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Partial Least Squares Modelling of Classroom Layouts to Learning Motivation and Student Performance

[1] Karl Benedict Ong, [2] Jazmin Tangsoc, [3] Jose Edgar Mutuc [4] Richard Li [5] Willy Zalatar
[1] De La Salle University, [2] De La Salle University, [3] De La Salle University, [4] De La Salle University, [5] De La Salle University
[1] karl.ong@dlsu.ed.ph, [2] jazmin.tangsoc@dlsu.edu.ph, [3] jose.edgar.mutuc@dlsu.edu.ph, [4] richard.li@dlsu.edu.ph, [5] willy.zalatar@dlsu.edu.ph

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Abstract:

Building constructions and renovations require large amount of investments for educational institutions. However, classroom layout is a low-cost design factor that can significantly improve the performances of students. This research considered seat arrangement, seat distances, and seat assignment schemes, and its relationship to learning motivation and student performance. Mediating factors, which are social interaction and comfort level, found significant were included in the analysis of the relationships.

Through a partial least squares modelling in SMART PLS, it was found that all path coefficients are supported, therefore significant. However, their ability to predict the endogenous variables are unequal. Social interaction is a strong predictor while participation level is a stronger indicator of student performance. Multi-group analyses on the layout design components and other factors uncovered that the significance of motivation and participation level of students are greatest for the u-shaped layout, and seat distances influence the relationships for boxed and u-shaped, but not for clustered design.

Keywords: *Classroom Design, Educational Ergonomics, Partial Least Squares Modelling, Room Layouts*

I. Background of the Study

With advancements in educational systems globally, the performance of students significantly improved over the years [1]; however, the rate of improvement for every student is unequal [2]. Total equality in education naturally does not exist due to the varying economic and political issues present in all nations as well as the differences in the environments where students are exposed [3]. Variability in performance does not only exist in education. It is universal to human condition and in all fields of human science, such as anthropometry, cognitive proficiency, and learning, variability is observed as natural phenomena [4]. A core principle of Human Factors and Ergonomics (HF/E) explains that interdependence exist between performance and design, such that neither can be realistically assessed in isolation [5]. This interaction between design and performance captures the essence educational ergonomics. Reference [4] defines educational ergonomics as a branch of ergonomics that attempts to understand the interaction between educational design and student performance. Despite the existence of the field, the benefits of HF/E applications to the design of educational systems that may improve student learning are not yet fully recognized [6].

Reference [7] reviewed existing studies and found that classroom and school building design factors are

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critical to explaining student performance. The research stated that the performances are directly influenced by the level of quality of the facilities, where teachers and students conduct learning activities daily. A relatively early study identified chair design, air quality, and noise as primary classroom design factors needing improvement, and the study provided an estimate that poor classroom design and maintenance lead to decrements of 10–25% in student performance [8]. Reference [9] supported this claim through summarizing evidence that the academic performance of K-12 students is adversely affected by poor control of classroom environmental indoor air, room ventilation, temperature, humidity, thermal comfort, lighting and acoustic quality.

The classroom environment has been found to have significant relationships with students' comfort, social interaction, performance, and satisfaction. Therefore, the design of the classroom should be highly considered by school administrators. Appropriate indoor environmental qualities of air, temperature, sound, light, visible and physical space, and occupants' ability to personally control these are key to improving the students' well-being and performance. Reference [10] tested the significance classroom ergonomics design factors by administering a satisfaction survey to 621 students and testing each factor to their overall satisfaction of the course.

This study explores the relationship of classroom layout designs and its components to student performance as measured by test scores and participation. Based on the existing studies reviewed, research gaps were identified that would be addressed in this research.

Reference [11] reviewed literature on the different possible effects of altering the classroom layout. Their empirical study listed student motivation, social interactions, and comfort level as factors that may significantly be affected by the classroom layout, but no study has incorporated these three constructs as variables that affect the main objective of educational ergonomics, which is optimizing student performance. Therefore, for this study, the three constructs will be tested to see how much it can explain student performance and possibly provide insights on the importance for students, teachers, and administrators.

Learning motivation, social interactions, and comfort level are latent constructs, which can't be directly observed and measured. An effective method of measuring latent constructs is through questionnaires that must be validated to ensure its ability to capture the ideas of different relevant factors. This study adopted questionnaires that were validated and this include the Motivated Strategies for Learning Questionnaire (MSLQ) [12], Social Context and Learning Environments (SCALE) survey [13], and Comfortability-in-Learning Scale (CLS) [14]. Items from the existing questionnaires have been modified and translations were provided to the test subjects.

Reference [15] measured student performance with the level of participation of each student. Alternative seat arrangements were used in the study and self-administered questionnaires were answered by the students before and after the experiment to see observe the changes in participation level. Another construct considered in their study are the social interactions that occur in the classroom. They found that social interactions have a positive relationship with participation. However, the measurement of participation is based on the perception of the students alone. In contrast, this study will utilize the teacher's evaluation to arrive on a better representation of the level of participation each student exhibits by reducing the personal bias that occurs when a self-administered questionnaire is used.

II. Motivation

In recent years, there is an increasing focus on the topic of layout and how they affect student performance. Research most often explores the effect of varying arrangement on student engagement and social interaction [16], [17]. Other topics of research discuss the conditions surrounding students which impact student academic achievement, including seating location within the classroom [18].

Optimizing the performance of the students in the classroom should be a priority of educational institutions. While improving curriculum and teaching quality can improve educational quality, investments in better facilities contribute to improving quality. Constructing better buildings and adopting technology benefits the school, but it requires massive investments. However, improving facilities may mean configuring the existing facilities available in the classroom and school, which can involve less investments for school administrations, and one area rarely explored is the configuration of the layout of the classroom. Institutions must acknowledge that learning and pedagogy are constant updating, so they must commit themselves to proper facilities planning. To cope with modern education, the classroom should be updated not only with modern technology, but as well as the layout of the furniture inside. The goal of this study is to contribute knowledge in improving classroom design to improve the quality of education, and consequently, the performance of the students.

III. Objectives

Due to the lack of studies that explore the relationship of classroom layout design components with learning motivation and student performance, there is a need to develop a participatory ergonomic experiment that incorporates multiple alternative classroom layouts to assess its effect on quantitative test scores and student participation. This study considers the following objectives:

- Understand the relationship of the classroom layout design factors to student performance as measured by test grades
- Understand the relationship of the classroom layout design factors to student performance as measured by student participation
- Measure how much learning motivation explain the relationship of classroom layout with student performance

IV. Methods

A. Research Methodology Design

The research methodology is divided into 4 phases. The first phase of the methodology involved the formation of the proposed framework of classroom layout to learning motivation and student performance through model formulation. This incorporates the constructs found in literature and the hypotheses this study has explored.

The second phase of the methodology focused on the development of the participation measurement tools and questionnaires required to gather data on the identified constructs from the model formulated. Based on the methodologies of the previous studies on the topic, the researcher improved on the existing tools and altered it to fit the context of the participants. All the tools adopted and developed were tested to ensure its validity and the necessary adjustments were implemented before the actual experiment.

The third phase of the methodology included all experimental preparations. Upon the approval of the school coordinator, the teacher and student participants were identified along with the subjects and topics discussed for each day of the experiment period. After the tools developed were validated then adjusted and the participants, both teachers and students, were oriented, then experiment begun. The classroom of the students involved were adjusted according to the experiment plan prepared. For each of the design alternative implement, examinations and questionnaires were administered to the students. Also, the teacher-observer was asked to evaluate each of the students' participation level.

Finally, the fourth phase of the methodology involves the analysis of the data to draw findings for the study. This starts with screening the data through SPSS software and then a structural equation modelling through Smart PLS M3 software was performed to explore the relationships between the constructs considered in the study. A replication of the experiment was done to confirm the results of the study. At the end of the study, conclusion and recommendations were drawn by the researcher on the relationships between classroom layouts design factors and the motivation and performance of students in class.

B. Software Used

The instrument used to tabulate and screen the collected data was IBM SPSS Statistics 25. It was used to conduct factor analysis to assess the validity and reliability of the constructs during pilot test of the study. Furthermore, it was used to detect missing data and prepare the dataset for the partial least squares modelling analysis. The hypothesized model was tested using Structural Equation Modelling – Partial Least Squares (SEM-PLS) in Smart PLS M3 version 3.0. Features of the software include the PLS algorithm, bootstrapping, importance-performance map analysis, and multigroup analysis, which were relevant for the set objectives of the study.

V. Results

A. Sample Size and Replications

This study considered a classroom, which consisted 40 students who were aged 18 to 25. There were 26 total replications conducted, 13 for the experiment proper and 13 for the replication study. After an initial screening, data from only 30 students were considered in the study, so the total number of entries in the dataset is 780. All subjects signed consent forms to participate in the study, but their names and faces are not shown in the study to maintain anonymity.

Based on most recent studies, the minimum sample size required for PLS-SEM tests to achieve acceptable levels of predictive power is based on the effect size associated with the path coefficients under observation [19]. Smaller samples are required if the effect size is high and if an estimate value is known. However, for this study, new constructs were introduced, so there is not enough information about the relationships to assess its effect size. For this case, it is recommended that the sample size should be 10 to 15 sample for each construct in the study [20]. Since there are 5 scale variables and 5 ordinal variables that transforms into 14 dummy variables, 190 to 285 is the recommended sample size. This is substantially met by the data gathered.

B. Model Specification

The model specification translates the reviewed literature to a theoretical-conceptual model that research wishes to explore in the study. This stage in the experiment deals with the setup of the inner and outer models. The inner model displays the relationships between the constructs being evaluated, while the outer models are used to evaluate the relationships between the indicator variables and corresponding constructs [21]. Evaluations on mediating variables and multi-group analysis were include as these were needed to capture the entire conceptual model.

Based on the studies reviewed, there were 5 constructs considered in forming the inner model. As shown in Fig. 1, Social Interaction and Comfort Level are exogenous variables that are linked to the endogenous variables, namely Learning Motivation, Test Scores, and Participation Level. However, the Learning Motivation construct is special because it has arrows pointing in and out. Since it is between multiple constructs, it is considered as a mediating variable.

Mediating variables exist when at least two different exogenous and endogenous constructs are connected to a construct. The mediation to some extent absorbs the effect of an exogenous on an endogenous construct in the path model. This creates a direct and indirect effect that together explains the dependent variable. In this study, learning motivation is a mediating variable that mediates four relationships, which includes (1) Comfort Level to Test Scores (2) Comfort Level to Participation Level (3) Social Interaction to Test Scores and (4) Social Interaction to Participation Level.

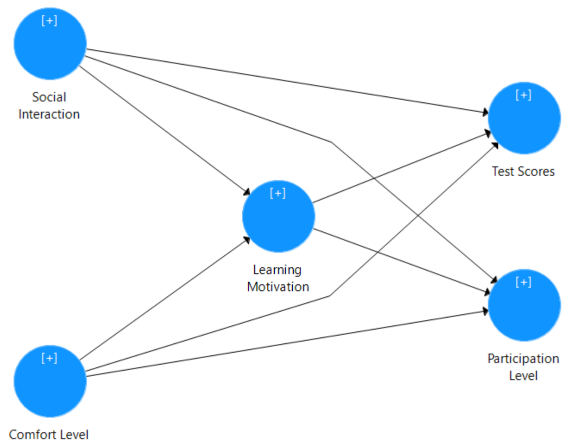

Fig. 1

Once the inner model has been specified, the outer model should be established. This is done by assigning indicators (yellow boxes in Fig. 2) to their respective constructs. These indicators could come from survey results or any data that may describe the construct it is connected to. In forming the outer models, the researcher distinguished between reflective and formative measures. The two approaches to measurement are based on different concepts and therefore require consideration of different evaluative measures.

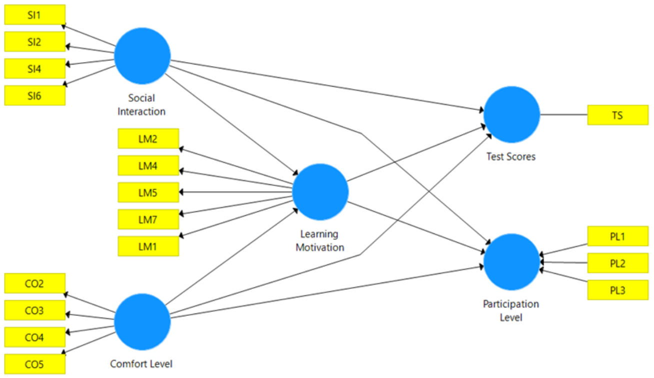

Fig. 2

C. *Model Validation*

Partial Least Squares models estimate parameters for links between measures and constructs as well as link between the constructs. These are analyzed sequentially in two stages: (1) the assessment of the reliability and validity of the measurement models, followed by (2) the assessment of the structural model. By assessing the reflective and formative measurement models, the researcher can assure that the conclusions drawn from the model are reliable and valid. For the reflective measurement model, the adequacy was assessed by evaluating the (1) indicator reliability (2) convergent validity (3) internal consistency and (4) convergent validity.

D. *Structural Model Assessment*

With the model specification and validation completed, the outer model has been tested and the inner model can now be evaluated. The following criteria facilitated this assessment: Coefficient of determination (R^2), effect size (f^2), predictive relevance (Q^2), and the path coefficients. Prior to this assessment, the inner model was tested for potential collinearity issues.

1) *Collinearity Issues (VIF)*

In testing for collinearity issues, the constructs are tested whether they are highly correlated. Collinearity assessment in the inner model is of pivotal importance when the model includes formatively measured constructs. To perform the assessment, the same measures in the evaluation of formative measurement models need to be applied. Each set of predictor constructs needs to be assessed separately for each subpart of the structural model. Reference [22] suggests that the VIF values should be below 5. All VIF values in the results is below 5, so each construct is differentiable.

Table I. Inner VIF Values

	CL	SI	LM	PL	TS
CL		1.436	1.984		2.263
SI		1.436	1.529		1.605
LM			1.888		2.801
PL					3.370
TS					

*CL = Comfort Level; SI = Social Interaction; LM = Learning Motivation; PL = Participation Level; TS = Test Scores

2) *Coefficient of Determination (R^2)*

R^2 is a measure of a model's predictive accuracy. It represents the exogenous variable's combined effect on the endogenous variables. Higher values of R^2 indicates that the model can adequately predict the dependent variables with the independent variables. Low values indicate that there may be other factors not considered that affect the results of the dependent variable. A rule of thumb widely accepted in literature is that R^2 with values of 0.75, 0.50, 0.25, describe substantial, moderate, or weak levels of predictive accuracy, respectively [23].

Table II. R-Square Values – Predictability Strength

	R Square	R Square Adjusted	Predictability Strength
Learning Motivation	0.470	0.467	Moderate
Participation Level	0.703	0.701	Strong
Test Scores	0.277	0.269	Weak

3) *Effect Size (f^2)*

The effect size of each predictor to an endogenous variable evaluates whether the omitted construct has a substantive impact on the construct. This is determined by calculating for Cohen's f^2. This is computed by noting the change in R^2 when a specific construct is eliminated from the model. The model is

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estimated without the construct and f^2 is computed as in (1). In assessing the effect size, values with 0.02, 0.15, and 0.35 have small, medium, and large effects respectively [24].

$$f^2 = \frac{R^2_{included} - R^2_{excluded}}{1 - R^2_{included}} \tag{1}$$

Table III. Effect Size

Predictor	Endogenous Variable	Effect Size	Effect
Comfort Level	Learning Motivation	0.379	Strong
Social Interaction	Learning Motivation	0.062	Weak
Comfort Level	Participation Level	0.131	Moderate
Social Interaction	Participation Level	0.051	Weak
Learning Motivation	Participation Level	0.461	Strong
Comfort Level	Test Scores	0.003	Weak
Social Interaction	Test Scores	0.003	Weak
Learning Motivation	Test Scores	0.001	Weak

4) *Predictive Relevance (Q^2)*

Also known as the cross-validated redundancy, the predictive relevance value Q^2 of exogenous constructs uses the Blindfolding procedure where every nth data point in the endogenous construct's indicators is omitted to estimate the parameters with the remaining data points [25]. The smaller the difference between predicted and original values means the greater the Q^2 and thus the model's predictive accuracy. It should, however, be noted that while comparing the Q^2 value to zero is indicative of whether an endogenous construct can be predicted, it does not say anything about the quality of the prediction. Values of 0.02, 0.15, and 0.35 indicates small, medium, and large predictive relevance respectively for a certain exogenous construct on the model [21].

Table IV. Q-Square Values – Predictive Relevance

Predictor	Endogenous Variable	Predictive Relevance	Effect
Comfort Level	Learning Motivation	0.087	Weak
Social Interaction	Learning Motivation	0.036	Weak
Comfort Level	Participation Level	0.059	Weak
Social Interaction	Participation Level	0.033	Weak
Learning Motivation	Participation Level	0.203	Moderate
Comfort Level	Test Scores	-0.001	No Effect
Social Interaction	Test Scores	-0.001	No Effect
Learning Motivation	Test Scores	-0.001	No Effect

5) *Path Coefficients*

After running a PLS model, estimates were provided for the path coefficients, which represent the hypothesized relationships linking the constructs. Path coefficient values are standardized on a range from -1 to 1, with coefficients closer to 1 representing strong positive relationships and coefficients closer to -1 indicating strong negative relationships. Although values close to -1 to 1 are almost always statistically significant, a standard error must be obtained using bootstrapping to test for significance [26]. After verifying whether the relationships are significant, the researchers considered the relevance of significant relationships. Reference [21] stated that many studies overlook this step and merely rely on the significance of effects. If this important step is omitted, researchers may focus on a relationship that, although significant, may be too small to merit managerial attention.

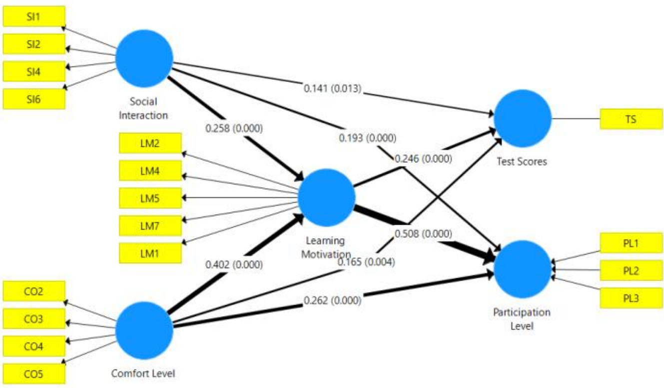

Fig. 3

The bootstrapping results for the base case can be found in Fig. 3 and it is summarized in Table V and VI. All the path coefficients for direct relationships have p-values of below 0.01, which indicates that they are supported or valid. The relationship drawn is significant and the results of the R-square, f-square, and Q-square dictate the strength of these relationships. These results include the whole dataset, but to explore the effects of the different design components on this model, multi-group analyses were conducted.

6) Multi-Group Analyses

To observe the relationship of classroom layout design components and other factors considered to the structural model on learning motivation and student performance, multi-group analyses were performed on seat arrangement, seat distances, and seat assignment scheme. The aim of these analyses is to uncover the changes in the relationships with varying variables.

VI. Discussions

A. Findings from Structural Model Assessment

There are 3 endogenous variables in the model considered in the study, namely Learning Motivation (LM), Participation Level (PL), and Test Scores (TS). Results in Table II show that they have moderate, strong, and weak predictability strengths, respectively. Motivation can be moderately predicted by the quality of social interaction and comfort level experienced by the students, but there may be other factors that contribute to it. Since motivation is an intrinsic value, there may be other causes, such as their physiological conditions that were not considered in the study. During the post-test interview, students 16 students mentioned that interest in the subject or topic is a driver for their motivation to study. If this is added to the model, it is likely that the predictability strength of motivation would significantly increase.

Both participation level and test scores are significant indicators of student performance, but their R-square values are different. It was found that participation is a better predictor of performance if social interaction, comfort, and motivation are considered. When students were asked about 6 were unsure of how their participation changes, but 16 were unsure how their test scores are affected. When considering test scores, there are more external factors that may affect their performance, so it is a weaker predictor in this case.

By examining the effect size of each endogenous variable, the contribution of each variable can be known. For learning motivation, it is seen that learning motivation has a strong effect, so it is more important. When students were asked, 22 of them mentioned that their comfort in the classroom affects how they concentrate and put effort to perform well. For social interaction only 13 mention that their interaction with both students and teachers are important factors. By comparing the effect sizes, learning motivation has a strong effect to participation, but not to test scores. This confirms with the R-square results found.

The relationship of learning motivation and participation level is greater than the relationship of learning motivation to test scores. This proves that participation is positively more related to learning motivation. It can be argued that it is a better indicator of student performance. It was found that all indirect effects are supported. Even though the standard beta values are significantly lower to the direct effects, the comfort level and social interaction constructs still help explain the measures of student performance. The results are consistent with the trend that participation level is a better indicator compared to test scores for this model.

Results of the multi-group analyses show that there is a significance difference in comparing boxed-u-shaped and u-shaped-clustered. Motivation and participation are higher for the u-shaped design. When students were asked of their preferred layout, 19 of them mentioned that they prefer the u-shaped layout the most because they can interact with the teachers and students well. They argued that the layout facilitates better conversation with the teacher because everyone is at roughly the same distance to him or her compared to the boxed and clustered layout. These contribute to their motivation to study for the class.

Varying distances were tested for each of the seat arrangement to assess if it affects the relationships of the constructs in the model. For the clustered layout, social interaction and comfort level did not change with the 3 levels of distances. However, for the boxed and u-shaped layout, the varying distances influenced the relationships. It was found that when the seats are farthest, comfort level is most significant, while when the seats are at a normal distance, the social interaction is most significant.

In the assessment of seat assignment scheme, it was found that the two alternatives do not produce significantly different results. The values for social interaction and comfort level differ from each other, but it is not enough to pass the t-test statistics. When students were asked about the assignment scheme, 27 of them prefer to choose their own seat. However, a common reason they give is that they want to be seated with their friends. It was observed that it may increase social interaction, but it may not necessarily improve its quality towards academic learning. Students may engage in unproductive social interaction that negatively affects their participation and test scores in class. Another consideration provided by the students is they sit where they feel comfortable. Some prefer to sit at the back so they can concentrate, and some prefer to sit in front to maximize their engagement with their teachers.

B. Importance & Performance Matrix (IPMA)

The Importance and Performance Matrix (IPMA) simple technique for identifying attributes of products or services that are most in need of improvements or that are candidates for possible cost-saving conditions without significant detriment to overall quality [27]. It is useful for prioritizing which variables to focus on based on importance. It extends the results of the PLS-SEM by providing a table that shows the performance of each construct based on the data provided and this could lead to managerial considerations. It is preferable to primarily focus on improving the performance of those constructs that exhibit a large importance regarding their explanation of a certain target construct, but at the same time, have a relatively low performance. The IPMA grid (Fig. 4) is used to determine a course of action for each of the construct given the dataset tested in the PLS model.

Fig. 4

The importance-performance map analysis was also done in SMART PLS for each of the endogenous constructs. Results show comfort level is already performing at a high level. However, social interaction in the classroom should be improved. Not all students take an effort to interaction with either their teachers or students. While 25 of them think that social interaction is an important factor, only 13 recognize that they should interact to both their teachers and classmates. Moreover, the social interaction occurring in class should be productive, so it contributes more to the performance of students. Even for the participation level and test scores, shown in Fig. 5 and 6, the variable that needs to be improved is social interaction.

However, the IPMA uses relative values to assess the performance of the constructs. If participation and test scores are compared, it can be observed that the total effect values are greater for participation because it is positive more related to the motivation, social interaction, and comfort level.

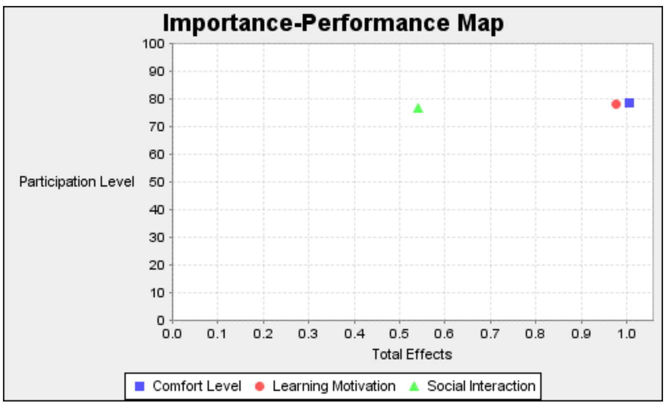

Fig. 5

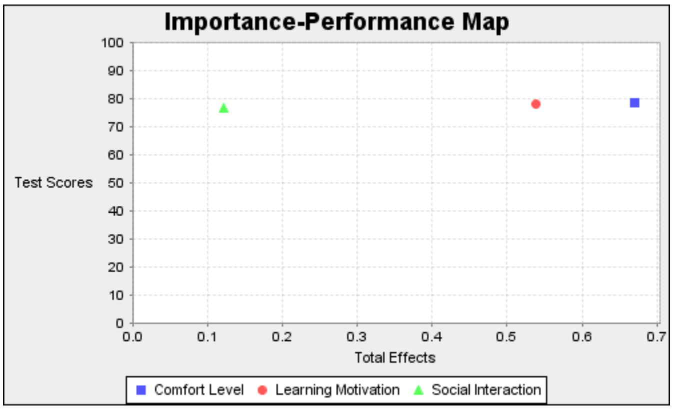

Fig. 6

CONCLUSION

The study produced results on the relationship of factors considered and these have several implications and applications to the field of education as well as other industries or fields. This includes the benefits that stakeholders may reap from the findings of the research. Results of the study should guide teachers and administrators in designing the layout of the classroom. Moreover, administrators or even policy makers can work together to form classroom layouts to maximize the motivation and performance of students based on their subject or activity. The main contribution of the study is the established relationships, but for students and teachers to benefit, these must be put to practice.

Findings from the study show that participation level is a better predictor of performance compared to test scores. However, in the review of literature, studies on educational ergonomics normally use test scores to measure performance. This may be a convenient indicator because it is more readily available to researchers, but it was found that it has its weaknesses. Teachers and administrators should review how students are graded in classes. In most traditional schools, a bulk of the grade is allocated to written examinations, while participation is only given a small weight or sometimes even none. In some cases, participation is equated to attendance, which takes its place in the grading system of a school. Based on this study, schools may need to adjust their grading systems to better reflect the performance of students in the classroom.

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