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Partial Least Square Structural Equation Modeling in the Final Phase of Product and Instrument Development Using Universal Design and Agile Development Model

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ABSTRACT

The partial least squares path modeling or PLS-PM, is best known as the partial least squares structural equation modeling or PLS-SEM. It is a method of structural equation modeling. This method allow the estimation of complex cause and effect relationship models with latent variables. This paper explain how this method can be use in the final stage of a product design and development study. In the study, learning outcome becomes the center for universal design, development and implementation processes. There are two stages of major processes. First is the instructional design processes while the second is the development processes. The development processes ends with usability test. The next phase is the evaluation phase. Last phase is the modeling processes. The paper will first explain about the localized model of product design and development procedure. Subsequently it will elaborate the final phase of the second stage processes, which is important in impact study of product design and development. While at this, the partial least square structural equation modeling will be explain. It is a powerful statistical technique yet misconceptions happen a lot. Proper techniques is essential for methodological assumptions in order to attain robust results. Using latest software alone is not enough.

Keywords: PLS-SEM, UDin model, DDRM, design & development research, second generation statistics

INTRODUCTION

This paper aims to explicate a method in engaging developmental research project. Developmental research includes design and development research known as DDR (Din 2017a; Din 2017b; Sahrir et al. 2011; Alias 2007; Richey & Klein 2007; Wang 2005; Richey & Klein 2005; Bannan-Ritland 2003) or research and development studies known as R&D (Chachulia et al. 2020; Atmowardoyo 2018). At the final stage of development study, a numerical analysis using partial least square structural equation modeling will be explain. This is to ensure products designed and developed systematically, deliver positive outcome.

The method is based on a localized model namely the Universal Design and Agile development model, abbreviated as the UDin model. The model can be use as a guide to analyze, design, develop and test new product and prototype. This is Type 1 Design and Development Research (DDR) study. In addition, the model formed a guideline for evaluation and modeling of the product implementation in real industrial, training, community or classroom environment. This final phase is the Type 2 DDR study. Generalizations derived from the results. In addition specific context use the results for decision-making.

This article define developmental research in terms of the conventional ADDIE phases of analysis, design, development, implementation and evaluation. However, there are three added contemporary approach-using software engineering and agile method to allow some flexibility. The approach tolerate and considers (i) some phases to be conducted in alignment with other phases as deemed suitable, (ii) flexibility that suits the current product development in the fourth industrial revolution era and most importantly, (iii) testing procedures to be done before evaluation phase.

UDin is a comprehensive model (Figure 1). It combines instructional design with software engineering. The primary purpose is to design educational product based on theories without neglecting values integration in teaching and learning processes and to incorporate pedagogical and teaching strategies planning. Secondly, software engineering method is use to ensure usability of the product. This is to ensure products rigorous testing before implementation.

UDin is an agile model derived from a comprehensive developmental model for design, development, implementation, evaluation and modelling of any educational product aimed at giving meaningful learning with embedded values. The approach also focuses on differentiated learning with the universal design. The inner circle shown in Figure 1 originates from the eclectic universal design for learning model as zoomed in and shown in Figure 2 (Din 2016). A zoomed in figure of the outer circle in Figure 1 is shown

FIGURE 1. Redesigned from the three-layer UDin model (Din et al. 2018)

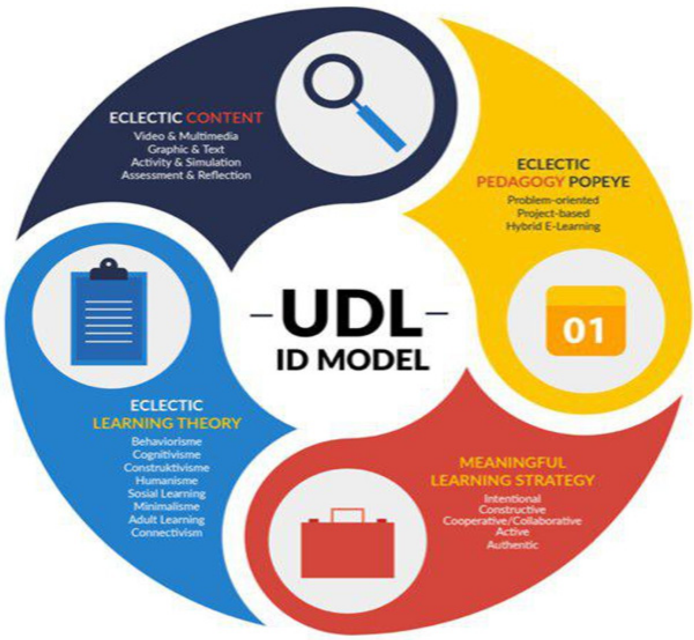

FIGURE 2. The origin instructional design model (Din 2016)

as in Figure 3. It is a derivation of the systematic iterative triangulation participatory design and validation method also known as Model Reka Bentuk & Pembangunan Sistem Pengajaran dan Pembelajaran or the Model RekaBangun SPP (Din 2016; Din 2001; Din 2006; Din 2010; Din 2017a; Din 2017b).

The complete transformation of the UDin Model will be explain from the early work of the Development Model in 1999-2001 till latest transformation in 2018. The explanation refer to the three stages depicted in the (i) central circle, (ii) inner circle of design and (iii) outer circle for developmental processes. These processes are as the new 3-layer UDin model in Figure 1. At the centre of the model is the learning outcome. Learning outcome is the first component. Its' achievement is determined by assessment processes at the end and during the learning processes.

Outside the centre is the inner layer of the model. It comprises of the instructional design model. In the initial models, instructional design model (Figure 2) is embed into developmental phases.

The outer layer of UDin Model represent developmental phases used to develop, test and validate various applications, systems and educational product development. The initial model was first tested and validated in 2001 as

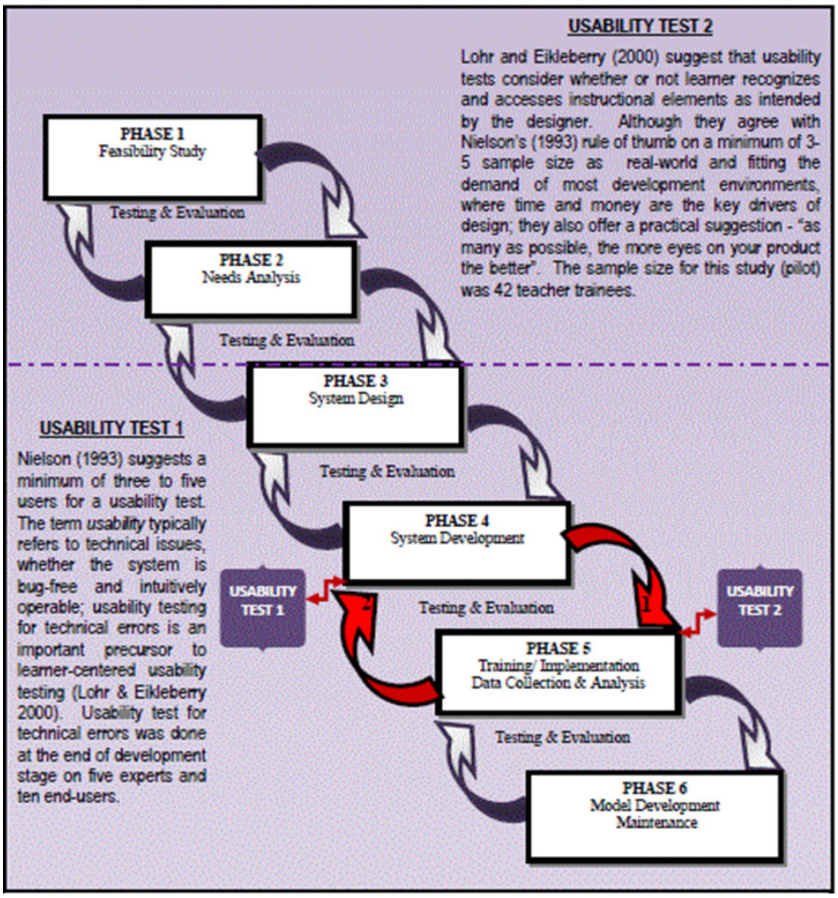

FIGURE 3. The early version of UDin outer circle for developmental processes

Model Pembangunan Sistem (Din 2001). The improvised Model Reka Bentuk dan Pembangunan Sistem version II came later in 2006 (Din 2006) and version III came out in 2010 (Din 2010) while version IV came out after rigorous use and testing after method and model was published in 2014 and reprint in 2017 (Din 2014; Din 2017a).

The UDin model aims to help novice designers start with defining the product with its learning outcome. Then proceed with defining the processes. Design phase focuses on five elements. The first element is the eclectic content. Second, is the values to embed in the educational product and during implementation. Third is the pedagogy for content and product delivery. Fourth, is learning strategy use during product implementation. Finally, the fifth is to plan for learning theories for application and integration in the educational product during design, development and implementation. The design and development method were tested to ensure product quality not sacrificed when transforming to agile solution. Some of the studies derived from early models and frameworks of the UDin model are the work of researchers from the personalized education research group in UKM (Atef et al. 2015; Atef 2015; Aziz 2015; Salleh et al. 2015; Salleh 2016; Atwa et al.2017; Atwa 2016; Bataineh et al. 2017; Bataineh 2016; Azizul & Din 2016; Othman & Din 2016; Murat et al. 2016; Alias et al. 2016; Zain 2018; Adnan et al. 2015; Adnan 2019) and many others as concluded in an editor's note (Din 2016).

Previously instructional design and development activities had not explicitly include the Learning Outcome and Assessment components in any relevant models. However, due to much disregard for constructive alignment of content, theory, strategy, pedagogy and values with learning outcome and assessment in many products evaluated in previous years, the UDin model explicitly include LOA at the center of the model resembling the bull's eye. All five components in the instructional design layer targeting to meet the learning outcome are in alignment with LOA as represented by the anti-clockwise motion of the arrows in between the two innermost and outer layer of the model (Figure 1).

Previously most impact studies on newly developed products and prototypes especially those developed using the conventional ADDIE model, would skip the rigorous testing procedures. This is to accelerate the process of progressing to the evaluation phase. Testing are skip or merge into the subsequent phase. This is the evaluation phase. Rationally, most often than not the result of pre and post experiment will show that the products have an effect on the stakeholders. That is if the design and development of the product were systematic. In addition, in the beginning of the study analysis phase are perform to ensure products are developed base on stakeholders needs. Thus, if one knows that the result would be positive due to the early procedure undertaken, why waste money and effort to do

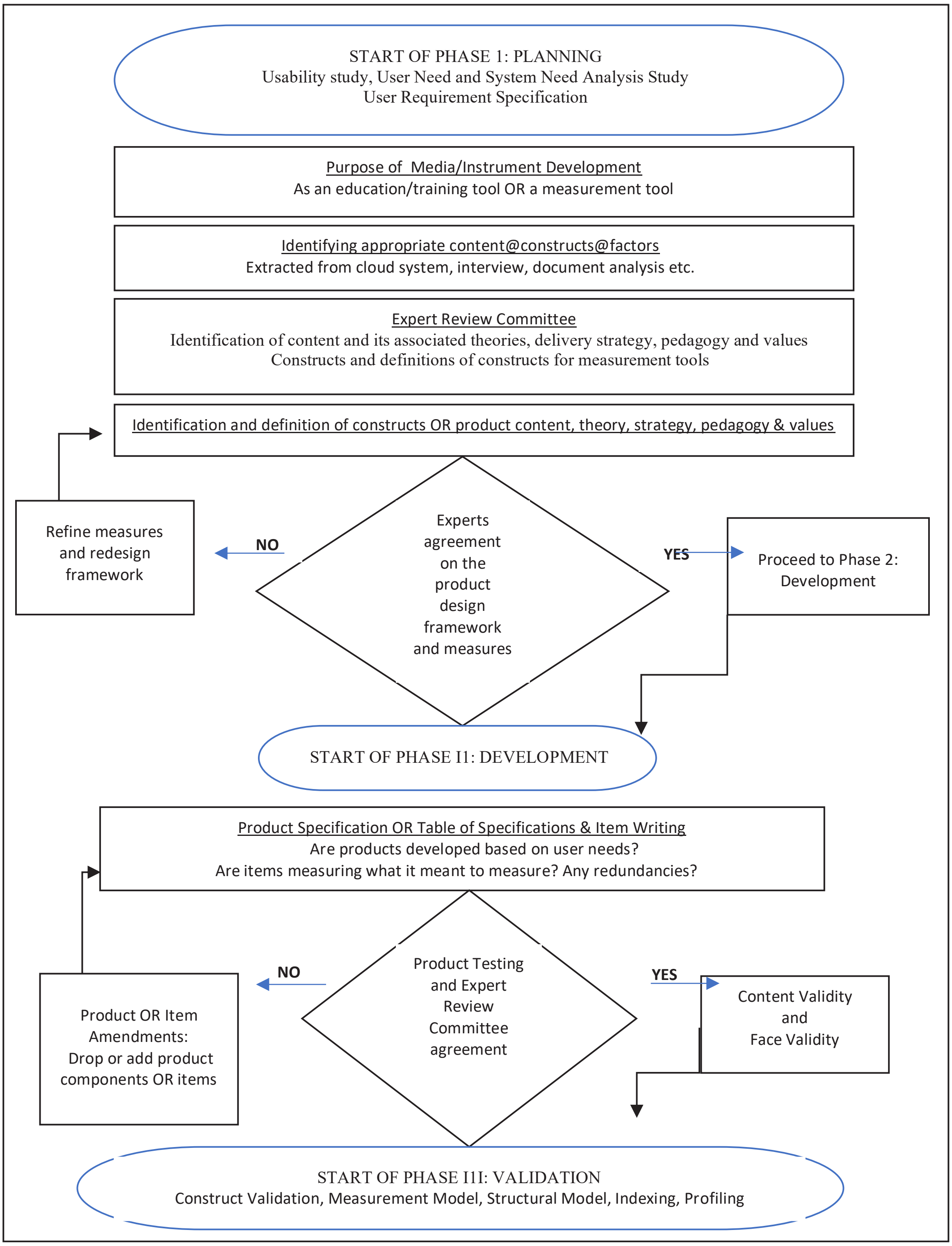

FIGURE 4. DDRM method to conduct Type I design and development studies

another experiment? On this note, similar to the connotation made by Michael Allen on Leaving ADDIE for SAM, I would personally make a similar suggestion on Leaving Experiments for SEM. Some misconceptions occur when using SEM in evaluation and modelling phase of DDR studies. The following section will discuss and guide new researchers to proceed with SEM.

METHOD FOR TYPE I STUDIES: PHASE I & II FOR PLANNING AND DEVELOPMENT OF TOOLS & PRODUCTS

The UDin model guide measurement tool development and educational product design, development, testing, evaluation and modeling. For product development there are Type I studies that focuses on product design and development. These studies ends with testing. Testing that

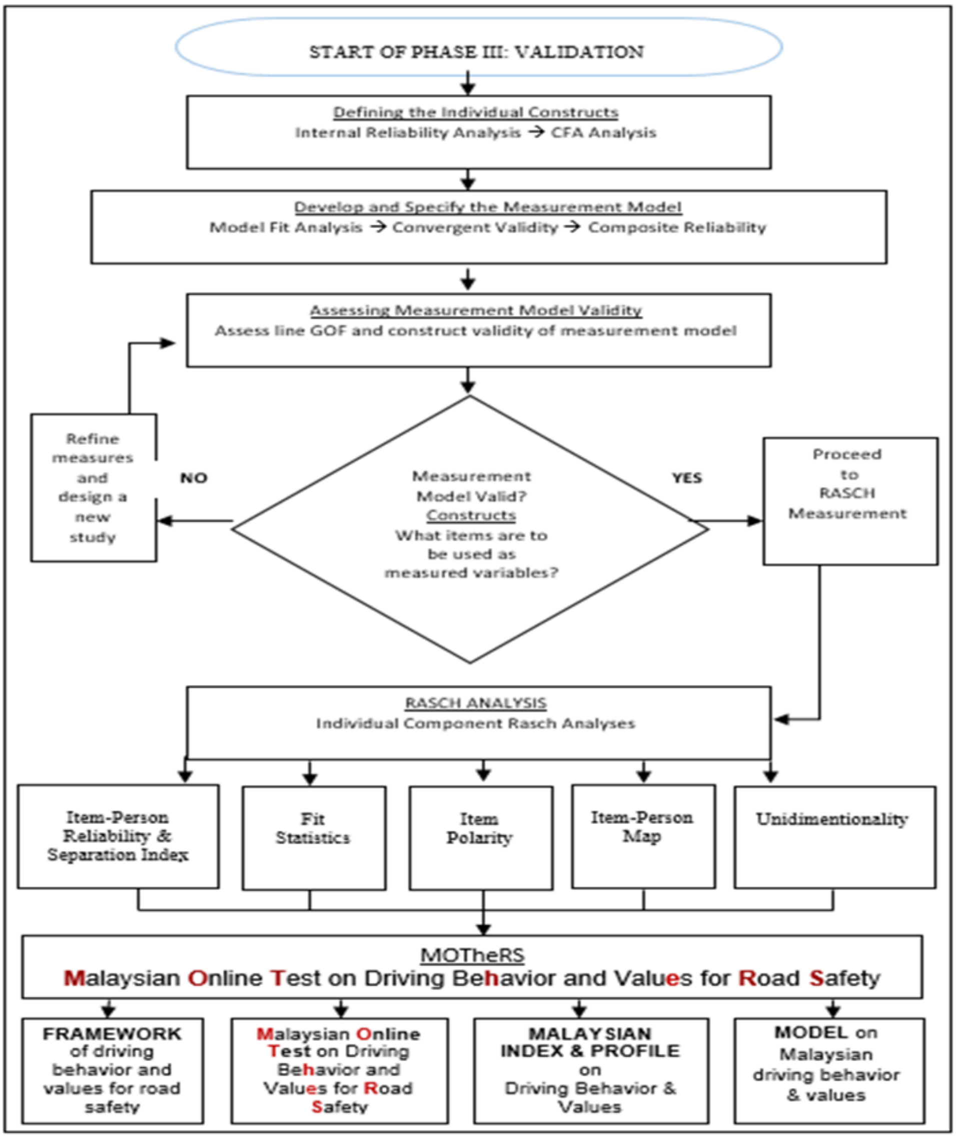

FIGURE 5. Measurement Model Validation Procedure

are usually included in these Type I studies are usability test for technical and educational verifications based on product requirement specifications (Din 2016; Din 2001; Din 2006; Din 2010; Din 2014; Din 2017a; Din 2017b) as shown in Figure 4.

METHOD FOR TYPE II STUDIES: PRODUCT VALIDATION, MODELING AND MEASUREMENT MODEL FOR INSTRUMENTATION: PHASE III

Figure 5 shows procedures to conduct validation processes to obtain measurement model for a Malaysian Online Test on Driving Behavior and Values for Road Safety. The measurement model is also known as confirmatory factor analysis model. The initial validation uses Rasch model analysis.

Subsequently, to confirm its reliability and validity of the measurement model, a Structural Equation Modeling procedure will be use to validate the measures using and to run a structural analysis to identify factors within the measurement model influencing other latent variables associated to the model. If enough data are collected, SEM-AMOS can be use especially for instrument development to show model fit. If there is problem in getting normal distributed data, SEM-PLS can be use. SEM-PLS can also handle small sample of data.

METHODOLOGY USING SEM-PLS TO MODEL PRODUCT IMPACT: PHASE IV

Exploratory research can use PLS-SEM to evaluate product impact or use in educational environment when “theory is less developed” (Hair et al. 2017). Specifically, when product had been developed and tested in Phase II or after validation of measurement tool during Phase III. In UDin model, impact studies and ROI are perform in Phase III.

At this stage, the primary focus of the research is to predict and explain the main factors of the study. It can also identify the main factor or key driver constructs (Hair et al. 2017). PLS-SEM would also be the preferable choice as compared to SEM-AMOS when formative constructs are part of a model (Hair et al. 2014). A formative construct is like a regression model. The indicators (or items) are to affect a latent construct (Hair et al. 2011). Hence, for models with formative constructs, or combination of both reflective and formative constructs, PLS-SEM has the advantage over SEM-AMOS. It is a covariance based SEM (CB-SEM). In addition, it also facilitates both modes (regression and correlation weights) in the measurement model more efficiently (Hair et al. 2017).

PLS-SEM can handle complex structural models even with numerous constructs and indicators. Thus, PLS-SEM is an appropriate analytical method (Hair et al. 2017) for such studies (Samar et al. 2019; Rahman 2017; Chan 2013; Islam & Tsuji 2011; Chen et al. 2014; Chen 2011, Chen & Li 2010; Lin et al. 2007; Lin & Hsieh 2006; Lu et al. 2005; Lu et al. 2005; Lee et al. 2003; Agarwal & Karahanna 2000; Davis et al. 1989). Moreover, data characteristics, such as small sample size and non-normal data, can be reasons to choose PLS-SEM. Hair et al. as in (Hair et al. 2017) ratified that the complexity of a structural model does not require large sample size because "PLS algorithm does not compute all the relationships at the same time" (p. 24). PLS-SEM is soft modeling. This is because of its greater flexibility to accommodate distributional assumptions (Hair et al. 2017). Hence, when multivariate normality assumption is a concern, PLS-SEM would be a better option for analysis (Hair et al. 2017).

Nevertheless, there is a caveat on this issue. PLS-SEM can stop to perform effectively if the sample size is too small and the data is extremely not normal. A small sample size must be justifiable by matching it against the population. Besides, albeit what bootstrapping does, screening and cleaning the data before performing data analysis, such as checking multivariate kurtosis and removing influential outliers must be taken care of.

CONCLUSION

SEM is a powerful statistical method that can identify relationships and impact of a newly developed product using a newly developed measurement tool. As researchers, we should consider the two SEM approaches as complimentary. Each technique should be applied accordingly base on the research objectives. When selecting, model set-up and data characteristics should be address to. The hybriding of Rasch measurement model analysis before confirming the measures is an added advantage. Although summated scores is a solution when converting data from Likert scales to continuous data, using logit measures from Rasch measurement would be best.

DECLARATION OF COMPETING INTEREST

None.

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