmeyer, Shogren, Palmer, & Lee, 2017), measuring family outcomes (Chiu, Seo,

Turnbull, & Summers, 2017) and academic staff satisfaction with the university (Daniel, 2017).

This study aimed to investigate and identify the features of XRace game board research instrument using EFA. The results obtained will be used to help in determining XRace potential as an innovation alternative teaching tool conducive for students' motivation and enjoyment of learning statistics.

2.0 METHODOLOGY

Factor analysis is a technique that is used in this study to reduce a number of variables x_1, x_2, x_3,…,x_n into fewer number of domains. Therefore, the number of variables must be greater than the number of domains, besides there should not be any multicollinearity problem between the variables. Another critical assumption of EFA is its appropriateness for sets of non-nominal variables, where interval data are assumed. Again, this study applied EFA that assumes any variable may be associated with any domain.

This procedure has several steps including of prior analysis, factor extraction, factor rotation, factor loading and factor labeling. The prior analysis included the Kaiser-Meyer-Oikin (KMO) and Barlett's test to determine whether exploratory factor analysis is feasible or not. Kaiser-Meyer-Oikin (KMO) should account the higher value and Barlett's test should account the smaller significant value (p-value). Related together, these figures provide a prerequisite which should be passed before conducting the exploratory factor analysis. Communality is the extent to which variable correlates will all other variables. If communality for a particular variable is less than 0.4, then the variable may conflict to load significantly on any domain and it is considerable to remove that particular variable.

The output generally revealed the eigenvalues when we choose principle component analysis as the method of factor extraction. Several methods are available, but principle component analysis is most commonly used. According to Kaiser Criterion, eigenvalues is a good criterion for determining a factor where it should be considering as a factor when the eigenvalue is greater than one. Besides, cumulative amount of the total variance for different domains is very useful to describe the data. The higher the cumulative amount of the total variance, the lesser information will be missing. Scree plot were used for the graphical support in factor extraction which displays a downward curve that revealed the optimal number of domain to be retained in the analysis.

Next after factor extraction, SPSS will rotate the domains to better fit the data. The next procedure is to select a rotation method. Varimax is an orthogonal rotation method that produces independent factors which is necessary to overcome the multicollinearity problem by minimizing the number of variables that acquire high loadings on certain factors. Again, several methods are

available, but Varimax rotation is most commonly used. Also, Varimax rotation method will assist to simplify the interpretation of the factors based on the higher loading factors for each component.

3.0 ANALYSIS AND RESULT

Essentially, 33 variables showed Cronbach's alpha score of 0.955 and there is no item removed considering the communalities values are all above moderate (min=0.583, max=0.837). It is considerable to remove that particular variable if communalities for a particular variable are less than 0.4 on account of the variable may conflict to load significantly on any factor.

Table 1
The Summaries of the First Run Domains

Variables	Variables Removed	Cronbach's Alpha	Communalities
33	0	0.955	Min=0.583, Max=0.837

Results below shows the Kaiser-Meyer-Olkin (KMO) value of 0.895 and a significant result (Sig. < 0.05) indicates matrix is not an identity matrix which means the variables do relate to one another enough to run a meaningful EFA. Related together, these figures provide a prerequisite which should be passed before conducting exploratory factor analysis.

Table 2
Kaiser-Meyer-Olkin (KMO) and Barlett's test

Kaiser-Meyer-Olkin		0.895
Barlett's test	p-value	0.000

The initial number of domains is the same as the number of variables used in the EFA. However, not all 33 variables will be retained. Table 3 shows only six domains will be retained from the extracted solution considering the eigenvalue with more than one which account for 71.18% of the total variance which considerably reduce the complexity of the data set with only 28.82% loss of information.

Table 3
Eigenvalues and Factor Extraction

Domain	Eigenvalue	Percentage of variance	CPTV
1	14.643	44.372	44.372
2	2.719	8.239	52.611
3	1.973	5.980	58.591
4	1.770	5.365	63.955
5	1.217	3.689	67.644
6	1.166	3.533	**71.177**

*CPTV: Cumulative percentage of the total variance

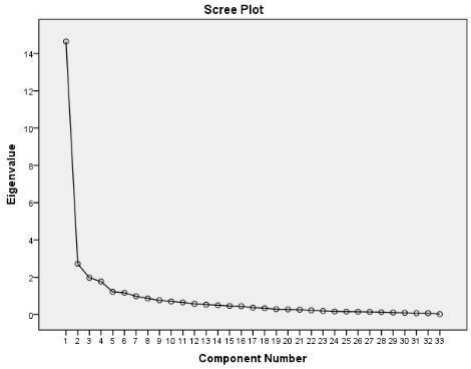

Figure 1: Scree plot

Scree plot shown in Figure 1 were used for the graphical support in factor extraction which displays a downward curve that revealed the optimal number of component to be retained in the analysis. The scree plot graphs the eigenvalue against the factor number. It significantly shows that only six domains will be retained which is similar with the results from the extracted solution. From the sixth domain onwards, the line is almost flat accounting for smaller and smaller amounts of the total variance.

Seven items that were loaded onto Factor 1 were labeled as 'Motivation'. As illustration, refer to the first row, the highest loading is 0.546 that load on component 1. Next row account 0.776 as the highest loading that loads on component 1 and so on. Five variables that were loaded onto Factor 2 were labeled as 'Novelty'. Eight variables that were loaded onto Factor 3 were labeled as 'Fun learning'. Four variables that were loaded onto Factor 4 were labeled as 'Commercialization'. Six variables that were loaded onto Factor 5 were labeled as 'Product features' and three variables that were loaded onto Factor 6 were labeled as 'Eco friendly'.

Consequently, this study found six important domains of the XRace research instrument. Table 5 listed all these domains. It is observed that two domains, Motivation and Fun Learning are related to learning whereas the other four domains are related to the product features.

Table 4
Varimax with Kaiser Normalization

Variables	Components					
	1	2	3	4	5	6
23	.546	.136	.512	.195	.314	-.022
24	.776	.084	.279	.123	.029	.060
25	.685	.202	.171	.173	.263	.053
26	.695	.265	.318	.134	.333	.036
27	.776	.206	.211	.288	.201	.155
28	.794	.222	.165	.293	.190	.158
29	.692	.098	.375	.100	.135	.211

1	.197	.782	.031	.116	.168	.006
2	.085	.859	.113	.154	.089	-.001
3	.231	.788	.109	.113	.206	.019
4	.154	.863	.128	.080	.162	.026
5	.064	.767	.269	.202	.097	.251
6	.272	.317	.467	.465	-.043	.000
14	.312	.120	.714	.377	.079	.117
15	.316	.150	.617	.461	.073	.155
16	.356	.430	.619	.105	.124	.260
17	.224	.180	.729	.281	.022	.320
18	.207	.500	.583	.126	.222	.025
19	.159	.123	.670	.193	.361	.229
22	.362	.005	.620	.225	.422	-.070
7	.183	.376	.303	.595	.050	.040
8	.022	.173	.253	.658	.428	.055
9	.337	.102	.229	.705	.103	.226
10	.267	.138	.265	.718	.111	.138
20	.327	.095	.325	.101	.529	.320
21	.078	.255	.183	.008	.725	.108
30	.311	.204	.136	.331	.665	.160
31	.417	.256	.121	.121	.537	.159
32	.466	.156	-.065	.327	.494	.072
33	.320	.124	.061	-.025	.368	.221
11	.150	.117	.172	.530	.075	.536
12	.107	.036	.179	.098	.189	.846
13	.140	.041	.097	.144	.170	.870

Table 5
Factor label of all 33 variables into 6 domains

Domains	Variables
1 (Motivation)	- Encourage determination to solve problems - Encourage hard work to win the game - Requires strategic thinking - Requires thinking skill. - Improve rapport with friends. - Improve communication skills. - Improve confidence.
2 (Novelty)	- Originality - Uniqueness - It is a new game. - Different from the others - Innovative
3 (Fun learning)	- A suitable learning tool for self or group study - Help to increase learning interest - Learn in a fun way - Enjoy playing the game - Engaging game. - New learning game - Help to enhance learning as compared to the traditional and online learning - Encourage Mathematics/Statistics learning

4 (Commercialization)	- Suitable for learning at school, college or university level - Commercial value - Marketability - Recommendation to friends /relatives.
5 (Game elements)	- Easy to understand the rules - A challenging game - Challenging questions - Thrilling elements of the mystery cards - Attractive layout. - Sufficient time to answer the questions
6 (Eco friendly)	- Fair use of local materials - Probability - Easy storage.

4.0 CONCLUSION

The greatest beneficiary of the XRace game board is the students. This product was constructed so that experiential learning can be promoted to help students acquire knowledge and soft skills better than the traditional method. Besides, the game strategy used provides a conducive learning environment where motivation and inspiration are nurtured. This study is able to identify six important domains in evaluating students' perceptions on the XRace game board. It is hoped that these results can boost the product potential therefore there is a need to document its development. Future research is recommended to proceed with the predictive model using multiple regression analysis to see the significant contribution of these six domains.

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