Journal of Research in Instructional
e-ISSN: 2776-222X
Vol. 4(2) 2024, pp. 495 – 506
https://doi.org/10.30862/jri.v4i2.483

Using structural equation modelling to investigate the mediating effects of TPACK on intention to use technology

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Submitted: 31-08-2024

Accepted: 09-10-2024

Published: 15-10-2024

Abstract: This article aims to understand, through structural equation modelling (SEM), how the knowledge of technological pedagogical and content knowledge (TPACK) mediates the intention to accept and use technology by teachers' college lecturers. The ultimate aim is to come up with a sem-generated model which teacher training colleges can use to train lecturers in technology use. Structural equation modeling is a sophisticated multivariate statistical process that enables researchers to analyze the direct and indirect effects of variables on one another, construct theoretical concepts, test the reliability of their measurements, hypothesize and test a theory about their relationships, and account for measurement errors. A questionnaire founded on the unified theory of acceptance and use of technology (UTAUT) was employed to gather data from instructors at ten teacher-training colleges. Simple random sampling was used to select 300 valid questionnaires used in the analysis. Statistic package R was used to run SEM and the results confirmed the mediating role of TPACK in the behavior intention to accept and use technology by lecturers.

Keywords: Mediation, structural equation modelling, TPACK, use of technology, UTAUT

Abstrak: Artikel ini bertujuan untuk memahami melalui pemodelan persamaan struktural (SEM), bagaimana pengetahuan pedagogi teknologi dan pengetahuan konten (TPACK) memediasi niat untuk menerima dan menggunakan teknologi oleh dosen perguruan tinggi keguruan. Tujuan utamanya adalah untuk menghasilkan model semi-generated yang dapat digunakan oleh perguruan tinggi pelatihan guru untuk melatih para dosen dalam penggunaan teknologi. Pemodelan persamaan struktural adalah proses statistik multivariat canggih yang memungkinkan peneliti menganalisis efek langsung dan tidak langsung dari variabel satu sama lain, membangun konsep teoritis, menguji keandalan pengukurannya, mengajukan hipotesis dan menguji teori tentang hubungan mereka, dan memperhitungkan kesalahan pengukuran. Kuesioner yang didasarkan pada *unified theory of acceptance and use of technology* (UTAUT) digunakan untuk mengumpulkan data dari instruktur di sepuluh perguruan tinggi pelatihan guru. Simple random sampling digunakan untuk memilih 300 kuesioner valid yang digunakan dalam analisis. Paket statistik R digunakan untuk menjalankan SEM dan hasilnya mengkonfirmasi peran mediasi TPACK dalam niat perilaku untuk menerima dan menggunakan teknologi oleh dosen.

Kata kunci: Mediasi, structural equation modelling, TPACK, penggunaan teknologi, UTAUT

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INTRODUCTION

In recent years, the integration of technology in teacher training has become a pivotal focus. As national authorities and multinational organizations emphasize the importance of information and communication technologies (ICT) in schools and universities, teacher education faces a triple challenge. Firstly, it must determine how new technologies can enhance the quality of learning experiences for student teachers during their tertiary studies (Yılmaz, 2021). Secondly, it needs to identify the new skills that future teachers will require to effectively teach in technologically rich school environments (Bindu, 2016). Thirdly, colleges must see that all the lecturers have accepted and can use the technology.

Current pre-service teachers are ICT savvy because the majority of them have been exposed to some form of technology from infancy.

Research has shown that though such pre-service teachers have positive attitudes towards technology, 80% of them spent greater time on social-communication activities and only 10% spent time on education-related activities (Lei, 2014). Before these preservice teachers can be redirected to use technology effectively, there is need to interrogate, firstly, if their trainers (lecturers) have fully accepted technology and have knowledge and skills to be role models for technology integration. Education instructors serve as technology role models for prospective teachers, as they are a critical component in technology learning (Koch et al., 2012; Kopcha, 2010; Thomas et al., 2013). There seems to be a lack of literature to suggest that issues of technology acceptance by and training of lecturers in Zimbabwean teachers' colleges have been scrutinised. Against this background, this study investigates factors impacting the intention to accept and use technology and develops a model that explains lecturers' intention to use technology.

Individual and organisational behavioural intention to use technology has been studied by researchers for more than a decade. Literature is replete with theoretical models used to determine individual or organisational behavioural intentions to use technologies in educational settings. But one would say the overarching model is the unified theory of acceptance and use of technology (UTAUT) (Venkatesh et al., 2003). The UTAUT framework, though, is a synthesis of eight adoption and use of technology models. UTAUT is used for predicting individual usage behaviour (Venkatesh et al., 2003). Whereas the UTAUT model is used to determine user acceptance and use of technology, this study proposed that an individual's knowledge (self-efficacy) of TPACK plays a mediatory role on behavioural intentions to use technology in education. TPACK blends the teachers' knowledge of technology (digital and non-digital artefacts in education), content (the specific content intended for instruction and acquisition) and pedagogy (the process and practice or instruction and learning methods) into one framework to explain the basis of good teaching.

The concept of mediation

Mediation refers to the conveyance of an impact from an independent variable to a dependent variable via one or more intermediary (mediator or intervening) factors. Mediation in path analysis refers to the indirect impact of an independent variable on a dependent variable, facilitated by one or more mediator variables (Hayes, 2013; Hayes & Rockwood, 2017). The indirect impact is calculated by multiplying the component paths of the effect. The size of the indirect effect indicates the degree of mediation via the relevant mediator variables. Mediation may be classified as either partial or complete. On one hand there is complete mediation. This is the mechanism via which the whole influence of an exogenous variable on an endogenous variable is conveyed via one or more mediating variables. This means the independent variable has no direct effect on the dependent variable (Baron & Kenny, 1986). On the other hand, there is partial mediation where there are both indirect and direct effects on the dependent variable. A direct effect is not mediated but an indirect effect passes through the mediator or intervening variable (Baron & Kenny, 1986).

To comprehend mediation, one must grasp the link between the independent and dependent variables. In mediation, the independent variable induces a change in the mediator, which then affects the dependent variable.

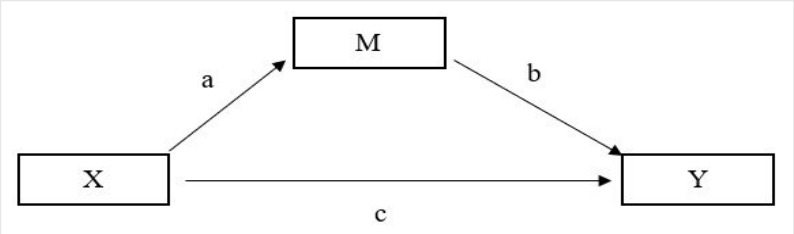

Fig. 1. Simple mediation diagram

In Figure 1 there are two consequent variables (M) and (Y), and two antecedent variables (X) and (M). X is considered to be causally influencing M and Y, and M causally influencing Y. In one path at least one causal factor (X) is suggested as influencing an outcome Y through an intervening variable M. There are two causal paths. The first (path c), X to Y without passing through M is called a direct effect of X on Y. The second, path a through b, from X to Y is the indirect path called an indirect effect of X on Y through M (Hayes, 2013). Therefore, the variable M is called the mediator variable. Although academics discuss causation, the link among the independent variable, mediator, and dependent variable is not empirically examined for causality, but rather for correlation (Baron & Kenny, 1986). Regression calculates and assigns weights or coefficients for each relationship between variables. The coefficients indicate the direction and magnitude of the effect of one variable on the other.

This study attempts to establish the mediatory effects of TPACK on the UTAUT and BI relationship. The direct effects of UTAUT, as the independent variable, on BI will be estimated and tested. Its effects through the mediator variable, TPACK, will also be regressed. The hypothesis being tested is whether TPACK constructs have positive effects on the relationship between UTAUT constructs and BI.

This study proposed a model in which one's TPACK has a mediating role in lecturer acceptance of technology. In our case the independent variables are PE and EE and technology pedagogy CK the intervening (tpck) variable. The behaviour intention (BI) stands as the dependent variable. To follow Baron and Kenny (1986), and Muller et al. (2005), to prove mediation the following must be satisfied in our case:

- Show that the causal variables, PE and EE, are correlated with the outcome BI. This demonstrates that there is an influence that may be mediated.
- Show that the causal variables, PE and EE, are correlated with the mediator variable, TPCK. In this regression the mediator is treated as the dependent variable.
- Show that the TPCK (mediator) affects the BI (outcome variable). In this regression the causal variable must be controlled because the mediator and outcome variables may be correlated because they are caused by the same causal variables PE and EE.

METHODS

This study took the positivist view of knowledge development and used the descriptive survey research design to investigate the phenomenon. Surveys provide quantitative or numeric descriptions of opinions or attitudes of a sample under study

intending to generalise the findings to a population (Kitchenham & Pfleeger, 2001). The study used a five-point Likert scale-type instrument adapted from other researchers. The target population (N) entailed lecturers from fourteen Zimbabwean primary and secondary teachers' training colleges. The study employed the simple random sampling (SRS) technique to select 300 respondents of which 220 completed and returned the questionnaires. SPSS (v 25) was used to analyse descriptive data whereas the Structural equation modelling was used to design a model.

RESULTS AND DISCUSSION

Structural model evaluation

Structural model assessment follows after measurement model assessment. This step deals with testing the hypothesised theoretical model or relationships between constructs or latent variables (Hair et al., 2014; Horn, 1965). The structural model, also called path model, shows the relationship between independent and the dependent variables. The researcher is guided by experience and use of theory to understand which independent variables predict each dependent variable (Schumacker & Lomax, 2004). The next step is SEM. In designing the structural model double-headed arrows (correlations between constructs) were replaced with single-headed (causal) arrows.

With regard to the current study, the specified predictor (independent/exogenous variables) latent variables are performance expectancy (pefexp) and effort expectancy (efftexp). Tpck and technological knowledge (techknow) were specified as the mediating variables, whereas behaviour intention (bevint) was specified as the dependent (endogenous) variable. In the mediation paths the techknow and tpck constructs become endogenous variables because some arrows point into them. The verification of the standardised path coefficients and the model fit indices was a component of the structural model procedure evaluation. This goal was to explore which hypothesized relationships were supported or not. The standardized coefficients are anticipated to be significant at the $p < 0.05$ level and to be >0.30 to be considered meaningful in the context of the hypothesized relationships (Hair et al., 2014; Schumacker & Lomax, 2004; Tabachnick & Fidell, 2014). The subsequent section contains the findings of the structure model assessment.

Initial hypothesised model

The initial hypothesised model has five factors. Originally there were six factors.

1. **Factor A (tpck)**: so named because the majority of loading items were from the tpk and tck observable variables.
2. **Factor B (pedknow)**: items mainly from PK observable variables
3. **Factor C (efftexp)**: items mainly from EE observable variables
4. **Factor D (pefexp)**: mainly made up of PE observable variables
5. **Factor E (techknow)**: mainly made of TK observable variables
6. **Factor F (bevint)**: mainly made up of BI observable variables

The hypothesised model for the data predicts that both *pefexp* and *efftexp* observable variables directly lead to increased *bevint*. Other factors *tpck* and *techknow* and *pedknow* have a mediating effect on the *bevint* factor.

The researcher used the covariance matrix of the observed variables for the SEM. The indirect effect of pefexp and efftexp on bevint is the product of the mediator coefficients. Finally, we determine whether the total effect of pefexp and efftexp on bevint is significant. Unlike the Confirmatory Factor Analysis (CFA), where the researcher was interested in the parameters, in SEM we are interested in the structural parameters made up of direct and indirect effects on the total effects. As in the CFA analysis, the SEM model is based on two models, namely 5-factor model (with correction for low communality in observable variables), and 4-factor model (with correction for low communality in variables). For further discussion only two models were used, with one (model 2) being adopted as usable for this study's analysis of direct and mediating effects. See the two models below.

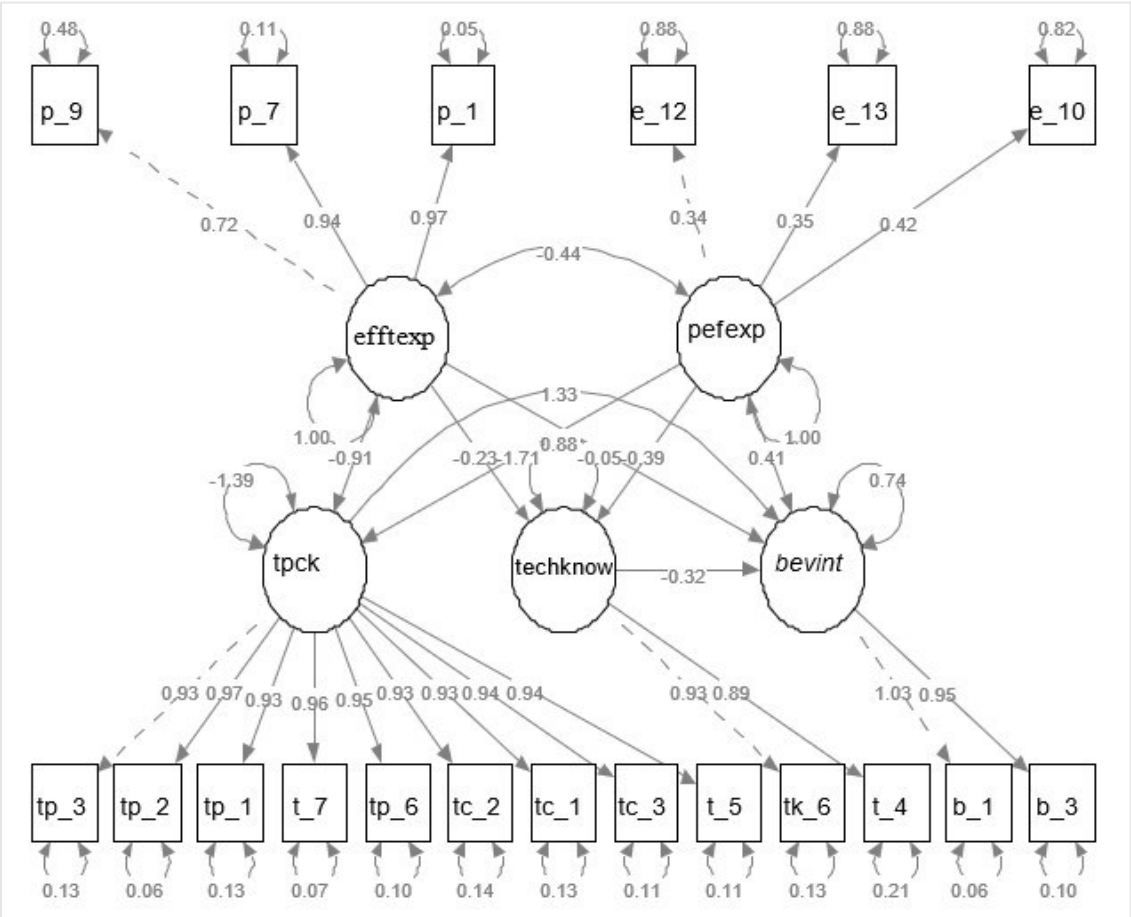

Fig. 1. Tested proposed 5-factor structural model 1

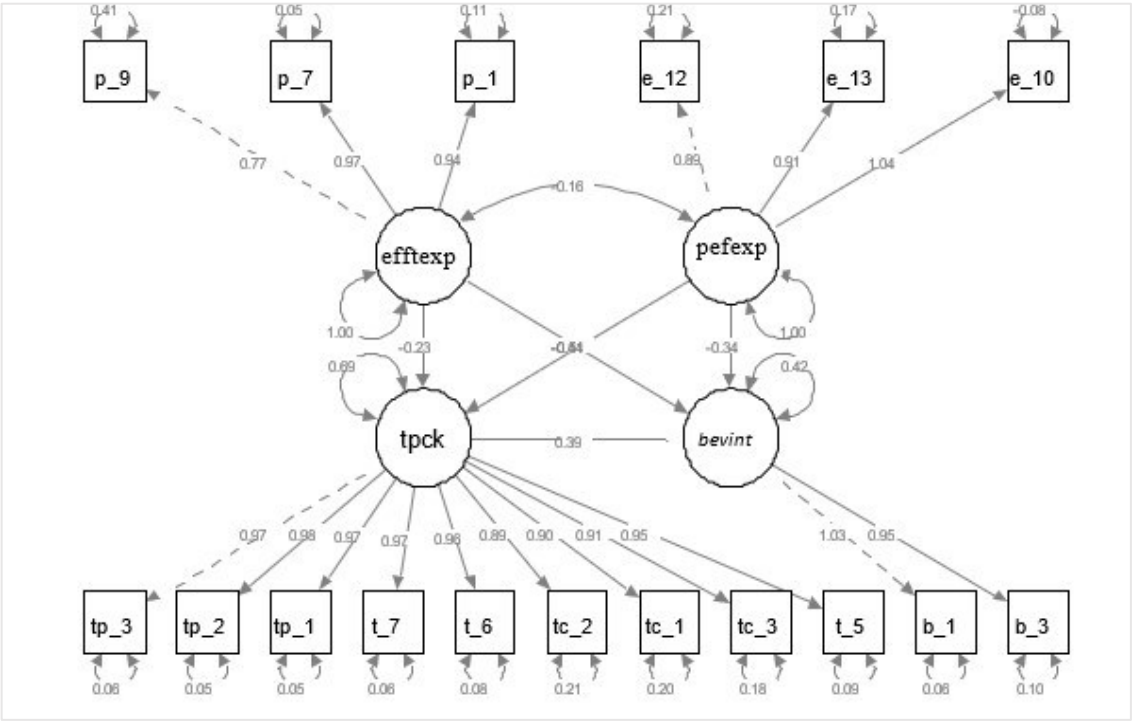

Fig. 2. Tested proposed 4-factor structural model 2

Table 1. Fit indices for models 1 and 2

Model	χ2/df	TLI	CFI	RMSEA	SRMR
5-factor model 1	1.919	0.734	0.787	0.167	0.056
4-factor model 2	1.744	0.654	0.713	0.150	0.054

Table 1 was used to conclude the choice of models. Both the 4 and 5 factor models provided better fit to the model (though fit indices fall short of recommended thresholds values). The Chi square statistic on which goodness of fit is based on works under the assumption of multivariate normality and reasonable sample size. The table shows both 4 and 5 factor models have Chi sq/df of approximately 1.9 and 1.7 respectively, which are within the recommended and acceptable set standards (Khan et al., 2020). It can therefore be concluded that there is better fit assuming effect of sample size and multivariate normality violations.

Hypothesis testing

The principal research focus is hypothesised to identify the TPACK constructs that mediate the effects of acceptance determinants on behaviour intention to use technology. There are two proposed models resulting from the CFA processes; Model 1 has five factors (independent variables – pefexp and efftexp; mediating variables – tpck and techknow; dependent – bevint). The four-factor model, Model 2, has the techknow construct removed.

The study felt that this aspect is covered in the tpck factor. Model 2 was chosen as the final modified model. Model 1 is excluded because most of its structural path estimates are not significant. It should be noted that some of the latent variables in the theoretical frameworks used in this study were discarded during FA. The UTAUT framework was composed of the performance expectancy (PE), social influence (SI), effort expectancy (EE), and facilitating conditions (FC) exogenous variables and two endogenous variables, BI and UB. Of these constructs PE and EE remained while SI and FC were discarded. Of the seven TPACK framework constructs, two remained: the technology, PCK and technological knowledge. Model 2 has the following variables: pefexp and efftexp as exogenous independent variables; tcpk as mediating (endogenous) variable and bevint as the dependent variable.

The 4-factor model, with factor techknow construct excluded from the SR model, produced the following model fit statistics: $\chi^2/df=1.773$, CFI=0.713, TLI=0.614, RMSEA= 0.15 and SRMR=0.054. The χ^2/df ratio < 3.0 and the SRMR < 0.08 fall within the recommended thresholds. Hence the model can be considered to fit the data. Most of the analysis will focus on interpretation of structural construct coefficients (both direct and indirect effects). The direct and indirect effects as reflected in Model 2 are discussed. The reported SEM findings are assessed based on estimated path coefficient β value with critical ratio (CR equivalent to t-value), and p-value. The recommended standard decision rules (t-value ≥ 1.96 and p-value ≤.05) are applied here to determine the significance of the path coefficients between the DV and IV (Hair et al., 2014) although other researchers suggest p-value ≤.10 as a determining marginal level of significance.

Assessment of the mediation effects

The adopted 4-factor model (Model 2) hypothesised five path effects. Two directly impacted the behaviour intention to use technology directly and two indirect effects. In this instance, we investigated the significance of the direct relationships.

Table 2. Model 3 standardised direct effects (DE)

Relationship	Regression	Standardised β	S.E.	P-val	Hypothesis Decision
pefexp ------> bevint	IV - DV	-0.344	-2.306	0.021*	Accepted
pefexp ------> tpck	IV - MV	-0.544	0.053	0.000***	Accepted
efftexp ------> bevint	IV - DV	-0.409	0.122	0.013*	Accepted
efftexp ------> tpck	IV - MV	-0.232	-2.094	0.036*	Accepted
tpck --------> bevint	MD - DV	0.389	0.072	0.006**	Accepted

p ≤0.001***; p≤0.01 **; p≤0.05 *

MD = Mediating variable

DV = Dependent (endogenous) variable

IV = Independent (exogenous) variable

Table 2 summarises the direct effects and the significance of the exogenous latent variables variable/constructs towards endogenous latent constructs. The mediator affects the product variable in this case. The technology pedagogy content knowledge construct is both exogenous and endogenous because it has arrows pointing in and out of it. The study results showed that all direct effects (except for one) are significant, though negative.

- There are significant direct effects of PE and EE on BI. In other words, the two determinants affect one's behavioural intention to use technology.
- PE and EE also had very significant direct effect on the mediating variable, tpck. In testing for mediation the independent (causal) variable must correlate with the mediator (Baron & Kenny, 1986).
- There is a positive and significant (estimated β value of 0.389; p =.006) direct effect of the mediating variable on the dependent variable. The reading suggests that the higher the understanding of TPCK the higher one's intention to use the technology. Technological pedagogical content knowledge covers all the domains one needs for the appropriate integration of technology in education. Participating individuals in the sample strongly believed that tpck is key influencing element in for users' uptake of technology.

Indirect (mediated) effects

Table 3: Indirect effects

	Std.Err	**Estimate**	**z-value**	**P(>|z|)**	**Std.lv**	**Std.all**
Ab	0.050	0.084	1.678	0.093	0.126	0.126
Total	0.161	-0.301	-1.870	0.062	-0.627	-0.627

Understanding the indirect effects of the independent variables (pefexp and efftexp) on behaviour intention is essential to explain the causal effects of paths in the model. In the analysis of mediation, it can be observed that the indirect effect is positive and slightly significant (β= 0.126, p-value= 0.093) (see Appendix C.8) while the total effect is negative and insignificant (β= -0.627; p-value= 0.062). Because of both negative direct effects and positive indirect effects structural coefficients on behaviour intention, the total effect is negative and insignificant (in fact it is null). Since the indirect effects contain paths that are critical, we conclude that there is partial mediation.

Discussion on mediation

This study proposed that the understanding of TPACK mediates the relationship between behaviour determinants and lecturer BIU towards technology. Prior studies have shown that there is an association between UTAUT and TPACK and that computer self-efficacy is a predictor of performance and EE (Cheung et al., 2017). The current study also confirmed this relationship. The findings suggest that lecturers' knowledge domains (content, pedagogy and technology) have some influence on determinants (PE and EE) of behaviour intention of technology.

How does TPCK intervene between behaviour determinants and behaviour intention? TPCK is the subtle knowledge of the interaction between technology, pedagogy and content. One's deep understanding of the interaction between these three domains creates confidence or self-efficacy which in turn influences one's level of technology acceptance. One's knowledge of technology influences one's perception of the usefulness of that technology. A high technology self-efficacy means the individual would be less frustrated by any hindrances he or she might face in technology use. The individual is more likely to appreciate the usefulness of a technology.

An understanding of TPCK implies the ability to know why, when, where and how technology will contribute to learning and teaching objectives. This knowledge and ability gives individuals confidence to accept and adopt a piece of technology to enhance performance.

PE was found to have a direct effect on BIU technology. PE as revealed in the literature section is synonymous with perceived relative advantage or PU of the technology. That is the degree to which a lecturer believes a particular technology will enhance his or her job performance. That implies that the more one believes the technology is going to be useful or improve job performance, the more likely one is to have a positive intention to use. The converse is equally true: the less one perceives technology as useful, the lower the behaviour intention to use. PE direct effect on the mediating variable, TPCK, was also statistically significant.

The direct effect of EE on BI was statistically significant. EE is what we may call ease of use of a particular technology, meaning how easy the technology is to understand and operate, and how easily technology will free the task from additional efforts (Davis, 1989; Sair & Danish, 2018). The greater the perception that the technology requires less effort from the user, the greater the likelihood of intention to use the technology. If a lecturer feels that the use of technology will require more energy to accomplish a task then he or she is likely not to accept it.

The mediating tpck factor in this study was so named because it was composed mainly of items from the TPK and TCK items. Tpck refers to the basic understanding or knowledge expected of teachers for infusing technology into their teaching in any content area (Schmidt et al., 2009; Shulman, 1986). In their study of pre-service teachers' intention to use technology. Joo et al. (2018) found that TPCK played a critical role in helping teachers' decision to use technology. This study did find that the participants had a good level of TPACK understanding. Such participants would find it easier to accept technology or would perceive it as a helpful teaching tool. The researcher is therefore suggesting that a broad training program should be provided to improve lecturer TPACK level which will in turn influence perception on PE and EE. This is in accord with the findings of previous studies (Joo et al., 2018).

For the last option, it is deeply grounded in the writing that when people know how to utilize PCs or potentially become more alright with utilizing them, they are bound to foster uplifting perspectives towards them too (Teo, 2011). In that sense, when technological become simpler to use, educators tend to develop positive attitudes and perceptions towards the use of them, which positively increases the likelihood of the usage behaviour. On the other side, technological difficulties result in negative effects on PU.

Lecturer training model

The study also sort to develop of a generic training model which can be used across different teachers' training colleges in the development of TPACK-compliant lecturers. The findings showed that TPACK mediates between behaviour intention to accept and use technology and its determinants. The derived recommendation is that the acceptance of technology by lecturers focus on the development or increasing their understanding of TPACK (Harris and Hoffer, 2011).

Lecturers are conversant with subject content and pedagogy. The new model focuses on the constructs which combine the three basic concepts technology, pedagogy and content, which are TCK, TPK, PCK and TPACK. This is because lecturers as educators are already conversant with their subject content and of pedagogy. Although basic computing skills are vital on their own, skills-based courses are not good enough. Hence such skills will be developed as they go through the suggested constructs. Figure 4 shows graphically the proposed sequence of the training of lecturers in TPACK.

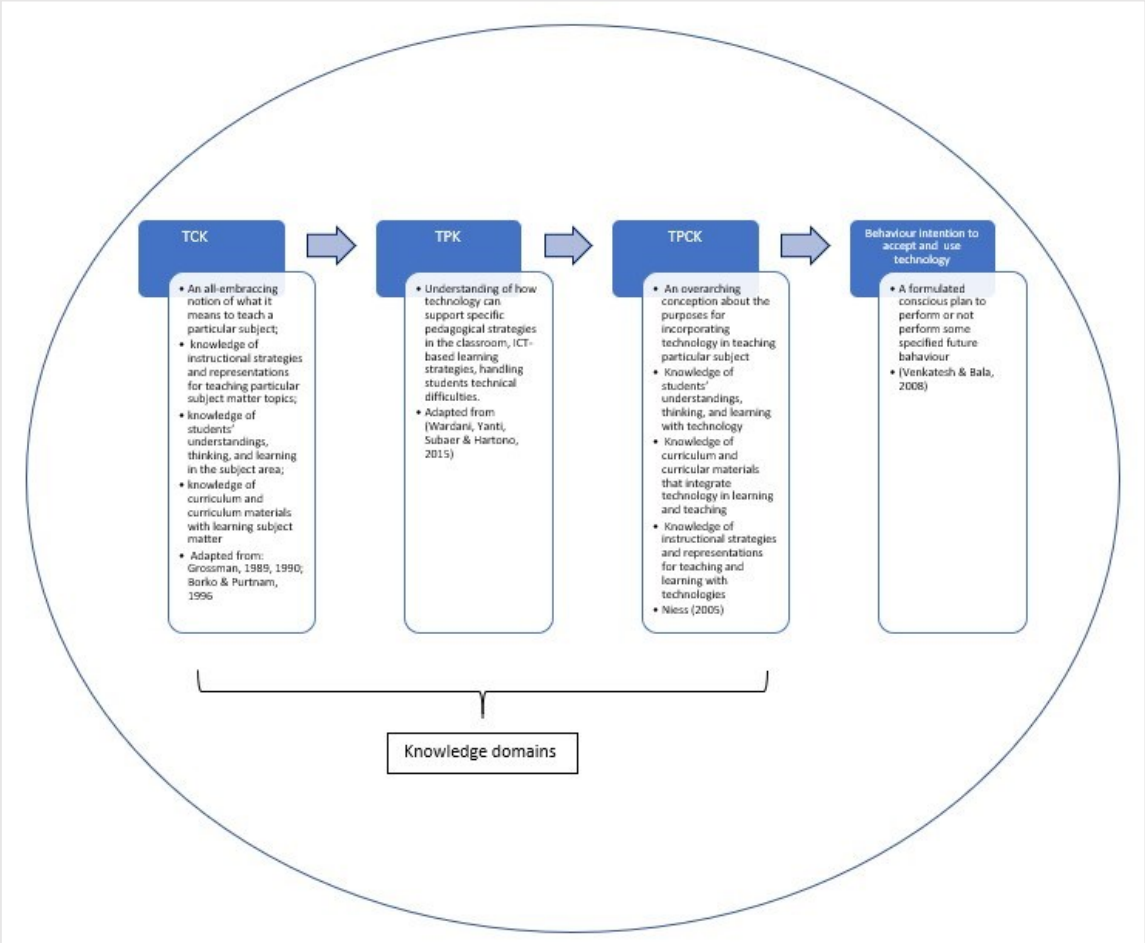

Fig. 4. Lecturer training model

The discussion above suggests important contributions to both theory and practice in teacher education.

CONCLUSION

To answer the basic research question this study developed a rudimentary conceptual model and competing model. Based on the SEM rubrics competing models were tested as modified models and a parsimonious and comparatively better fitted model was identified. In our model it was found that the knowledge of technology, pedagogy and content interactions had partial mediation on the effects of performance and effort expectancy on lecturers' intention to use technology. Therefore, for a successful technology adoption it is critical that teachers' colleges regularly upgrade and develop lecturers' TK constructs. The sharpening of methods to apply technology in pedagogical content settings encourages lecturers to adopt the technology effortlessly and confidently.

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